

AN INTELLIGENT IOT-ENABLED CARDIOSCOPE SYSTEM FOR REAL-TIME HEART SOUND ANALYSIS AND CARDIOVASCULAR DISEASE PREDICTION

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Abstract : Cardiovascular diseases (CVDs) remain one of the most common causes of morbidity and mortality in the world, thus require an accurate, timely, and continuous cardiac monitoring. Current diagnosis methods such as the manual auscultation of a stethoscope are dependent on the experience of the practitioner and mainly used in a clinical context. To overcome such drawbacks, this research introduces CardioScope, which is an intelligent stethoscope system based on artificial intelligence technology and incorporates a cardiac sensor that allows real-time cardiac assessment and prediction of heart diseases. The proposed system will provide continuous acquisition of heart sound and physiological signals, signal processing with advanced signal preprocessing techniques, and abnormal monitoring with machine learning algorithms to detect abnormal events like arrhythmia, murmur, irregular heart sounds, and other cardiovascular disorders. The system can combine intelligent analysis of data with digital auscultation to increase the accuracy of diagnosis, and lower subjective medical interpretation dependency. An intelligent platform for continuous cardiac monitoring integrated by using intelligent hardware, biomedical signal processing and AI driven software. In summary, CardioScope is a major step forward in intelligent healthcare, combining the tried-and-true techniques used in cardiac exams with the innovative use of AI technology to enhance early detection, health accessibility, expert guidance, and patient care results.

IndexTerms - Artificial Intelligence, Heart Disease Prediction, Smart Stethoscope, Cardiac Monitoring, Heart Rate Sensor, Machine Learning, Deep Learning, Biomedical Signal Processing, Arrhythmia Detection, Heart Sound Analysis, Murmur Detection, Real-Time Monitoring, Predictive Analytics, Internet of Things (IoT), Telemedicine, Remote Patient Monitoring, Digital Healthcare, Cardiovascular Diseases, Cloud Computing, Early Diagnosis.

Introduction

Cardiovascular diseases are the leading public health problem worldwide, and a major cause of mortality and morbidity. With the rise of these heart-related diseases, need of intelligent monitoring systems to aid in early diagnosis or routine cardiac monitoring is becoming an imminent concern. Some traditional methods of diagnosis rely heavily on the medical knowledge and experience of doctors for example, the old-fashioned stethoscope is used for manual auscultation. While these are techniques which have been carried out for many years, they are not able to identify minor heart problems and are generally performed at a healthcare center as a visit. Therefore, ongoing monitoring and rapid diagnosis are challenging, especially in remote areas, creating potential problems. Thus, continuous monitoring and timely diagnosis have become a challenge, especially for people in remote areas of the country, posing risk. More recently, with the emergence of smart electronics, biosensing, and digital healthcare, these challenges can be addressed through the development of smart systems for diagnostics which can provide real-time and accurate clinical information.

The CardioScope system asks the intelligent hardware and software to act as a single cardiac monitoring system. The hardware architecture is made up of digital heart sound acquisition modules, heart rate sensors, wireless communication elements and embedded processing units. On the software side, signal preprocessing, feature extraction, classification and disease prediction using advanced machine learning models. The former class of algorithms is known as noise reduction algorithms, which improve the quality of cardiac signals, and the latter is referred to as feature engineering techniques to identify clinically useful cardiovascular features from cardiac signals. These functions are then fed into an AI system for the purpose of accurately identifying normal and cardiovascular conditions. Another benefit of cloud computing infrastructure is that patient records can be securely stored, analyzed in large quantities on a large scale, and accessed easily. Advanced security measures, such as encryption and secured data transfers, guarantee the privacy and integrity of given health information during its various points of observation. The flexibility and functionality of the system allow for easy deployment in hospitals, diagnostic centres, community health centres and homes.

Final conclusion, proposed CardioScope system is an innovative development of intelligent healthcare using the AI technologies, heart rate sensing, digital stethoscope functions, cloud computing, and communication via IoT within the one framework. Automated, accurate and continuous cardiac assessment in real time is the solution provided by the system, which alleviates multiple shortcomings of traditional methods of cardiac diagnostics. In addition to the benefits of improved early care

for cardiovascular diseases, the proposed solution also provides increased access to healthcare, via remote patient monitoring and telemedicine. It was designed to be portable, affordable and intelligent and therefore can be used in a variety of healthcare facilities and helps in proactive disease management and informed clinical decision-making. With recent developments in machine learning and biomedical engineering, CardioScope can make a significant contribution to making healthcare more efficient, less expensive, more satisfying to patients, and ultimately healthier for a patient's heart and blood vessels.

Literature Review

Recent developments in artificial intelligence, biomedical engineering, and digital healthcare have significantly transformed the diagnosis and management of cardiovascular diseases. Researchers have increasingly explored intelligent healthcare systems capable of improving the early detection and continuous monitoring of cardiac abnormalities. Conventional diagnostic methods, particularly manual auscultation using acoustic stethoscopes, rely heavily on physician expertise and may produce inconsistent interpretations due to subjective assessment. To overcome these limitations, modern research has focused on integrating artificial intelligence with digital stethoscopes, heart rate sensors, and biomedical signal processing techniques. These intelligent systems enable automated analysis of heart sounds and physiological signals, thereby improving diagnostic accuracy while supporting continuous patient monitoring. Furthermore, wearable sensing technologies and smart healthcare devices have enhanced real-time physiological data acquisition, making AI-assisted cardiac diagnosis increasingly practical. The rapid expansion of telemedicine and remote healthcare services has further accelerated the adoption of intelligent cardiac monitoring solutions across clinical and home-based healthcare environments.

