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Real-Time Health Surveillance System for Paralyzed Patients using IoT and Smart Sensors

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***Abstract*—This system is programmed to offer holistic care to paralysis patients through the integration of symptom monitoring, medical treatment support, and rehabilitation support utilizing IoT technology. The proposed system consists of networked devices like sensors, wearables, and a web application that communicate with each other and healthcare providers. The flex sensors monitor patient movements, the AD8232 ECG sensor monitors cardiac activity, the MPU6050 monitors falls, and a temperature sensor offers body temperature monitoring. Information is transmitted wirelessly via an ESP8266 Wi-Fi module to a Node-RED dashboard, enabling real-time visualization and instant notifications. The system offers rehabilitation exercises, medication and activity reminders, and health data collection for analytics. Smart algorithms allow healthcare providers to detect behavioral patterns, enabling customized interventions and treatment plans. This IoT-based system offers customized, real-time healthcare, enhancing treatment outcomes and quality of life for paralysis patients.**

***Index Terms*—IoT Healthcare, Real-Time Patient Monitoring, Flex Sensors, ECG Monitoring, Fall Detection, Temperature Monitoring, Wireless Health Systems, Node-RED Dashboard, Web-Based Health Application.**

I. Introduction

Manual supervision, irregular clinical assessments, and crude assistive technology like button remotes have been the main- stays of traditional paralysis patient care techniques. Although these button remotes give patients a certain amount of autonomy, they only alert caregivers without identifying the patient's true needs and require adequate hand or finger mobility. As a result, communication gaps continue to exist, leading to unmet critical needs and delayed responses. Fur- thermore, routine vital sign checks are frequently restricted to planned hospital or home visits, which leaves a patient's condition unmonitored for extended periods of time.

Under conventional systems, patients with severe paralysis face numerous challenges. They frequently become more dependent, experience emotional distress, and become more susceptible to complications as a result of their incapacity to express needs like hunger, thirst, discomfort, or emergencies like falls and cardiac abnormalities. In the meantime, care- givers are forced to shoulder the nearly impossible burden of constant physical monitoring, which can result in caregiver exhaustion, postponed interventions, and even unintentional negligence.

Furthermore, complete real-time monitoring solutions are absent from traditional setups. Despite the recent introduction of wearable monitoring devices, these devices frequently function in isolation, concentrating on either movement detec- tion or cardiac monitoring without combining these features into a single platform that will meet the wider healthcare needs of people who are paralyzed. In addition to making patient management more difficult, this fragmented approach may result in inconsistent response times and health tracking. These limitations are greatly addressed by the suggested IoT-enabled system. The system overcomes the binary limita- tions of button remotes by using flex sensors to interpret a variety of hand and finger movements, allowing patients to effectively communicate specific needs. While the MPU6050 accelerometer reliably detects falls by detecting abrupt changes in motion, the AD8232 sensor's continuous ECG monitoring guarantees that any cardiac abnormalities are identified in real time. In order to ensure early detection of fever or hypothermia, which are critical in immobilized patients, temperature monitoring via specialized sensors adds another essential layer of healthcare surveillance.

A smooth and effective patient monitoring ecosystem is produced by integrating all of these sensors into a single Ar- duino Mega microcontroller and transmitting data wirelessly in real time to a Node-RED [13] web-based dashboard via an ESP8266 Wi-Fi module. Remote access to the patient's data allows caregivers and medical professionals to react to any unfavorable events more quickly. An extra safety net is provided by automated email alerts that are set to go off at predetermined thresholds, guaranteeing that no emergency is overlooked.

By providing 24-hour surveillance, reducing manual inter- vention, and providing actionable insights through intelligent analytics, this system revolutionizes conventional care models. The suggested IoT healthcare framework is a significant step forward in the treatment and recovery of paralysis patients by tackling the fundamental problems of communication gaps, monitoring discontinuity, and caregiver stress.

