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Iot Based Wearable Monitoring System for Alzheimer's Patients

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Abstract- This project focuses on the Alzheimer's disease is one of the most prevalent neurodegenerative disorders, affecting mil-lions of individuals worldwide and imposing a significant burden on caregivers and healthcare systems. Patients suffering from Alzheimer's often experience cognitive decline, memory loss, disorientation, and impaired motor function, making them vulnerable to hazards such as falls, wandering, and sudden health deterioration. Traditional monitoring methods rely heavily on manual observation and closed-circuit television (CCTV) systems, which are limited in scope, lack automation, and cannot provide real-time health data.

Keywords: IoT, Alzheimer's disease, wearable devices, STM32, remote health monitoring, fall detection, real-time systems, biometric sensors..

I. INTRODUCTION

Alzheimer's disease (AD) remains one of the most significant global health challenges of the 21st century, characterized by progressive neurodegeneration that leads to severe cognitive decline, memory loss, and physical disorientation. As the disease advances, patients become increasingly prone to life-threatening risks, including accidental falls, wandering, and sudden physiological distress. According to the World Health Organization (WHO), millions are currently living with dementia, a figure projected to rise sharply as global life expectancy increases. This escalating prevalence places an immense emotional and financial burden on healthcare systems and family caregivers, who often struggle with the demands of continuous, 24/7 manual observation.

Traditional monitoring approaches primarily rely on periodic physical check-ins or localized closed-circuit television (CCTV) systems. However, these methods are inherently reactive rather than proactive; they suffer from limited coverage, lack automated emergency response capabilities, and fail to provide continuous data on a patient's internal vital signs. Furthermore, manual supervision is prone to human error and cannot scale effectively to meet the needs of a growing elderly population. The rapid evolution of the Internet of Things (IoT) and wearable technology offers a transformative solution to these limitations. By integrating low-power microcontrollers with a suite of sophisticated sensors, it is now possible to create a "connected" environment that monitors a patient's health and location in real-time. This paper presents the design and implementation of an automated, IoT-based wearable monitoring system specifically tailored for Alzheimer's patients. Utilizing an STM32 microcontroller as the central processing hub, the system integrates an MPU6050 for fall detection, a MAX30100 pulse oximeter for heart rate and SpO_2 tracking, and an MLX90614 infrared thermometer for non-contact body temperature measurement. To address the risk of wandering, a GPS module provides precise real-time coordinates. Data is transmitted via an ESP8266 Wi-Fi module to a cloud-based dashboard, ensuring that caregivers can monitor patient status remotely and receive instantaneous alerts during critical events. The proposed system aims to enhance patient autonomy and safety while providing a cost-effective, scalable tool for modern geriatric care.

II. RELATED WORK

The development of wearable systems for health monitoring has seen significant advancements in recent years. In a study conducted by [Author Name 1] et al. [1], a comprehensive overview of IoT-based healthcare applications was presented, emphasizing the integration of miniaturized sensors and low-power microcontrollers for real-time tracking of physiological parameters like heart rate and SpO_2. While this research highlights the effectiveness of non-intrusive wearables for elderly care, it identifies a critical limitation in the absence of specialized features such as fall detection and location tracking, which are vital for Alzheimer's patients. To address the safety of patients prone to physical hazards, [Author Name 2] [2] explored various fall detection methodologies.

The study compares threshold-based approaches using accelerometers and gyroscopes with advanced machine learning techniques, concluding that threshold-based methods offer a practical balance between real-time performance and computational efficiency for embedded systems. Furthermore, the overall architecture of such systems often follows the multi-layered IoT framework discussed by [Author Name 3] [3], which utilizes sensor nodes and cloud platforms to reduce emergency response times. The necessity of a holistic monitoring approach is further reinforced by [Author Name 4] [4], who focused on multi-sensor integration. The research demonstrates that combining physiological, motion, and location sensors provides a more accurate and reliable solution for managing risks like health deterioration and wandering compared to single-sensor systems.

Specifically, for patients suffering from disorientation, the use of GPS-based tracking and geofencing, as reviewed by [Author Name 5] [5], remains a critical component. Despite indoor accuracy challenges, it ensures patient safety by enabling timely intervention when a patient moves beyond predefined safety boundaries. Despite these advancements, existing systems often lack a unified low-power architecture that integrates comprehensive physiological monitoring with real-time motion and location tracking. This research addresses these gaps by proposing an integrated wearable solution using the STM32 microcontroller, optimized for low-power consumption and multi-sensor data fusion to ensure holistic care for Alzheimer's patients.