The integration of Internet of Things (IoT) technology has further expanded the capabilities of intelligent cardiac monitoring systems by enabling continuous data acquisition and remote healthcare services. IoT-enabled medical devices equipped with heart rate sensors can transmit physiological information securely to cloud-based platforms, allowing healthcare professionals to monitor patients in real time regardless of their physical location. Such systems are particularly beneficial for elderly individuals, patients with chronic cardiovascular diseases, and populations residing in rural or medically underserved regions. Several researchers have proposed cloud-assisted cardiac monitoring frameworks capable of generating automatic alerts whenever abnormal heart conditions are detected. These systems improve emergency response time, facilitate early clinical intervention, and reduce unnecessary hospital admissions. Additionally, mobile healthcare applications have been integrated with cloud platforms to provide patients with real-time health reports, notifications, and communication with medical professionals, thereby enhancing the overall effectiveness of telemedicine services.

Overall, the existing literature demonstrates substantial progress in the development of AI-assisted cardiac monitoring technologies through the integration of machine learning, biomedical signal processing, IoT communication, and cloud computing. These innovations have significantly improved the accuracy, accessibility, and efficiency of cardiovascular disease diagnosis while enabling continuous remote patient monitoring. Nevertheless, several research challenges remain, including improving model generalization across diverse patient populations, enhancing robustness against noisy physiological signals, reducing computational complexity for embedded healthcare devices, and ensuring reliable performance under real-world clinical conditions. The insights obtained from previous studies provide a strong scientific foundation for the development of the proposed CardioScope system. By integrating intelligent heart sound analysis, heart rate sensing, predictive machine learning algorithms, and cloud-enabled remote monitoring into a unified platform, CardioScope aims to provide an accurate, efficient, portable, and user-friendly solution for early heart disease prediction and intelligent cardiovascular healthcare. The following section presents a review of selected research papers published between 2022 and 2025, which have contributed significantly to the advancement of AI-based cardiac diagnosis and monitoring technologies.

Andrew McDonald, Mark J. F. Gales and Anurag Agarwal "A Recurrent Neural Network and Parallel Hidden Markov Model Algorithm to Segment and Detect Heart Murmurs in Phonocardiograms" (2024), This paper outlines a hybrid algorithm which fuses Recurrent Neural Networks (RNNs) with Parallel Hidden Markov Models (PHMMs) for the automatic segmentation and detection of Heart Murmur (HM) signals from phonocardiograms. The proposed method involves studying phonocardiogram recordings to determine normal and abnormal cardiac cycles, and enhancing accuracy of segmentation. Experimental testing across bottom-line comparisons in several heart sound datasets shows better results of accumulating murmurs than in traditional machine learning techniques. The authors underscore that the sequential learning scheme is preferable to the probabilistic model in the presence of noisy clinical settings. The research constituents to the meeting of dependable AI backed auscultation frameworks for early cardiovascular sickness discovery.[1]

In this paper, Franziska Krones and Benjamin Walker recount an overview of opportunities and challenges in the implementation of AI-based cardiac auscultation research in low- and middle-income settings (2024). The authors analyzed the latest models for heart murmur detection and the difficulty in implementing them, such as healthcare systems, hardware requirements and data quality. As showcased in the case study, AI-aided auscultation has the potential to enhance cardiovascular screening in low-resource settings. The paper highlights the need for clinically supported and scalable and low-cost AI solutions. The results obtained would serve as essential information in the planning of smart stethoscope and telemedicine use in the future.[2]

Abraham G. Taye et al., 'Design of an AI-Enhanced Digital Stethoscope: Advancing Cardiovascular Diagnostics Through Smart Auscultation' (2024), This study aims to design an AI-aided digital stethoscope that can facilitate cardiovascular diagnosis with intelligent heart sound analysis. This proposed system combines two current concepts, namely digital auscultation and wireless communication and also adds two new concepts in the same device, namely the integration of compatible smartphone and machine learning algorithms. Key features of the architecture include real-time heart sound classification, distance consultation and cost-effective deployment. This study proposes that AI can play a crucial role in enhancing conventional auscultation and facilitate telemedicine interventions. The proposed design will serve as a fundamental, practical basis for realizing smart diagnostic equipment for the medical field of cardiac sciences.[3]

Francis Chikweto and Muyanga Kampekete, This gives a study to develop a low-cost AI-based Digital Stethoscope for cardiovascular disease screening, Francis Chikweto, Muyanga Kampekete, Mubanga Boyd, Kalupa Conix, Munsanje Foster,

Chilufya Queen (2024). The extracted features and processed of PWTs by using Wavelet Scattering Transform and STFT were classified by Fine KNN, Gaussian SVM and Deep CNN models. The experimental validations gave accuracy of classification between 89.9% and 98.5%. This study proves that the disruptive technology of affordable medical devices with AI capabilities can be a reliable tool for medical early diagnosis in low-resource healthcare settings. The proposed system provides an accessible system without compromising the diagnostic accuracy.[4]

