



Hybrid Machine Learning For IoT-Driven Heart Health Prediction

Priyanka Vijay Adate¹, Prof. A. A. Bhise²

Computer Engineering, Smt. Kashibai Navale College of Engineering, Pune¹

Guide, Computer Engineering, SKNCOE Pune²

Abstract: The rapid growth of intelligent healthcare technologies has enabled continuous monitoring of human health through connected devices and smart sensors. Heart-related illnesses require immediate attention and timely analysis because delayed diagnosis may lead to severe complications. This research presents a smart IoT-based framework designed for early heart risk identification using adaptive learning and sensor-driven analytics. The system acquires real-time physiological information through ECG, pulse oximeter, and temperature sensors connected to an embedded microcontroller platform. Unlike traditional healthcare prediction systems that depend completely on pre-labeled datasets, the proposed framework introduces an adaptive learning strategy capable of dynamically categorizing incoming health data patterns. Processed sensor readings are analyzed using Artificial Neural Network (ANN) and Random Forest techniques to determine the probability of abnormal heart conditions. The proposed approach improves prediction consistency, supports continuous monitoring, and minimizes dependency on cloud-based infrastructure. Experimental evaluation demonstrates that the framework provides reliable prediction performance with improved adaptability for real-time healthcare environments.

Keywords: Smart Healthcare, IoT Sensors, Heart Risk Detection, Artificial Neural Network, Random Forest, Real-Time Monitoring, Intelligent Healthcare

I. INTRODUCTION

Healthcare technology has experienced significant transformation with the introduction of smart monitoring devices and intelligent computing methods. Conventional healthcare systems mainly rely on periodic medical examinations and hospital-based diagnosis procedures. Although effective in many situations, these methods are not suitable for continuous monitoring of patients who require immediate medical attention. In particular, heart-related disorders often develop silently during the early stages, making regular observation extremely important. The advancement of sensor technologies and embedded systems has made it possible to continuously observe physiological conditions using compact healthcare devices. IoT-based monitoring systems can collect parameters such as pulse rate, oxygen level, electrical heart activity, and body temperature in real time. These systems reduce the burden on healthcare facilities and support remote supervision of patients.

Despite the benefits offered by smart healthcare systems, processing continuously generated biomedical information remains challenging. Real-time sensor readings are highly variable and frequently contain incomplete or unlabeled information. As a result, conventional machine learning approaches cannot always produce accurate predictions in dynamic healthcare environments. To address this issue, the proposed work introduces an adaptive learning mechanism capable of analyzing changing physiological conditions and generating suitable classifications automatically. The framework combines intelligent preprocessing, adaptive categorization, and hybrid prediction techniques to improve system reliability. Artificial Neural Networks are utilized for identifying complex hidden relationships among biomedical signals, while Random Forest improves classification stability through multiple decision structures. The combination of these approaches enhances prediction performance and increases system robustness for practical healthcare applications.

The developed framework focuses on creating a low-cost and efficient healthcare monitoring environment capable of assisting medical professionals in early identification of heart-related abnormalities.

II. LITERATURE SURVEY

P. Kumar and R. Singh [1] proposed a cloud-assisted remote patient monitoring framework using IoT devices for continuous healthcare supervision. Their system improved accessibility to patient information; however, dependence on

cloud infrastructure introduced communication latency and privacy concerns. L. Chen, Z. Zhou, and K. Li [2] developed an IoT-enabled healthcare analytics system capable of processing real-time biomedical information. Their framework utilized data analytics for monitoring patient conditions, but system performance decreased when handling large-scale real-time healthcare data. H. Alsharif, M. Alsubhi, and A. Alzahrani [3] presented a wearable sensor-based healthcare monitoring framework designed mainly for elderly patient supervision. Although the system improved mobility and remote observation, false alerts and sensor discomfort affected monitoring reliability.

R. Patel and N. Shah [4] introduced a cloud-assisted healthcare prediction framework for disease monitoring and analysis. The proposed model improved remote accessibility but suffered from security risks and communication delay caused by cloud dependency. S. Verma and D. Sood [5] proposed a smart healthcare monitoring system integrating IoT devices with machine learning models. Their work improved prediction efficiency; however, the system required large amounts of labeled healthcare data for accurate classification. M. Ali, F. Riaz, and S. Khan [6] discussed different architectures, challenges, and solutions related to IoT-based healthcare systems. Their survey highlighted issues such as scalability, privacy, communication delay, and data management in healthcare environments. Y. Wang, J. Sun, and X. Liu [7] developed a real-time wearable IoT monitoring system capable of continuously tracking patient physiological conditions. Although the system supported remote healthcare applications, maintaining stable prediction accuracy in dynamic environments remained challenging.

A. Rahman and S. Hossain [8] proposed a low-latency communication framework for IoT-enabled healthcare monitoring systems. Their work focused on reducing communication delay, but network congestion still affected overall system performance during continuous monitoring. K. Sultan, U. Ruhi, and S. Lakhani [9] designed a data-driven smart hospital healthcare system integrating IoT and machine learning technologies. While the framework improved healthcare automation, deployment cost and infrastructure complexity limited practical implementation. T. Nguyen and D. Kim [10] introduced an energy-aware healthcare monitoring system using Wireless Body Area Networks (WBAN). Their work improved energy efficiency for wearable healthcare devices; however, transmission range limitations affected continuous monitoring performance. From the literature survey, it is observed that existing healthcare systems still face challenges related to real-time data handling, prediction accuracy, cloud dependency, communication delay, and processing of unlabeled sensor information. The proposed work aims to address these limitations by integrating adaptive learning and hybrid machine learning techniques for intelligent real-time heart monitoring and prediction.