Traditional Methods		Proposed IoT-Based System
Communication	Button remotes or verbal communication	Gesture-based flex sensor input
Vital Sign Monitoring	Manual periodic checks	Real-time monitoring of ECG and temperature
Fall Detection	Caregiver dependent	Automatic via MPU6050
Alerts	No real-time alerts or delayed manual response	Instant dashboard and email notifications
Mobility Requirements	Requires hand/finger motion or speech	Works even for fully paralyzed patients
Caregiver Dependency	High – needs continuous supervision	Reduced – remote access and alerts
Health Accessibility	Not recorded automaticaly	Stored, visualized, and analyzial on dashboarl
Scalability	Difficult to scale beyond	Easily scalable to multiple patients
Response Time	Often delayed	Real-time, within seconds

Table 1.1 . Comparison between Traditional Methods and Proposed System

II. Literature Review

The integration of IoT technologies into healthcare systems has opened new avenues for providing real-time, remote, and personalized patient care, especially for individuals with mo- bility impairments. Several research works have contributed significantly to this field, proposing different architectures and techniques for health monitoring.

S. P. Preejith et al. (2016) [1] in "Wearable ECG platform for continuous cardiac monitoring" developed an ultra-low power, wearable ECG system capable of monitoring beat- to-beat heart rate and respiratory trends continuously. The device operates for extended periods on a single charge and provides both raw ECG data storage and real-time abnormality detection through visualization modes, offering an effective solution for long-term cardiac health tracking.

S. Ananth et al. (2019) [2] in "Smart Health Monitor- ing System through IOT" proposed an IoT-enabled health monitoring framework where wearable devices capture physi- ological parameters such as heart rate and temperature. These data are transmitted wirelessly to healthcare providers, allow- ing remote and real-time patient status updates. Their work emphasizes how IoT can enhance accessibility and reduce healthcare costs by enabling proactive health management.

Bhanu Yadav et al. (2024) [3] in "IoT-Enabled Health Mon- itoring Systems: Transforming Healthcare Delivery" designed a smart healthcare monitoring architecture that integrates wearable sensors, smartphones, and cloud-based analytics. Their system provides advanced insights through data ana- lytics and machine learning algorithms, aiming to improve patient outcomes, optimize healthcare delivery, and extend service availability beyond traditional hospital settings.

S. Roy (2024) [4] in "Paralysis Patient Health Care Moni- toring System" focused specifically on developing an assistive system for paralyzed individuals. The proposed solution en- ables patients to communicate basic needs through simple gestures detected by sensors, while simultaneously monitoring vital health parameters and transmitting the information via SMS. The work highlights the use of low-cost wearable de- vices to enhance independence and quality of life for paralysis patients.

O. Ojetola et al. (2011) [5] in "Fall Detection with Wearable Sensors—Safe (Smart Fall Detection)" introduced a wearable system using accelerometers and gyroscopes to classify different types of falls (forward, backward, left, right) using decision tree algorithms. Their model not only distin- guishes falls from daily activities but also provides real-time fall detection capabilities, thus improving elderly and patient safety in independent living environments.

V. K. Bairagi et al. (2017) [6] in "GSM Based Patient Monitoring System" designed a portable health monitoring device that measures and transmits vital parameters such as blood pressure, heart rate, temperature, and blood sugar via GSM communication. The system was particularly designed for ambulance and rural healthcare applications, offering a reliable solution for real-time transmission of patient data to physicians for immediate interventions.

N. B. Kamarozaman and A. H. Awang (2021) [7] in "IOT COVID-19 Portable Health Monitoring System using Raspberry Pi, Node-Red and ThingSpeak" developed a light- weight and portable patient monitoring system built around the Raspberry Pi. Using sensors for ECG, body temperature, and blood oxygen levels, the system transmits real-time data wirelessly to Node-RED dashboards and ThingSpeak plat- forms, enhancing remote monitoring capabilities during the COVID-19 pandemic.