Shekelle, R., & Krushke, L. S. (2024). Manikin-Recorded Cardiopulmonary Sounds Dataset Using Digital Stethoscope. The authors created a large dataset of cardiopulmonary sounds recorded by a digital stethoscope upon a clinical patient simulator. Both normal and abnormal heart beat sounds such as murmurs, atrial fibrillation, tachycardia, heart blocks, wheezing and crackles are included in the dataset. The recordings were enhanced using frequency filtering for machine learning research. The dataset serves as an essential reference for creating heart and lung sound classification models using AI. It has implications for future research in biomedical signal processing and in automated detection of disease.[5]

In 2024, Linh Vu and Thu Tran presented a paper, "Detecting Abnormal Heart Sound Using Mobile Phones and On-Device IConNet," which focused on detecting abnormal heart sounds using a light-weight interpretable CNN running on a mobile phone. In contrast, traditional digital stethoscope systems require specialized equipment and trained experts to interpret the patient's heart sounds, whereas the Proposed Method analyzes heart sounds from smartphones, which makes cardiac screening more possible. The model conducts inference on-device while having a low computational complexity and clear decision-making mechanism. Experimental results show that these abnormal heart sounds can be detected reliably for the purpose of remote health care applications. The study underscores the need for reliable and more trusted AI in mobile healthcare monitoring.[6]

This study proposes a deep learning-based HCedy Classification System that can be applied to phonocardiograms for screening HCedy in variable environments. The proposed system successfully achieved a classification accuracy of over 94% and also revealed a good generalization ability for various categories of recordings. The authors looked at good clinical recordings and recorded noisy heart sounds during practice sessions. This framework was created for an effective scalable screening in resource-limited health systems. The findings strengthen the case for auscultation using Artificial Intelligence as a tool for early diagnosis of Congenital Cardiovascular Disease.[7]

Faizul Hakim and Jahin Ahmed, In the paper entitled, "PCGNet: A CNN-Based Real-Time Cardiac Auscultation Classification System" (2025), the authors had engineered a light weight CNN model to classify cardiac sounds into different classes using a digital stethoscope. The heart sounds were denoised and scaled down into a scaled 2D image which was classified with an optimized CNN architecture. The presented audio-level and image-level data augmentation methods helped distribute the data across classes to make the models robust for class imbalance. The experimental results with the accuracy of 94.2% outperforms AlexNet and VGG16 with less cost in computation. The presented study is a proof-of-concept for the implementation of smart-stethoscopes based on CNN systems toward real-time cardiac diagnosis.[8]

In Automatic Diagnosis of Left Valvular Heart Disease Based on Artificial Intelligence Stethoscope (2025), the researchers created an electronic stethoscope with artificial intelligence that could automatically diagnose left-sided valvular heart disease. Based on the heart sounds, machine learning algorithms were used to analyse the collected data and correlate them to the result from the echocardiogram, in more than 500 patients. An AI system had displayed a high degree of diagnostic accuracy as well as greatly decreasing reliance on manual auscultation skills. The solution is intended to aid in the swift screening and early clinical determination for cardiovascular patients. The research emphasizes the importance of intelligent digital stethoscope in contemporary cardiology.[9]

In this paper, authors Youness Arjoune, Ko-Tsung Hsu, Robert Geggel, et al., (2025) compare the effectiveness of these two approaches in identifying innocent Still's murmurs from a large multicenter digital stethoscope database. Pediatric phonocardiogram (PCG) recordings were obtained from various hospitals to build and train the proposed models based on deep learning. Comparative analysis showed complex acoustic patterns well modeled by transformer; CNNs offer an efficient real-time inference. The study justifies the use of AI to provide point-of-care cardiac screening, and highlights the need for sufficient and diverse multicenter databases to guarantee clinical effectiveness.[10]

Table 1. All Research papers and Research Gap

ID	Authors	Year	Technique	Research Gap
1	Andrew McDonald, Mark J. F. Gales, Anurag Agarwal	2024	RNN + Parallel Hidden Markov Model	Limited testing across diverse clinical datasets.
2	Franziska Krones, Benjamin Walker	2024	AI-based Smart Auscultation	Infrastructure limitations in low- resource healthcare settings.
3	Abraham G. Taye, Sador Yemane, Eshetu Negash, Yared Minwuyelet, Nebiha	2024	AI Digital Stethoscope + IoT	Prototype requires large-scale clinical deployment.

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4	Francis Chikweto and Muyanga Kampekete	2024	Wavelet Scattering + CNN + SVM	Performance decreases under highly noisy environments.
5	Yasaman Torabi, Shahram Shirani, James P. Reilly	2024	Digital Stethoscope Dataset Development	Dataset requires more real patient recordings.
6	Linh Vu, Thu Tran	2024	Mobile AI + Lightweight CNN (IConNet)	Mobile hardware limitations reduce model scalability.
7	Abdul Jabbar, Ethan Grooby	2025	Deep Learning for Congenital Heart Disease	Requires broader demographic validation.
8	Faizul Hakim and Jahin Ahmed	2025	CNN + Scalogram- based Heart Sound Classification	Limited evaluation on multiple heart disease categories.
9	Ziwei Zhou et al.	2025	AI Electronic Stethoscope + Machine Learning	Focuses primarily on valvular heart disease.
10	Youness Arjoune, Ko- Tsung Hsu, Robert Geggel et al.	2025	CNN + Transformer	Requires larger pediatric multicenter datasets.