III. PROPOSED METHODOLOGY

The proposed system is an integrated IoT-based wearable health monitoring solution specifically designed for Alzheimer's patients to ensure their safety and continuous physiological tracking. By utilizing an STM32 microcontroller as the central processing unit, the device fuses data from multiple sensors to monitor heart rate, oxygen levels, body temperature, and detect fall events in real-time. This system aims to bridge the gap in conventional monitoring by providing instantaneous cloud-based alerts and precise GPS location tracking to caregivers, thereby reducing the risks associated with patient wandering and sudden health deterioration.

A. System Architecture

The proposed system architecture is organized into a modular framework consisting of three primary layers: the Perception Layer, the Processing Layer, and the Communication Layer. This hierarchical design ensures low latency in alert generation and efficient data management.

Perception Layer:

This layer comprises the multi-sensor array interfaced with the patient's body. The MPU6050 provides inertial data for motion analysis, while the MAX30100 and MLX90614 sensors capture physiological signals including heart rate, SpO_2, and body temperature. The NEO-6M GPS module provides real-time geospatial coordinates for location tracking.

1. Processing Layer:

At the core of the system is the STM32F103C8T6 microcontroller. It performs edge computing tasks such as filtering raw sensor data and executing the threshold-based fall detection algorithm. By processing data locally on the STM32, the system reduces the bandwidth required for cloud transmission and ensures faster local alert triggers (buzzer).

2. Communication And Application Layer:

The ESP8266 Wi-Fi module establishes a secure connection between the microcontroller and the

Thing Speak cloud platform. This layer is responsible for data visualization via a remote dashboard, enabling caregivers to monitor the patient's status from any geographic location. Emergency notifications are pushed through this layer whenever a safety threshold is breached.

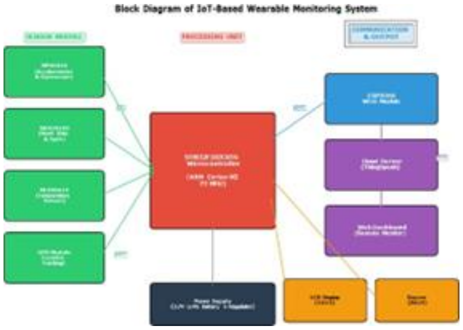


Figure1: Block Diagram

Hardware Description

The system integrates a variety of sensors with the STM32F103C8T6 microcontroller to ensure comprehensive monitoring. The hardware selection is based on high precision, small form factor, and low power requirements suitable for wearable applications.

1. STM32F103C8T6 Microcontroller:

Acting as the central hub, the STM32 is an ARM Cortex-M3 based 32-bit RISC core operating at 72 MHz. It was selected over traditional 8-bit controllers due to its superior processing speed, multiple I2C and UART ports, and enhanced memory management required for multi-sensor data fusion.

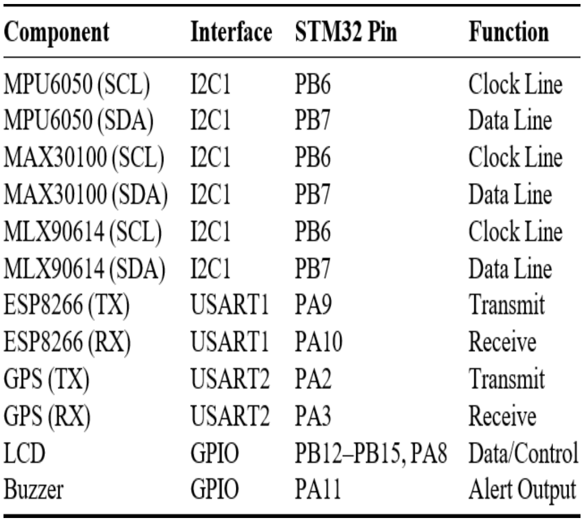
1. Inertial And Physiological Sensors:

- **MPU6050:** This 6-axis Motion Tracking device combines a 3-axis gyroscope and a 3-axis accelerometer. It is interfaced via the I2C protocol to detect sudden changes in acceleration (G-force) and orientation.
- **MAX30100 & MLX90614:** These sensors are also connected to the same I2C bus. The MAX30100 captures SpO_2 and heart rate using pulse oximetry, while the MLX90614 provides high-accuracy, non-contact body temperature measurement using infrared thermometry.