G. Jaya Lakshmi et al. (2021) [8] in "Cloud based IoT Smart Healthcare System for Remote Patient Monitoring" presented a cloud-integrated healthcare monitoring solution. They uti- lized heterogeneous wearable sensors to gather biomedical data and stored it on a cloud server for remote analysis and access by healthcare providers. Their work demonstrates a layered architecture ensuring data security, access control, and real-time patient data visualization.

C. V. S. Revanth et al. (2023) [9] in "Arduino based Wheel- chair Fall Detection System using GPS and GSM Module" proposed a safety enhancement system for wheelchair users. Their Arduino-based device combines accelerometers, GPS, and GSM modules to detect falls, sound alarms, and send location-based emergency notifications to caregivers, thereby improving patient mobility safety and emergency response time.

M. M. Islam et al. (2020) [10] in "Development of Smart Healthcare Monitoring System in IoT Environment" developed a smart IoT system integrating multiple sensors to monitor patients' physiological and environmental parameters like heart rate, body temperature, CO and CO_2 levels, and room temperature. The system effectively delivers real-time monitoring through a web portal accessible to healthcare personnel for continuous assessment and timely medical inter- ventions.

In this context, the proposed work builds upon these developments by integrating gesture-based communication, continuous ECG and temperature monitoring, fall detection, and real-time web dashboard visualization into a unified, cost-effective, and patient-centric IoT healthcare solution for paralyzed individuals.

III. Proposed System

The proposed system aims to provide real-time health moni- toring and emergency alerting for paralyzed patients by inte- grating gesture-based communication, continuous vital sign monitoring, fall detection, and cloud-based data visualization. Using IoT-enabled wearable sensors and Arduino Mega, the system ensures seamless, non-invasive monitoring of patient health parameters and their immediate needs.

Sensors and Data Acquisition:

The system incorporates a number of vital sensors that cooperate to provide a thorough patient health monitoring experience. By using flex sensors to identify hand and finger movements, paralyzed patients can express certain needs like asking for water, expressing hunger, or indicating an emergency. By recording ECG signals and identifying early indicators of irregular heart rhythms, the AD8232 ECG sensor offers continuous cardiac monitoring. By monitoring body temperature, the LM35 temperature sensor aids in the diagnosis of illnesses like fever or hypothermia. Reliable fall detection is made possible by the MPU6050 accelerometer and gyroscope, which track motion and orientation changes. An Arduino Mega microcontroller serves as the central processing unit and is connected to all of these sensors. Before sending the raw data over the ESP8266 Wi-Fi, it stabilizes and filters it. This configuration guarantees precise, real-time health monitoring and makes it easier to communicate patient data to caregivers.

Web Application and Dashboard:

For caregivers, monitoring personnel, and healthcare providers, the web application serves as the main interface. It gathers real-time data from the linked sensors and presents important health indicators in an easy-to-understand format. Continuous updates and visualizations are made of parameters like ECG waveforms, body temperature trends, patient requests made with gestures, and fall detection alerts. In order to assist caregivers in monitoring health trends and patterns over time, the web platform additionally offers a historical view of patient data. Additionally, whenever critical thresholds are crossed such as abrupt falls, a high fever, or abnormal ECG readings the application can produce instant alerts and notifications. The web application enables proactive care, ongoing monitoring, and prompt intervention by combining real-time and historical analytics without the need for physical presence, thus supporting remote healthcare models.