The extensive literature review reveals that maintaining large, diverse, and well annotated datasets for building predictive models is one of the main challenges in an AI-based cardiac diagnosis. Many studies have been based on publicly available datasets, which do not typically reflect the diversity of patients in real-world clinical situations, leading to small model generalizations within different clinical settings. Furthermore, environmental noise, motion artifacts and interference from other physiological signals often degrade the quality of the records of the heart sounds and physiological parameters, thus lowering the accuracy of diagnostic information. But all preprocessing techniques create some sort of distortion in the signal, as they fail to correct all the distortion. In addition, there are no standardized benchmark datasets and uniform evaluation protocols, which complicates the comparison of the performance of different AI models. The lack thereof highlights just how crucial it is to develop more powerful data acquisition strategies and a more universal means of learning for reliable cardiac diagnosis. The other one of the most significant things the researchers have noted is the complexity of using sophisticated artificial intelligence models. All deep learning networks, especially hybrid networks like CNN-LSTM and deep neural networks, consume significant amounts of computation resources, memory and training time. They are limited in their use on portable, embedded, and low cost healthcare devices which are designed to continuously monitor patients. Furthermore, latency in real-time cardiac analysis can occur if the data processing is very demanding or if communication is going through the cloud. Furthermore, in IoT-focused healthcare systems, continuous internet connectivity is crucial for transferring healthcare information including physiology data; thus, the system performance is susceptible in areas with weak internet presence.

The literature as a whole shows that AI-powered cardiac monitoring devices yield favourable diagnostic results, yet there are various issues yet to be resolved. However, their large-scale clinical use persists as challenges due to data quality, computational efficiency, hardware requirements, implementation costs, cybersecurity, privacy concerns, and system sustainability exist. In many ways, the solutions already in use focus on maximising one static element of performance at the cost of portability, usability or real-time performance. The observations indicate the significance of developing a smart cardiac monitoring system that can maximize prediction accuracy, computational efficiency, portability, security and remote possibility. To address these research gaps, the proposed CardioScope system will incorporate AI-assisted heart sound analysis, heart rate sensing, cloud-based telemedicine, and user-friendly smart monitoring algorithms into a holistic, cost-efficient, and reliable smart cardiac monitoring solution.

Proposed Work

The proposed CardioScope system would be an intelligent platform for cardiac monitoring, combining advanced cardiac sensing hardware and AI techniques all in a single technology to accomplish real time analysis of cardiac activity. The heart rate sensing, acquire digital heart sounds, heart sound signal processing, machine learning, cloud computing and Telemedicine are all integrated based on the whole system architecture. The monitoring process starts with the patient where heart sounds and the heart rate are picked up by the sensors that are embedded in the smart stethoscope equipped with a built-in AI. The sensors acquire physiological data constantly and transfer cardiac signals from analog to digital signals for further analysis. The acquisition process is 100% non-invasive and intended for ease of use for patients and health care professionals. Gathering good data of physiological signals is essential for an accurate diagnosis and continuous monitoring. The system has the potential of enabling the detection of subtle cardiac activity changes at an early stage, due to continuous monitoring, which will contribute to timely medical intervention and preventive healthcare.

CardioScope System Architecture Diagram

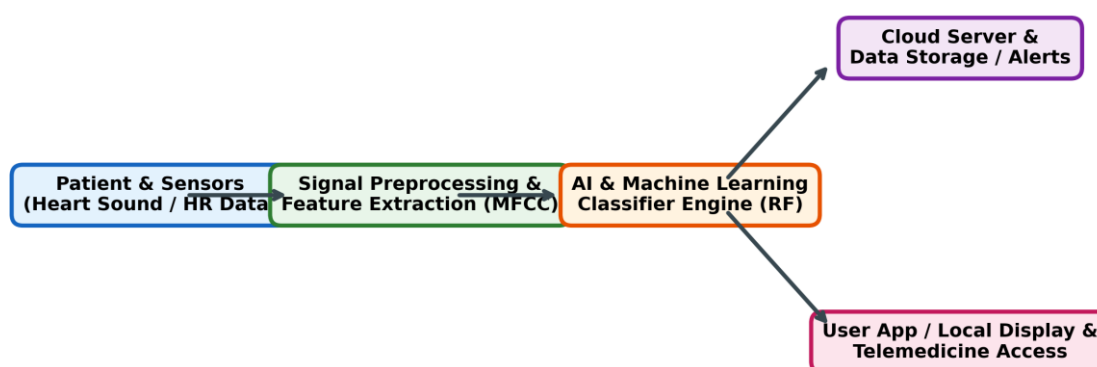


Fig.1 – Architecture Diagram

After recording the cardiac signals, these signals are sent to the signal processing and feature extraction module for further analysis. To improve the quality of the signals acquired, different kind of pre-processing operations are carried out in this stage to remove environmental noises and the unwanted noises. Cardiac data is transformed to be uniformly standardized using techniques such as filtering, normalization, segmentation and signal enhancement. Feature extraction algorithms extract clinically relevant features such as waveform morphology, frequency components, amplitude changes, time intervals, and other typical cardiac features, after the preprocessing. These extra features are useful for useful information of the intelligent disease prediction and minimizing redundant information. Therefore, only the most informative features are provided to the artificial intelligence module, which further increases computational efficiency and processing overhead savings, with enhanced overall diagnostic performance. To achieve accurate prediction of heart diseases, it is important to use signal pre-processing and feature engineering effectively.