III. METHODOLOGY

Existing healthcare monitoring systems still face several limitations related to real-time data processing, prediction consistency, and handling continuously changing physiological information. In many cases, sensor-generated healthcare data is unlabeled and difficult to process directly using traditional supervised machine learning methods. To overcome these issues, the proposed system introduces an intelligent IoT-based framework capable of performing continuous monitoring and adaptive prediction of heart-related abnormalities. In the proposed work, physiological data collected from IoT sensors is initially processed using an adaptive learning mechanism based on Q-Learning. The reinforcement-based learning approach helps in dynamically generating meaningful labels from raw sensor readings without depending entirely on manually prepared datasets. Once the labeling process is completed, the processed dataset is utilized for training and testing hybrid machine learning models including Artificial Neural Network (ANN) and Random Forest (RF).

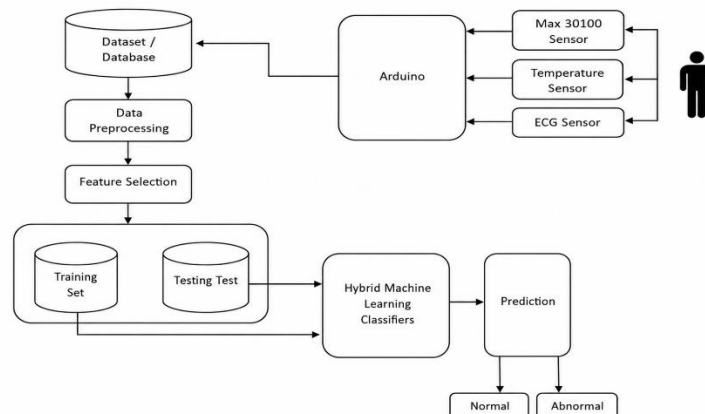


Fig: System Architecture

The proposed framework supports continuous monitoring through biomedical sensors connected to an Arduino-based microcontroller system. The collected sensor information is stored in a MySQL database for preprocessing and analysis. This non-invasive monitoring approach improves early heart disease identification and supports remote healthcare applications with reduced delay and improved efficiency.

The proposed architecture is divided into three major layers:

Data Acquisition Layer

This layer is responsible for collecting physiological information from patients using biomedical sensors connected to the Arduino controller.

Components Used

- Arduino-based monitoring system
- MAX30100 sensor for heart rate and SpO₂ monitoring
- Temperature sensor for body temperature measurement
- ECG sensor for electrical heart signal acquisition

Communication Layer: The communication layer manages the transfer and storage of sensor-generated data.

Processing Layer: This layer performs intelligent data analysis and prediction operations.

IV. EXPERIMENTAL RESULT AND DISCUSSION

The proposed framework was tested using sensor-generated biomedical data collected under different physiological conditions. The adaptive learning mechanism successfully improved data categorization quality and enhanced prediction consistency. Experimental observations indicate that the Artificial Neural Network effectively identified complex relationships among ECG patterns, pulse rate, and oxygen level variations. This improved the system's capability to recognize abnormal heart conditions at early stages. Random Forest demonstrated reliable classification performance even when slight fluctuations occurred in sensor readings. Due to its ensemble learning approach, the model produced stable outputs and minimized classification variance. The integration of adaptive learning with hybrid prediction techniques improved the overall reliability of the framework. The proposed system maintained efficient performance in continuously changing healthcare conditions. The experimental findings indicate that Java-based implementation using Eclipse IDE and WEKA.

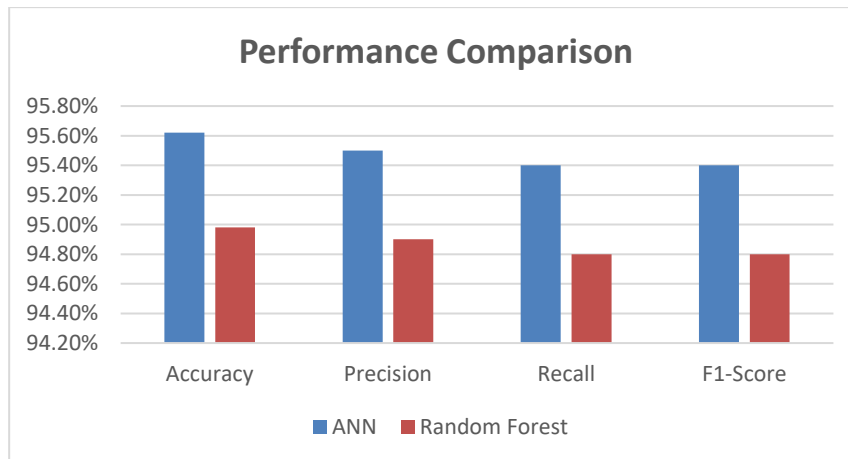


Fig: - Performance Metrics

V. CONCLUSION

The current research has introduced a novel, intelligent IoT-based system for real-time heart monitoring and early prediction of the risk of heart diseases. This system is designed to gather health data from various biomedical sensors attached to the platform based on the Arduino microcontroller. To handle real-time streaming data from sensors in real time without fully relying on hand-labeled datasets, an adaptive learning technique was employed in this work. The proposed system employs Artificial Neural Network and Random Forest algorithms to enhance prediction accuracy and classification performance. The results show that the system effectively handles real-time medical data with high accuracy and low delay in prediction tasks. Storing collected data locally further increases data privacy and decreases communication delay.

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