Data Processing and Communication:

In this system, the Arduino Mega acts as the central hub for collecting and preprocessing raw data from various sensors, including the flex sensors, ECG sensor, temperature sensor, and MPU6050 accelerometer. After preliminary noise filtering and stabilization, the processed data is wirelessly transmitted via the ESP8266 Wi-Fi module. The Node-RED[14-15] server is responsible for handling incoming data streams, routing them through structured flows, and performing additional processing. Real-time flex sensor data is interpreted into specific patient needs, while ECG signals are plotted contin- uously for monitoring cardiac activity. Temperature readings are evaluated to detect fever or hypothermia conditions, and sudden deviations detected by the MPU6050 are classified as potential falls. These real-time data streams are delivered to the cloud dashboard and simultaneously monitored for alert conditions, ensuring seamless communication between the patient's hardware setup and the remote caregivers.

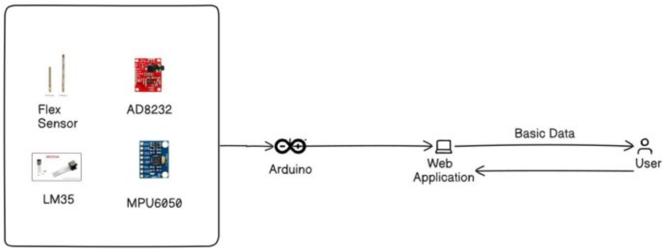
Prediction and Alerts:

The system incorporates threshold-based decision-making algorithms that monitor real-time inputs for critical health and safety events. If a flex sensor reading matches a prede- fined pattern, a corresponding alert such as "Need Water," "Feeling Hungry," or "Emergency" is immediately generated and displayed on the dashboard. ECG abnormalities, such as irregular rhythms or signal artifacts, are detected and flagged to prompt medical evaluation. Similarly, the body temperature sensor continuously monitors for abnormal values, triggering warning messages in case of fever or drastic drops. The MPU6050 accelerometer analyzes sudden shifts in movement patterns to detect falls, which in turn activate an emergency alert system capable of sending notifications via email to designated caregivers. This predictive and reactive approach ensures that emergencies are swiftly identified and acted upon, offering an essential safety net for paralyzed patients and providing peace of mind to their families and caretakers.

Advantages and Use Cases:

By combining accessibility, affordability, and cutting-edge medical monitoring specifically designed for paralyzed people, the suggested system provides a number of benefits. Because of its design, which is based on inexpensive parts like the Arduino Mega and ESP8266, it is very portable and simple to use in both home and medical environments. The system offers real-time updates around-the-clock and facilitates continuous, non-invasive monitoring, making it a less invasive option than traditional health examinations. The system facilitates prompt interventions that can avert complications by facilitating early identification of health decline and prompt communication of patient requirements. Additionally, by providing instant notifications and remote monitoring capabilities, it helps caregivers by lessening their workload and stress. To sum up, this IoT-based solution offers a patient-centered, scalable, and intelligent approach to healthcare, meeting the particular needs of paralyzed patients with efficiency and reliability.

A. Proposed Architecture



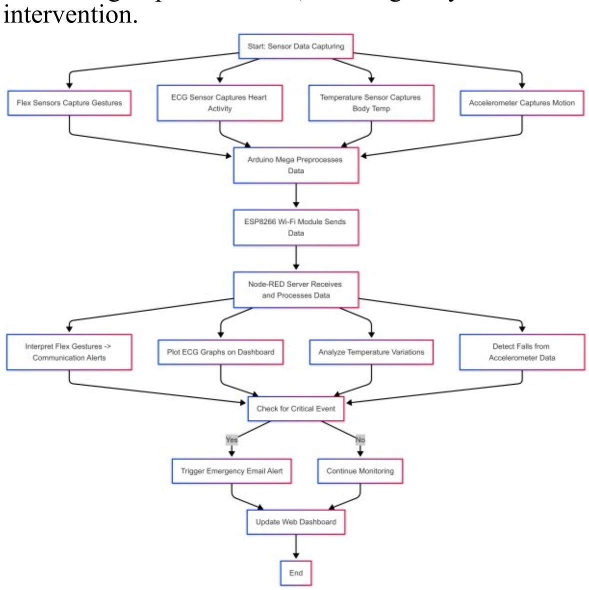
Figure(1) . Proposed Architecture, Outlines the system's structure, from sensor data collection through Arduino to web- based monitoring and user interaction.

