

# Design and Architectural Framework of Smart Health Monitoring System with AI-Driven Alerts Using IoT and Machine Learning

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**Abstract**—The main aim of this project is to design a smart health monitoring system that uses the Internet of Things and machine learning model. The system collects real-time vitals of the user such as heart rate, oxygen saturation with a wearable compact hardware. The main innovation is the usage of a machine learning model (Random Forest) that will process the collected data and detect anomalies. If the system finds an anomaly it will send an alert to a user, family member or healthcare. Sensors like MAX30102, MAX86150 are used to acquire photoplethysmography (PPG), heart rate (HR), electrocardiography (ECG) from the user. ESP32 is the microcontroller used as it integrates both wifi and bluetooth capabilities. Random Forest Algorithm is used on the publicly available cardiac dataset and the data from the sensor is classified as normal or anomalous. If any anomaly is detected by the machine learning model the ESP32 gives an alert to the GSM module which gives a call to the emergency contacts or healthcare. A technical architecture of a wearable health monitor is proposed in this paper.

**Index Terms**—Smart Health Monitoring System, IoT, ESP32, Random Forest, Machine Learning Algorithm, Heart Attack Detection, Healthcare, Anomaly

## I. INTRODUCTION

The burden of cardiovascular diseases is still rising worldwide. Most of the deaths due to heart attacks are considered preventable. According to the World Health Organization almost 17.9 million people are victims of cardiovascular disease caused death. This is 32% of the total deaths worldwide. No or late timely intervention is the most important factor that influences this number of deaths. Errors in continuous monitoring of health significantly

contribute to mortality [1]. The traditional systems lack the intelligence to analyze the data in real time [3]. In common or by traditional method the patient is required to visit a hospital to detect heart attack. However, the recent advancements in Internet of Things and Machine Learning promise a system that can monitor cardiac vitals and alert in real time. Previous research highlights the efficiency of microcontrollers such as Arduino and Raspberry Pi. However, intelligent diagnostic support remains a challenge. In this paper, we propose a system that uses ESP32 microcontroller and high precision sensors such as MAX30102, MAX86150. The system uses random forest algorithm to analyze and process the data in real time. If any anomaly is detected the system uses a GSM module to send alerts. This integration of AI and IoT can detect and prevent critical health threats before it occurs.

## II. LITERATURE SURVEY

In paper [1] titled “Smart Health Monitoring and Anomaly Detection Using IoT and AI” by P. Jayant, E. Vincent, Mohana, M. Moharir and A. K. A R published in 2024 explains about a system developed by AI and IoT system using NodeMCU ESP8266 with ECG and heart rate sensors for elderly care. Implemented PCA, Isolation Forest, and Z-score algorithms for anomaly detection and real-time alerts via Blynk and Streamlit dashboards. Enables continuous real-time monitoring with instant alerts. Provides an interactive dashboard (Blynk + Streamlit) for visualization.

In paper [2] titled “Intelligent and Smart Health Care Monitoring System based on Deep Convolutional Neural Network Model” by G. Anitha, R. Sankar, A. V. Juliet, V. Dhivya, B. Thiyaneswaran and A. K. Kumar explains a prototype for health monitoring using Raspberry Pi, BP, temperature, and pulse sensors was designed. It implemented a Deep CNN (AlexNet) model to classify and analyze patient health data. Achieved 97.13% accuracy, outperforming other models like SVM, ANN, and Autoencoder.

In paper [3] titled “: Real-time healthcare monitoring using smart systems: A step towards healthcare service orchestration” by V.Bhatt explains a system for healthcare professionals to continuously monitor the routine activities and health of patients in real time using IoT and AI. It creates an on-time response system for the patients. Creates services by networking with the professional. Provides a framework for development of health monitoring systems.

In paper [4] titled “Portable IOT-Based Health Monitoring and Prediction System with Machine Learning” by Arpan Biswas, Gargi Chakraborty, Sunipa Roy proposes an affordable and compact device that is designed for routine health checkups. It uses the ESP32 microcontroller and various other sensors that monitor the body temperature, oxygen levels, blood pressure etc. This system is particularly beneficial for individuals in remote areas, those living in accident-prone locations. Health related information can be transmitted to medical practitioners via cloud technology which ensures timely medical treatment.

In paper [5] titled “ML Based Multi-Faceted Health Monitoring Devices: Enhancing Elderly Well-Being” by S. P. Chaudhry and A. Malode explain a system that analyzes HR, stress, and hypertension in elderly population in real time. Improves the quality of life in elderly by the ongoing assessment. Real Time Monitoring of different parameters such as heart rate, stress level, fall prediction and hypertension.