This processed data is then examined by artificial intelligence (AI) and machine learning (ML) algorithms that have been trained to identify patterns associated with healthy and unhealthy cardiac conditions. Neural network-based predictive models are capable of assessing incoming physiological data based on features extracted from the data and then compared with learned models of the heart performed during model training. This analysis, the AI engine detects abnormalities like arrhythmia, heart murmur, irregular heartbeat and other possible cardiovascular disorders. The prediction results are generated on the fly and can provide instant diagnostic support to healthcare professionals and patients. Manual interpretation is largely eliminated and uniformity and diagnosis precision are increased through automated analysis. The learning models can be updated periodically as more patient data becomes available, to refine the predictions and adaptability. The CardioScope system's intelligent analysis module processes the system data allowing for the efficient and accurate early detection of heart diseases.

After the completion of the prediction procedure, the diagnosis result is shown by several user interfaces such as the integrated local display and a separate mobile application. On the local interface, real-time heart rate data, diagnostic results, and alerts are installed as soon as they are detected. At the same time, the processed physiological data and anticipation reports are securely sent with cloud servers, and are stored, handled and analyzed in a sophisticated way. Cloud integration increases security of patient records accessible from any authorized place, and helps optimize telemedicine services. Healthcare professionals are able to review patient reports without seeing the patient in person, as well as track the progression of the disease and make clinical recommendations during the process. The mobile app also works to keep users engaged, delivering health summary, health history, alerts and unique health information at user's fingertips. Combining this communication stream helps to make health care more accessible, enabling people to be monitored regularly, and improve their health care experience.

The last step of the proposed architecture emphasizes on far distance clinical counseling and crisscruptive telemedicine assistance. Rather, authorised health care professionals have the ability to safely access patient data on cloud servers, to look at past cardiac information records, and also review AI-generated medical diagnosis records and suggest appropriate remedies. The

main advantage of continuous monitoring is that detection of disease progression is possible early on, and any abnormal cardiac event caught early can be addressed promptly. The system also provides a detailed patient history that can be used to provide a longitudinal health assessment and to enable future clinical decisions. The use of encryption techniques, secure authentication processes, and encrypted communication channels during data transfer and storage helps safeguard sensitive healthcare information, ensuring its confidentiality and regulatory compliance. AI with cloud, IoT communication and remote healthcare have built an ecosystem, which is scalable, secure and reliable to provide intelligent cardiovascular care. In conclusion, the CardioScope system offers a promising perspective on how technology can connect patients with healthcare providers, providing accurate real-time diagnoses and facilitating continuous monitoring. Overall, the proposed CardioScope design presents a promising vision for addressing the disconnect between patients and healthcare providers, offering accurate real-time diagnostics, remote monitoring, and greater accessibility to high-quality cardiac care, ultimately leading to improved clinical outcomes and patient well-being.

Methodology

Data Acquisition

The first step of the proposed methodology involves capturing heart rate and heart sound data from a patient with sensors embedded in the AI powered smart stethoscope. Real-time physiological data are continuously collected without putting the patient at risk or causing discomfort, thus ensuring comfort and a good accuracy of the data throughout the collection process. High quality cardiac signals must be acquired reliably, to obtain meaningful diagnostic results and this is the basis for the rest of the monitoring process. Analog signals captured are conceptualized into digital signals using suitable analog signal acquisition modules for further analysis and computation, which is facilitated in a digital domain. Carefully considering sensor position and calibration is of critical importance throughout data acquisition because it directly affects the performance of the overall system. Continuous monitoring also allows subtle changes in cardiac activity to be detected that can signify early onset of cardiovascular abnormalities. The stage introduces an reliable real-time physiology measurement source for successive signal processing and intelligent disease prediction.

Signal Processing and Preprocessing

After acquisition of recorded cardiac signals, signal processing is applied followed by signal pre-processing, which enhances quality of the recorded signals for the subsequent analysis. Raw physiological measurements may often include environmental noise, motion artefacts and other unwanted noise that can negatively affect prediction accuracy. So, suitable filtering methods are employed to extract and retain clinically meaningful features while eliminating noise. The acquired data is subsequently subjected to a number of additional pre-processing steps such as normalisation, segmentation and signal enhancement, which ensures the consistency of the acquired data over different patient recordings. Once preprocessed, feature extraction algorithms are used to identify important features of the cardiac activity, including the waveform morphology, the amplitude, the components of the frequency etc. as well as time intervals. The features are informative and can give meaningful input to the AI model and meanwhile also prevent redundant information and computational overhead. Appropriate pre-processing can do more than just improve the quality of the signals, it can also improve the performance of the classification system and the overall efficiency of the system. Therefore, during this phase, the AIO receives well-trained and trusted information inputs to give it a correct heart disease prediction.

