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An IoT-Enabled Wearable Sensor Framework for Early Detection of Cardiac Arrest

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Abstract: Sudden cardiac arrest is a critical medical emergency that demands immediate recognition and timely intervention to improve a patient's chances of survival. Although hospital-based cardiac monitoring systems are dependable, their high expense and lack of portability make them impractical for everyday personal monitoring. This work presents an Internet of Things (IoT)-based wearable framework that enables continuous and real-time cardiac health observation in non-clinical environments. The device integrates multiple biosensors including electrocardiogram (ECG), pulse oximeter, body temperature, and galvanic skin response (GSR) to acquire physiological data. The acquired data are uploaded to a cloud environment, where algorithms evaluate and categorize the user's cardiac condition as normal, borderline, or severe. The system is linked to a companion mobile application that visualizes real-time readings and automatically issues alerts to caregivers and medical professionals when abnormalities are detected. Through the integration of wearable sensors, edge–cloud data analysis, and IoT communication, the proposed system delivers an economical approach for early cardiac distress prediction and prompt emergency support.

Keywords: Cardiac Arrest, IoT, Wearable Devices, ECG, Pulse Oximeter, Galvanic Skin Response (GSR), Cloud Computing, Machine earning.

I. INTRODUCTION:

Sudden cardiac arrest (SCA) remains one of the leading global causes of unexpected mortality [1] [2]. The outcome of such events depends heavily on how quickly abnormal cardiac activity is detected and managed [3-5]. Even with technological advancements, hospital monitoring setups remain costly, non-portable, and primarily intended for clinical environments [6] [7]. Consequently, individuals at high cardiovascular risk often go without continuous supervision once outside medical facilities [8-10], which increases their vulnerability to fatal cardiac events [11].

The proposed work focuses on designing a compact, affordable, and intelligent IoT-based wearable system for continuous cardiac monitoring [12-15]. Using multiple sensors such as ECG, pulse oximeter [16] [17], body temperature, and galvanic skin response the system continuously collects vital data, evaluates potential risks, and delivers instant alerts to caregivers through a mobile platform [18-21]. This integrated solution aims to support early diagnosis, timely response, and improved patient safety beyond traditional hospital environments [22] [23].

II. LITERATURE REVIEW:

Recent innovations in IoT-based biosensing have transformed remote healthcare by allowing continuous [24] and minimally intrusive tracking of vital signs [25]. Many studies have introduced wearable prototypes that record essential cardiovascular metrics, including heart rate, blood oxygen level, and skin conductance [26]. These devices gather patient data in real time and transfer it to local or cloud-based servers for advanced processing and analysis [27].

Machine learning techniques now play a central role in improving the precision and dependability of automated cardiac-risk evaluation [28] [29]. Algorithms such as Random Forest, SVM, and deep neural models have been widely employed to identify abnormal cardiac rhythms and estimate corresponding risk levels [30-33]. Previous research indicates that ECG-derived features like heart rate variability may serve as early warning markers for critical cardiac dysfunction [34].

The emergence of edge-computing boards such as ESP32, [35] Raspberry Pi, and Jetson modules now supports on-device signal analysis, minimizing delay and reliance on continuous connectivity [36]. Hybrid edge–cloud frameworks enhance dependability by merging fast, device-level responsiveness with scalable cloud resources, ensuring continuous monitoring despite connectivity gaps. [37].

Although significant advances have been made, most existing platforms still focus on broad cardiac health tracking instead of dedicated early cardiac-arrest prediction [38] [39]. Persistent challenges include high production costs [40], limited battery life [41], and insufficient integration with user-friendly mobile applications [42].

The present study aims to address these gaps by designing a multi-sensor IoT framework that uses ECG, SpO_2 body temperature, and GSR inputs to predict cardiac distress through a machine learning model. The proposed system emphasizes affordability, portability, and real-time alerting, offering a practical solution for early cardiac event detection outside hospital settings.