### III. PROPOSED ARCHITECTURE

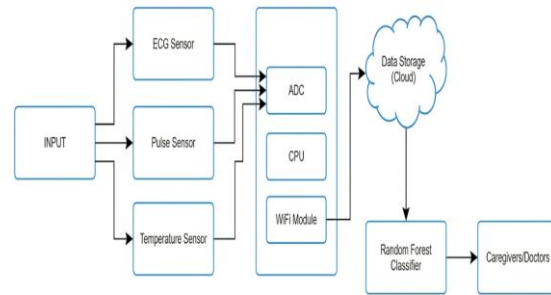


Fig 1- System Block Diagram

#### A. Hardware Architecture

ESP32 is used as the platform for the proposed system. It is then integrated with non-invasive sensors such as MAX30102 and MAX86150. The ESP32 microcontroller is used for its ability to integrate both wifi and bluetooth. MAX30102 sensor is used for sensing the PPG signals and blood oxygen saturation (SpO2). The MAX30102 sensor has inbuilt temperature sensor that can be used to collect the temperature value. The MAX86150 sensor integrates the ECG, PPG and heart rate sensor. By integrating both, high accuracy is obtained. It takes the delay in time between the arrival of PPG signals and R-peak of ECG signals to calculate blood pressure. This method is called Pulse Transit Time (PTT).

#### B. Data Preprocessing and ML

Random Forest Algorithm is used on the publicly available cardiac dataset (Kaggle) and the data from the sensor is classified as normal or anomalous. The gathered data then undergoes cleaning which removes noisy data. For handling multi-faceted health parameters Random Forest algorithm gives a superior performance [5]. The dataset is divided into training set and testing set. This algorithm will train the model to identify the differences between normal and anomalous values creating intelligence to the system. The model will gather data from the dataset and take the values like PPG, ECG, HR, SpO2 and label them either normal or critical. After this step data preprocessing and feature engineering will be done. Feature engineering is the process of extracting features that are most relevant. In data

preprocessing we handle missing values and normalization will be done. Once the training test and testing set is ready, we do model training where we train the Random Forest Classifier using the database. The random forest will collect all decision trees and minimize overall classification error. The testing set will be used to test the model and its performance will be evaluated using the performance metrics like accuracy, precision, recall, f1 score. Finally, the model deployment is done where the random forest file will be loaded to the ESP32 for real time interface. This algorithm will run continuously on the microcontroller ESP32. In real time execution ESP32 continuously monitors the sensors MAX86150 and MAX30102. When data is received from the sensors preprocess of data is done removing noise and to this data Random Forest is deployed. The model will either detect normal or anomaly.

*C. Alerting*

Medical practitioners can view the real time vitals remotely through a cloud platform [4]. If any anomaly is detected SMS alert is triggered by the GSM module. If the result is anomaly, then an alert trigger signal is sent to the ESP32 which then activates the GSM module. The GSM modules execute and an emergency call or alert will be sent to the designated contacts. If no anomaly is detected and the result is normal the system continues with monitoring the vitals.

IV. EXPECTED PERFORMANCE

This report proposes a Smart health monitoring system with alerts using the GSM module. It determines various health parameters like blood pressure, temperature and heart rate with the help of various sensors. This project explains the need for Remote patient Monitoring. For people that suffer from chronic diseases like cardiac issues, hypertension, hypoxia and others that require constant monitoring as they are fatal.

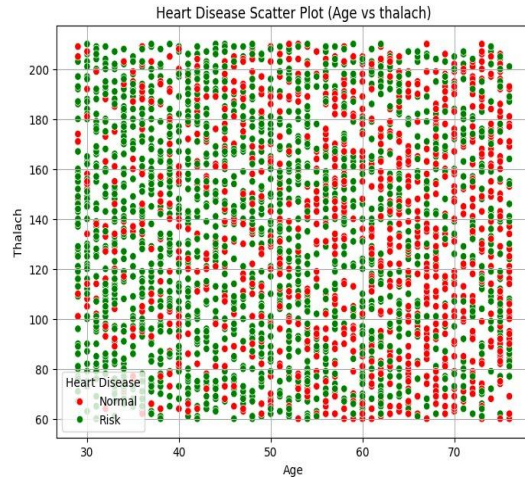


Fig 2- Heart Disease Scatter Plot

The distribution of cardiac data set and distinction between the normal class and anomalous class are represented in the scatter plot in Figure 2. The high variance between healthy states and cardiac states are demonstrated in the scatter plot. A high accuracy, similar to 97.13% reported by Anitha et al. [2] is expected by the Random Forest classifier.

A. Classification Analysis

The accuracy and effectiveness of the Random Forest classifier is demonstrated in the scatter plot analysis shown in Figure 2. The coloured clusters and their clear separation demonstrate the decision boundary between normal states and anomalous states.

B. Comparative Performance Table

Table 1: Comparative Performance

System/Author	Algorithm used	Reported Accuracy
Proposed System	Random Forest	High accuracy expected
Prabu Jayan et al[1]	XGBoost with GridSearchCV	High
G Anitha et al [3]	DCNN	High Classifier Power
Choudhry & Malode [5]	Random Forest & SVMt	Enhanced Predictive Analytics

V. FUTURE WORK

Chennai, India, 2024, pp. 1-6, doi:  
10.1109/ICMACC62921.2024.10894381.

Based on this study, even though the AI model has been validated with high accuracy based on the clinical data, the next step in this research is to physically integrate the prototype and perform clinical trials to assess the performance of the system under different environmental conditions.

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