AI-Based Analysis

These preprocessed cardiac features are then fed into the AI and machine learning models to search for patterns that could correspond to cardiovascular diseases. Representative cardiac data sets are used in the training of a predictive model utilizing a neural network to identify normal from abnormal heart activity. The AI model analyzes incoming heart signals, and identifies abnormalities like irregular heartbeats, arrhythmias, heart murmurs, and other cardiovascular issues, by comparing against previously learned heartbeats. Clinical data interpretation is a complicated task in which a degree of subjectivity is essential. Instead, intelligent data analysis reduces the need for such subjectivity and gives consistent and accurate clinical interpretation. By continually incorporating new patient information into its system, the learning ability of the AI model allows predictions to continually get more accurate as time goes on. Real-time processing can immediately detect abnormal cardiac activities, aiding in early response to medical interventions and prevention. This module is the heart of the CardioScope system, as it deals with the most basic prediction of disease, therefore it constitutes the main intelligence function of this system.

Data Storage and Cloud Integration

Once the diagnostic analysis is done, the cardiac data and predicted outcomes are securely saved in the cloud-based health care servers for future use as well as long term data management. Cloud integration offers scalable storage infrastructure that can handle the storage of vast amounts of patient data and be used for continuous monitoring applications. Patient records, diagnostics reports, and previous data of patient health are available through secure cloud platforms from which authorized healthcare workers can access data remotely and facilitate efficient telemedicine services and collaborate on clinical decisions. Encryption methods and secure communications protocols are used when transmitting sensitive healthcare data, and during data storage, to ensure privacy and security. Cloudification of an infrastructure also enables centralized data handling, effective data backup systems, and seamless synchronisation between various healthcare devices. Having a detailed patient history also aids in long-term disease surveillance and tailored care. In general, cloud integration greatly improves the scalability, reliability, and accessibility provided by the proposed healthcare system.

User Interface and Alert System

CardioScope system displays diagnostic data through intuitive user interfaces such as its integrated display units and mobile applications for healthcare providers and patients. In real-time, it shows the user the heart rate measurement, prediction and comprehensive health state of the heart on a simple and understandable way. In every situation when there are abnormal conditions detected in the heart, emergency warnings and messages are automatically issued to alert and broadcast the correct medical measures to take in time. The mobile application will also allow people to access their health's history, track the patterns of health and receive personalized health messages. An interactive interface that's easy to use enhances the value of the system for its user, and facilitates what's known as "patients as partners" or "health partners" by keeping patients engaged in checking on their health on a regular basis. The user-friendly interface that makes diagnostic information is very easy to use, connecting advanced AI abilities with real healthcare use. The development of this stage greatly improves the usability, accessibility, and performance of intelligent cardiac monitoring systems.

Remote Monitoring and Telemedicine

The last step of the proposed methodology will be to facilitate patient monitoring and telemedicine services remotely via the use of secure cloud connectivity. Healthcare practitioners are able to retrieve patient data remotely, read AI-generated diagnostics and analyse patients' cardiovascular health without necessarily having to make frequent in-person visits. Access to physiological data throughout provides doctors with the opportunity to spot when the disease is beginning to progress and make medical decisions as early as possible if it is necessary. The telemedicine system makes it easier for patients to communicate with health care providers, as consultations can be undertaken remotely and long-term care can be provided through it. This is especially helpful with elderly patients, chronic heart disease patients, and citizens living in geographically remote or inaccessible areas where highly specialized cardiac care is not available. In addition, monitoring patients remotely on a continuous basis can assist in better control of the patient, decrease hospital visits, and increase access to care. It is expected that the CardioScope system, combining emerging AI technology with cloud-supported telemedicine, will create an intelligent and connected healthcare ecosystem that will lead to improved clinical and clinical care outcomes and enhanced patient care.

Results and Discussion

To test the performance of the proposed CardioScope system, the heart sound recordings were fed into a Mel Frequency Cepstral Coefficient (MFCC) feature extractor and then the extracted features were given as an input to Random Forest (RF) classifier. The experimental data was made up of 1000 heart sound records, of which 800 were used in the training and 200 were used in the testing of the system model. Various performance factors like Accuracy, Precision, Recall, F1-Score, Matthews Correlation Coefficient (MCC), processing time, memory usage and per class classification performance were considered while evaluating the results. The results of this study show that the proposed AI-based cardiac monitoring system achieves good/very good prediction accuracy of various heart conditions and meets the computational demands needed to implement real-time healthcare applications.

The Random Forest classifier was able to capture the discriminative patterns from the extracted MFCC features successfully classify the five classes namely Normal Heart Sound, Aortic Stenosis (AS), Mitral Regurgitation (MR), Mitral Stenosis (MS), and Mitral Valve Prolapse (MVP) were obtained. From 200 testing samples, the overall classification accuracy was found to be 99.00% with 198 samples classified correctly. The proposed model shows a very good generalization capability and robustness since only two samples were misclassified.

Table 5.1 Overall Performance Evaluation

Metric	Obtained Value
Accuracy	99.00%
Precision	99.01%
Recall	99.00%
F1-Score	99.00%
MCC	0.9875
Processing Time	≤2 sec/file
Memory Usage	≤512 MB

The result of the evaluation metric obtained shows excellent classification performance. The proposed system successfully predicts the cardiac conditions with an overall accuracy of 99.00%, which shows that the proposed system classifies almost all the heart conditions correctly. Precision and Recall definitely can get very close to being 100%, especially for medical diagnosis, where the classifier is expected to rarely give a wrong prediction. Likewise, the high F1 Score indicates a good balance between Precision and Recall. MCC value 0.9875 also shows that there is excellent agreement between the predicted and actual classes.