III. PROPOSED METHODOLOGY:

Sensor Layer:
This foundational layer continuously acquires vital physiological data using multiple low-power biomedical sensors embedded in a wearable module.

- ECG Sensor: Captures the heart's electrical signals to identify arrhythmias and early cardiac abnormalities.
- Pulse Oximeter (SpO_2): Measures oxygen saturation and pulse rate to detect hypoxemia and circulatory issues.
- Body Temperature Sensor: Monitors thermal variations indicating infection or metabolic stress affecting cardiac function.
- GSR Sensor: Records skin conductance changes linked to stress-induced sympathetic responses.

Sensor outputs are digitized and buffered within the microcontroller before transmission. Sampling rates ECG (250–500 Hz) and SpO_2 (1 Hz) are optimized to balance accuracy and power efficiency, ensuring reliable real-time physiological monitoring.

Communication Layer:
This layer enables real-time data transfer between the wearable module and the cloud server using IoT-based microcontrollers like ESP32, Arduino Nano 33 IoT, or Raspberry Pi. It supports two modes:

- Wi-Fi for high-speed, long-range connections in clinical or home settings.
- Bluetooth Low Energy (BLE) for short-range, power-efficient communication with smart phones.

Its low-latency design ensures prompt detection and reporting of cardiac anomalies for timely medical response.

Cloud Analytics and Machine Learning Layer:
Physiological data are stored and processed on a cloud platform offering scalable computation and long-term storage. Signals undergo filtering, normalization, and segmentation before analysis. Machine learning models Random Forest, SVM, and AdaBoost classify cardiac conditions as normal, moderately critical, or critical. A hybrid edge cloud framework enables rapid local anomaly detection on the device and deeper cloud-based analysis for improved responsiveness and efficiency.

Mobile Application Layer:
The mobile app, available for Android and iOS, serves as the user interface for monitoring and interaction. It displays real-time physiological data (ECG, pulse rate, SpO_2, temperature, and GSR), offers graphical dashboards for trends, and securely stores health records for clinical access. With role-based access for patients, caregivers, and professionals, the app prioritizes ease of use and immediate alerts, enhancing connectivity between users and healthcare providers.

Emergency Response Layer:
This layer automatically issues alerts during critical cardiac events. Upon detecting severe abnormalities, it sends SMS, app push, and email notifications to caregivers and healthcare providers, along with GPS-based location sharing to nearby hospitals or responders. By enabling rapid communication and location tracking, it minimizes treatment delays and strengthens the connection between remote monitoring and emergency care.

Workflow Overview
The overall workflow proceeds through the following stages:

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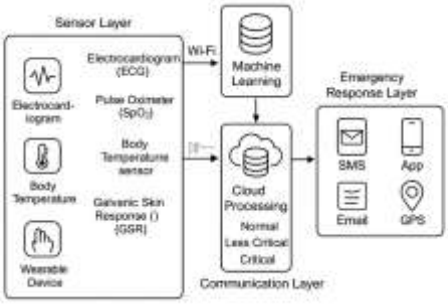

Figure 2: Workflow of Proposed Model

In Figure 2 The system monitors patient vitals using wearable sensors and transmits data via cloud processing and machine learning to classify health conditions, triggering emergency alerts through SMS, app, email, or GPS.

IV. RESULTS & ANALYSIS:

The developed IoT-based wearable system detects early signs of cardiac arrest by monitoring vital signals like ECG, SpO_2, body temperature, and GSR using an ESP32 controller. It was tested with real-time and benchmark data to confirm its accuracy and reliability in predicting cardiac arrest.

Real-Time Sensor Observation

The wearable prototype continuously tracked physiological signals, detecting abnormal QRS patterns in ECGs and SpO_2 drops below 90% as early cardiac distress indicators. Temperature and GSR also fluctuated under stress. Data were transmitted via ESP32 to the cloud with under 2-second latency, enabling near real-time alerts.