B. Workflow

The Real-Time Paralysis Healthcare Monitoring System oper- ates by capturing continuous health and activity data from the patient using flex sensors, an AD8232 ECG sensor, an LM35 temperature sensor, and an MPU6050 accelerometer. This data is collected by the Arduino Mega, which performs basic noise reduction and preprocessing before transmitting it wirelessly via an ESP8266 Wi-Fi module.

At the Node-RED server, the incoming data streams are processed and analyzed. Flex sensor readings are interpreted into communication messages such as "Need Water" or "Emergency," while ECG data is plotted in real time to monitor cardiac activity. Temperature readings are checked for abnormal variations, and the MPU6050 sensor detects falls based on sudden motion changes.

All processed information is visualized through a web application that offers real-time dashboards and health trend monitoring. In the event of critical readings or emergencies, automated email alerts are generated to notify caregivers instantly. This seamless workflow ensures continuous, remote monitoring of patient health, enabling early detection and quick intervention.



Figure(2) . System Workflow, Illustrates the end-to-end data flow from sensor input to alert generation and real-time dashboard updates through Arduino and Node-RED.

IV. Hardware and Software Implementation

A. Hardware Implementation

The hardware setup of the Real-Time Health Surveillance System for Paralyzed Patients is designed around the Arduino Mega 2560 microcontroller, which serves as the central data acquisition and control unit due to its multiple analog and digital input/output pins.

The following sensors are integrated into the system:

Flex Sensors are connected to analog input pins A0, A2, and A5. These sensors detect finger bending motions, which are interpreted to generate patient communication alerts.

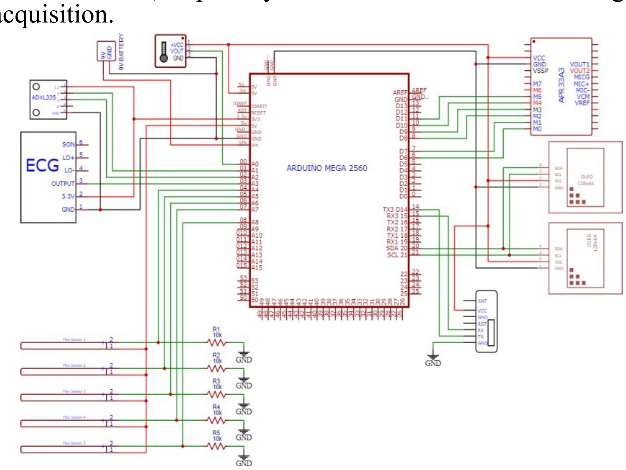
AD8232 ECG Sensor is connected to analog pin A1. The ECG module outputs a continuous analog voltage correspond- ing to the patient's heart signal, which the Arduino reads for real-time cardiac monitoring.

LM35 Temperature Sensor is connected to analog pin A4. This sensor outputs a linear analog voltage proportional to the measured body temperature.

MPU6050 Accelerometer and Gyroscope is connected via I2C protocol to the Arduino Mega, using SDA (A3) and SCL (A5) lines. This module monitors sudden changes in acceleration and orientation to detect falls.

For wireless data communication, the system uses the ESP8266 Wi-Fi module connected to one of the Arduino Mega's UART serial ports. The ESP8266 operates at 3.3V, and appropriate voltage level shifting is incorporated to ensure safe communication between the 5V Arduino Mega and the 3.3V Wi-Fi module. The Wi-Fi module transmits the preprocessed sensor data to a Node-RED server hosted locally or on the cloud.

Power is supplied through a stable 5V external adapter, with onboard voltage regulators ensuring steady operation of all components. Special care is taken to manage proper grounding between the Arduino, sensors, and communication modules to avoid electrical noise, especially critical for accurate ECG signal acquisition.