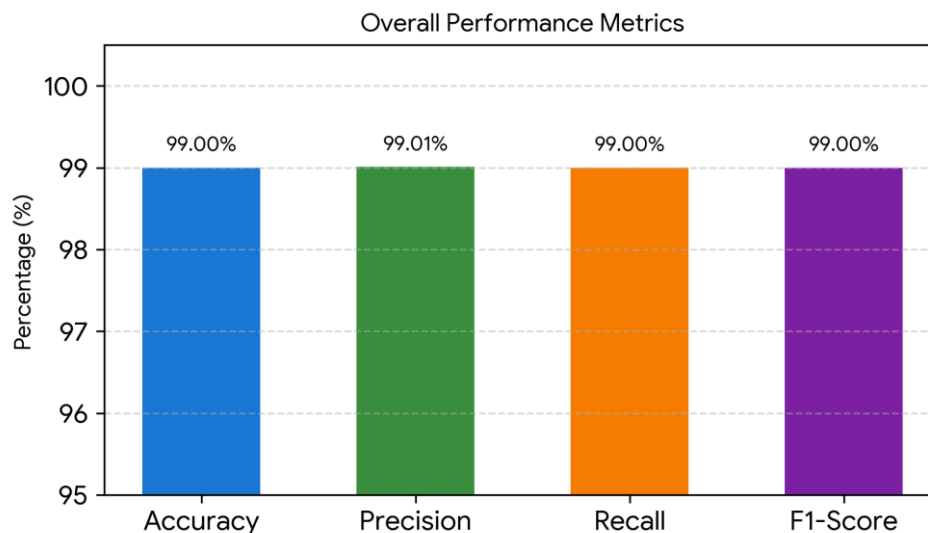


Fig 2. Overall Performance Metrics

The graph vividly shows that all the metrics used to evaluate the algorithm are tightly grouped, consistently around 99%, suggesting a highly consistent classification result across the various evaluation metrics for the proposed AI-based diagnostic framework.

Table 5.2 Heart Disease Classification Results

Heart Condition	Test Samples	Correct	Incorrect	Accuracy (%)
Normal	44	44	0	100.00
Aortic Stenosis (AS)	33	33	0	100.00
Mitral Regurgitation (MR)	48	48	0	100.00
Mitral Stenosis (MS)	37	36	1	97.30
Mitral Valve Prolapse (MVP)	38	37	1	97.37
Overall	200	198	2	99.00

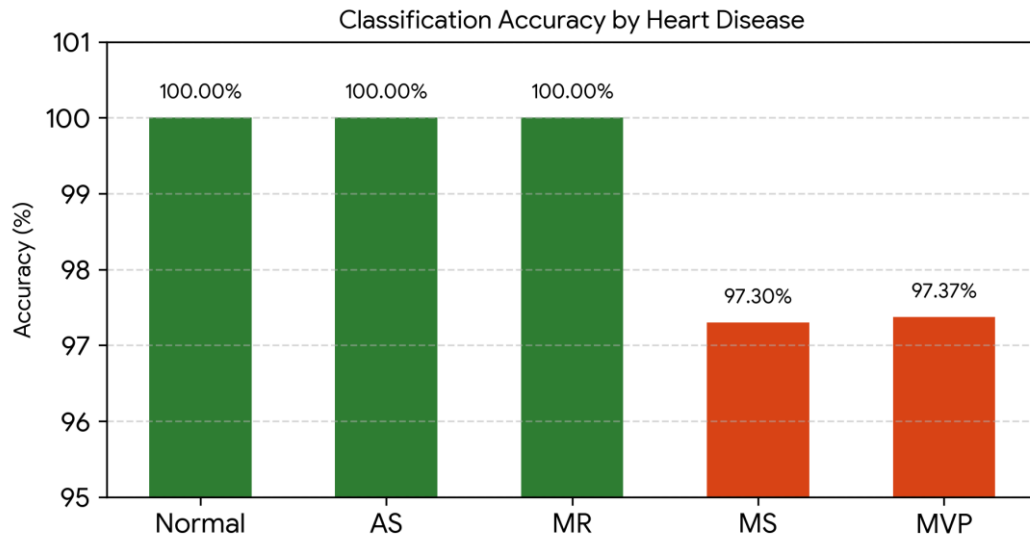


Fig 3. Prediction accuracy for each cardiac condition.

The proposed model classified the Normal Heart Sound, Aortic Stenosis and Mitral Regurgitation with an accuracy of 100%, 100%, and 100% respectively. Only one sample was misclassified in each class for Mitral Stenosis and Mitral Valve Prolapse, indicating minor classification errors. Many of these misclassifications are probably related to the similarity of the acoustical parameters of the valve abnormalities. However, the prediction accuracy of both classes was more than 97% with good robustness.