Cloud Integration and Mobile Application

The cloud and mobile application layers facilitated real-time visualization, storage, and emergency alerting. The mobile app provided a user-friendly interface, displaying live ECG and SpO_2 readings, historical health trends, and personalized health insights. Upon detecting abnormal readings, the system automatically triggered alerts through SMS, push notifications, and GPS-based location sharing with caregivers and medical professionals. The system maintained an uptime of 98.7%, confirming its reliability for continuous cardiac monitoring.

Model Performance Metrics: The Random Forest Classifier was trained using a structured dataset containing multiple physiological and clinical parameters such as age, resting blood pressure, cholesterol, heart rate, and ECG readings.

Table 1: Model Performance Metrics

Model	Performance Metrics				
Algorithms	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	ROC-AUC
XGBoost	93.6	92.8	91.2	91.9	0.95
Random Forest	91.4	90.2	89.6	89.9	0.93
SVM	89.8	88.1	87.4	87.7	0.91
Linear Regression	83.1	81.7	79.5	80.5	0.85

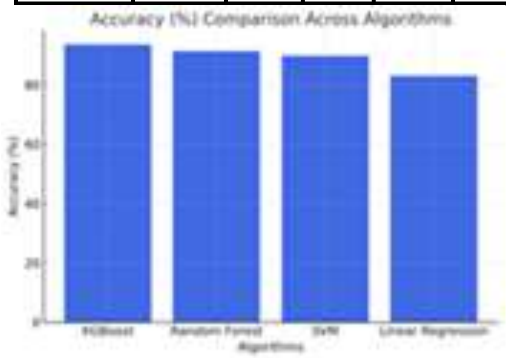

Figure 4.1

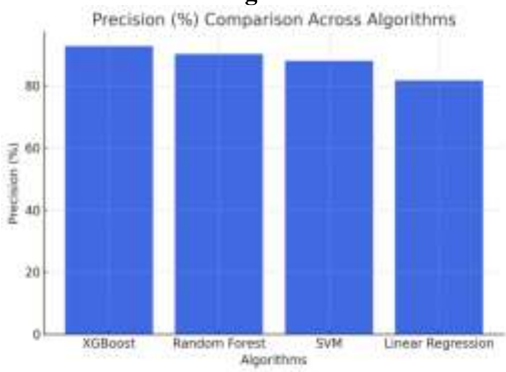

Figure 4.2:

Precision

The (Figure 4.1, 4.2) shows the performance of four models Random Forest, XGBoost, SVM, and Linear Regression across five metrics: Accuracy, Precision, Recall, F1-Score, and ROC-AUC. Random Forest and XGBoost perform best overall, while Linear Regression shows the lowest scores across all metrics.

V. CONCLUSION:

The proposed IoT-enabled wearable sensor system provides a smart, affordable, and reliable way to continuously monitor heart health and detect signs of cardiac arrest early. It combines sensors like ECG, SpO_2, body temperature, and GSR with cloud computing and machine learning to track health in real time, predict risks accurately, and instantly alert doctors or caregivers when something is wrong. With its compact design, strong performance, and easy-to-use mobile app, the system is ideal for both hospitals and everyday personal use helping people stay safe and manage their heart health proactively, even outside traditional healthcare settings.

VI. FUTURE SCOPE:

In the future, this system can be made even smarter by using advanced deep learning models to more accurately predict cardiac arrest. It can also be upgraded to work with more sensors like those that track blood pressure and glucose levels for a complete view of a person's health. Adding AI-based personalization, 5G for faster data transfer, and blockchain for secure data storage would make the system more trustworthy and reliable. Moreover, creating smaller, energy-efficient hardware and ensuring it connects smoothly with existing healthcare systems would make it easier to scale up. Altogether, these improvements would move us closer to a fully intelligent, connected, and holistic health monitoring ecosystem.

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