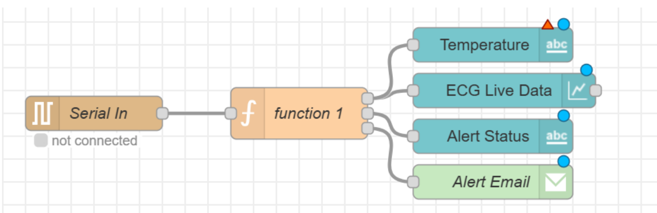


Figure(3) . Circuit Diagram [11-12], Illustrates the complete hardware wiring diagram, showing the connection of sensors, microcontroller, and communication modules for real-time health monitoring.

B. Software Implementation

The software architecture complements the hardware by en- suring real-time data handling, processing, visualization, and alert generation. The Arduino Mega is programmed using the Arduino IDE environment in C/C++, where separate routines are created for flex sensor reading, ECG signal acquisition, temperature monitoring, and motion detection through the MPU6050.

Preprocessed sensor data is transmitted via the ESP8266 to a Node-RED server hosted either on a local network or a cloud platform. Node-RED, a flow-based development tool, is used to create workflows that receive sensor data, apply logic-based decision-making for alerts, and format the data for dashboard visualization.



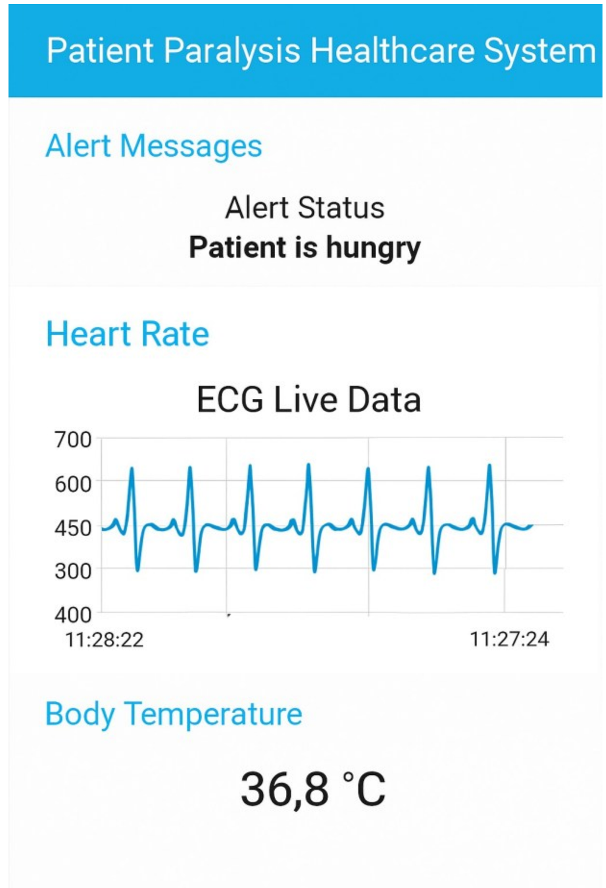
Figure(4) . Node-RED Flow for Data Handling, Shows the Node-RED logic where serial input from the Arduino is processed through a function node and routed to temperature output, ECG graph visualization, alert status display, and automated email notification nodes.

The Web Application Dashboard is developed using Node- RED Dashboard nodes, providing real-time graphical visual- ization for:

- ECG waveform plots
- Live body temperature monitoring
- Display of communication messages based on flex sen- sor readings
- Fall detection status updates