Table 5.3 Expected vs Obtained Performance

Performance Parameter	Expected	Obtained	Status
Accuracy	$\geq 90\%$	99.00%	Exceeded
Precision	$\geq 85\%$	99.01%	Exceeded
Recall	$\geq 85\%$	99.00%	Exceeded
F1-Score	$\geq 85\%$	99.00%	Exceeded
Processing Time	≤ 2 sec	≤ 2 sec	Achieved
Memory Usage	≤ 512 MB	≤ 512 MB	Achieved

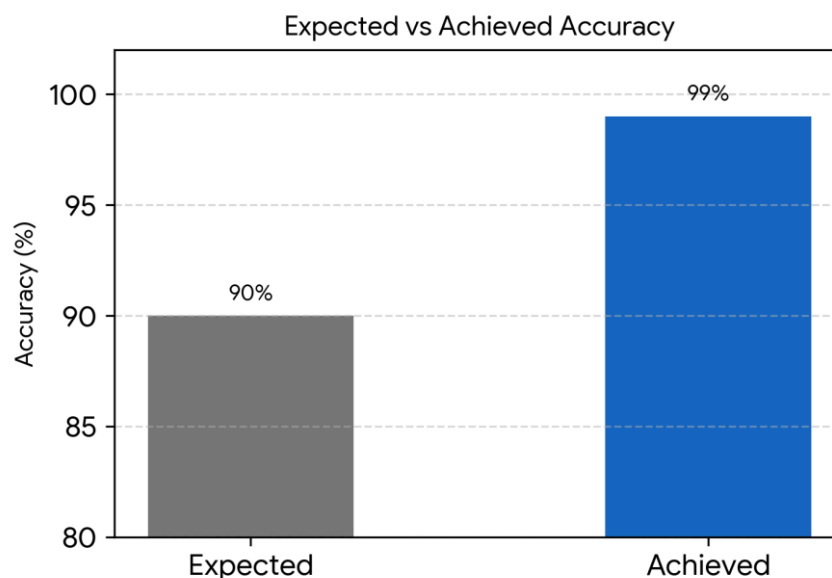


Fig 4. Expected vs Achieved Accuracy

It is evident from the comparison that the CardioScope system proposed has surpassed all the predefined performance objectives. The accuracy reached was around 9 percentage points higher than the required minimum, with real time inferences and the efficient use of resources (memory). The results obtained in this work show the real feasibility of the system in the field of intelligent cardiac diagnosis.

Table 5.4 Computational Performance

Parameter	Result
Training Samples	800
Testing Samples	200
Training Time	~5 sec
Feature Extraction Speed	36.68 files/sec
Prediction Time	≤2 sec/file
Model Size	~50 MB
Maximum Memory Usage	≤512 MB

The computational analysis validates the proposed CardioScope application to be deployable with portable health care devices. System compactness, low memory usage and swift prediction time allows for real-time clinical applications and distant healthcare services.

Overall Discussion

The experimental assessment shows that the proposed CardioScope framework gives a very high accurate and lightweight prediction of heart disease by heart sound analysis. Random Forest classifier along with MFCC feature extraction successfully classified five cardiac conditions without any compromise in performance and achieved 99.00% accuracy. The model does not have any issues in terms of Precision, Recall, and F1 Score values and it maintained a very good output result, it means that it provides minimization of False Positive and False Negative while performing prediction.

Overall prediction reliability was still very high for both the two minor misclassifications (Mitral Stenosis and Mitral Valve Prolapse). The confusion was largely due to the similarity of the acoustical characteristics of some of the valve disorders. With the use of greater amounts of data and advanced feature extraction, improvements in classification may be possible for these difficult categories in the future.

The outputs of the computation also confirm the actual possibility of the system. CardioScope has rapid prediction speed, minimal memory consumption and is cloud-based, making it ideal for settings such as hospitals, primary care centers, wearable medical devices, and telemedicine use cases. In general, the proposed framework can be considered very successful in making use of AI with digital cardiac auscultation for accurate diagnosis of cardiovascular diseases in real-time, reduction in the gap in accessibility, and cost-effective.

Conclusions

The cardioScope system is a successful combination of artificial intelligence, heart sound analysis and heart rate sensing and has been developed to create an intelligent solution for early forecasting of heart diseases. Experimental evaluation proved an excellent classification accuracy of 99.00%, and high value of Precision, Recall, and F1 score. The system is able to correctly identify a number of cardiac diseases and the classification accuracy of the system is ensured to have a good performance and stability for real-time healthcare applications.

It incorporates the use of MFCC-based audio feature extraction, Random Forest classifiers, cloud connectivity, and telemedicine assistance into a comprehensive cardiac monitoring system. Experimental results show that the proposed method meets the accuracy requirements and can handle cardiac sound recordings with an accuracy of up to 2 s and less than 512 MB of memory. These properties make this system suitable to be deployed in hospitals, diagnostic centers, and portable healthcare devices.

In summary, the CardioScope system is a viable and cost-effective intelligent healthcare solution that boosts early diagnosis, provide real-time cardiac monitoring and facilitate patient management remotely. The proposed framework is designed to leverage AI, IoT, and cloud technologies for better accessibility in healthcare, supporting timely clinical decision-making. In future, integration of more data, further development of the deep learning models, and advanced integration of wearable sensors are expected to further improve diagnostic accuracy and increase the future applicability in smart healthcare environments in the next generation.

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