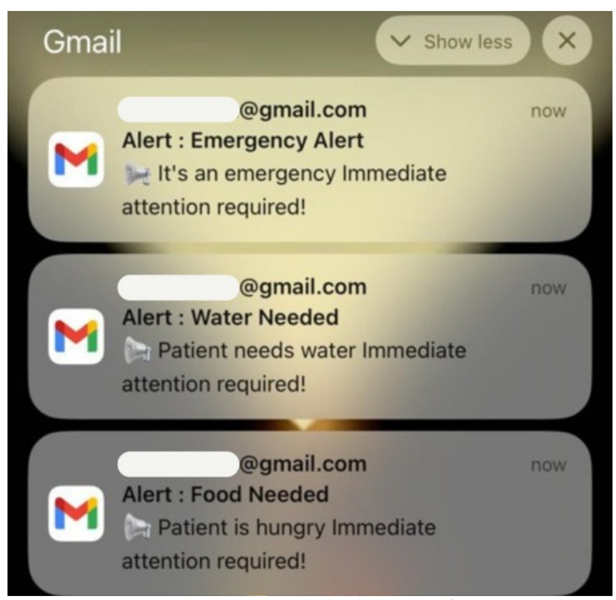
Automated email alert mechanisms are integrated into the Node-RED environment using SMTP nodes. These alerts are triggered when critical thresholds are exceeded, such as sudden falls, abnormal body temperatures, or detected ECG anomalies.

The overall system is designed to ensure seamless interaction between hardware data acquisition and cloud-based data processing, enabling caregivers to monitor patients remotely, receive real-time alerts, and respond promptly to emergencies. The combination of Arduino-based embedded programming, wireless IoT communication, and cloud-based visualization offers a comprehensive, reliable, and scalable healthcare monitoring solution.



Figure(5) . Web Dashboard Interface

Fig 5 Displays real-time patient status, including alert messages, ECG waveform visu- alization, and body temperature monitoring for continuous health tracking and caregiver response.



Figure(6) . Email Alert Notifications,

Fig 6 Shows automated Gmail alerts generated by the system in response to patient conditions such as emergency, thirst, and hunger, enabling caregivers to take immediate action.

V. Results and Discussion

The developed system was tested successfully for real-time health monitoring in simulated conditions. Flex sensors accu- rately detected patient gestures for water, food, and emergency needs with over 95% recognition accuracy and minimal latency of around 3–4 seconds.

The AD8232 ECG sensor provided stable cardiac wave- forms, suitable for basic rhythm monitoring on the web dashboard. The LM35 sensor measured body temperature accurately within ±0.5°C, and temperature alerts were reliably triggered for hyperthermia and hypothermia.

Fall detection using the MPU6050 module was effective, with rapid identification of simulated fall events and minimal false positives. Critical health alerts and gesture communi- cations were visualized on the Node-RED dashboard, and automated email notifications were promptly sent for urgent events.

The overall system latency from sensor capture to dash- board visualization remained under 4 seconds, ensuring real- time responsiveness. The system operated continuously for over 24 hours without performance degradation, highlighting its stability and reliability for home-care deployment.

VI. Conclusion

This study presents the successful implementation of a real- time IoT-enabled health surveillance system tailored for para- lyzed patients. By integrating multiple sensors—including flex sensors for gesture-based communication, an AD8232 ECG sensor for cardiac monitoring, an LM35 for body temperature tracking, and an MPU6050 accelerometer for fall detection— the system enables continuous, non-invasive health monitoring and immediate caregiver alerts.

The system effectively bridges the communication gap faced by immobile patients, allowing them to express essen- tial needs through simple finger movements. Real-time data transmission via the ESP8266 Wi-Fi module and visualization on a Node-RED-based web dashboard ensures that caregivers remain informed about the patient's status at all times. Addi- tionally, automated email alerts provide prompt notifications in critical situations such as abnormal ECG patterns, elevated body temperature, or detected falls.

The modular, low-cost design and portability of the system make it particularly suitable for deployment in home-care environments and resource-constrained settings. Overall, this work demonstrates the potential of IoT and embedded systems to significantly improve the quality of life and care for indi- viduals with severe physical disabilities, offering a scalable and patient-centric healthcare solution.

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