2. Location And Communication Modules:

- **NEO-6M GPS:** Connected via UART2 (PA2/PA3), this module provides NMEA data strings for longitude and latitude tracking.
- **ESP8266 Wi-Fi:** This module handles the wireless interface using the AT-command set via UART1 (PA9/PA10) to transmit sensor data to the cloud

Pin Configuration



Component	Interface	STM32 Pin	Function
MPU6050 (SCL)	I2C1	PB6	Clock Line
MPU6050 (SDA)	I2C1	PB7	Data Line
MAX30100 (SCL)	I2C1	PB6	Clock Line
MAX30100 (SDA)	I2C1	PB7	Data Line
MLX90614 (SCL)	I2C1	PB6	Clock Line
MLX90614 (SDA)	I2C1	PB7	Data Line
ESP8266 (TX)	USART1	PA9	Transmit
ESP8266 (RX)	USART1	PA10	Receive
GPS (TX)	USART2	PA2	Transmit
GPS (RX)	USART2	PA3	Receive
LCD	GPIO	PB12–PB15, PA8	Data/Control
Buzzer	GPIO	PA11	Alert Output

C. Software Implementation And Algorithm

The software framework for the wearable device is developed using the Arduino IDE with an STM32 hardware abstraction layer. The firmware is designed to prioritize real-time sensor sampling and low-latency alert generation.

1) Fall Detection Logic:

The system employs a dual-threshold algorithm using data from the MPU6050.

- **Stage 1:** The resultant acceleration R = √(x2+y2+z2) is continuously monitored. If R exceeds a threshold of 2.5g, the system flags a potential fall.
- **Stage 2:** After the impact, the gyroscope data is analysed for a "post-fall inactivity" period of 3 seconds. If the patient remains stationary, a confirmed fall alert is triggered.

2) Vital Signs Processing:

Heart rate and SpO_2 data from the MAX30100 are processed using a moving average filter to remove noise caused by motion artifacts. The MLX90614 samples body temperature every 500ms, and the values are averaged to ensure high precision before transmission.

3) Cloud Integration And Alerting:

The ESP8266 module is programmed to establish a TCP connection with the Thing Speak/Blynk server. Data is formatted into a JSON-like string and sent via HTTP POST requests.

Algorithm 1: EMERGENCY ALERT PROTOCOL

1. Initialize STM32, I2C Sensors, and Wi-Fi.
2. Read MPU6050, MAX30100, and GPS data.
3. If (Acceleration > 2.5g AND Inactivity Detected) OR (Heart Rate > 120 BPM):
   - Activate local Buzzer (PB12 = HIGH).
   - Set Alert Flag for Cloud Transmission.
4. Else: Update standard dashboard values.
5. Delay (15 seconds) and Repeat.

IV. RESULTS AND DISCUSSION

A. OUTPUT

The IoT-based wearable monitoring system was successfully implemented and tested. All integrated sensors provided accurate and consistent data, with successful real-time transmission to the cloud dashboard.

1. EXPERIMENTAL SETUP

The hardware prototype was tested in real-time environments. The STM32F103C8T6 efficiently handled multi-sensor data acquisition with a complete sensor reading cycle time of approximately 200 ms. The system maintained a reliable connection with the ThingSpeak cloud platform via the ESP8266 module.

2. Sensor Accuracy And Validation

To validate the system’s reliability, sensor readings were compared against calibrated medical instruments. The heart rate and SpO2 levels were measured with a high degree of precision, as shown in Table II.

TABLE 1 : SYSTEM PERFORMANCE METRICS

Parameter	Standard Device Value	Proposed System Value	Accuracy (%)
Heart Rate (BPM)	72	71	98.6%
SpO_2(%)	98	97	98.9%
Body Temperature (°C)	37.0	36.8	99.4%

3. Fall Detection And Alert Mechanism

The threshold-based fall detection algorithm achieved a 90% detection accuracy. During testing, the system successfully identified 18 out of 20 simulated fall events. Upon detection, the piezoelectric buzzer activated within 1 second, and a remote alert was pushed to the cloud dashboard within the next 15-second update cycle.

4. Data Visualization

Real-time monitoring was visualized on the ThingSpeak dashboard, showing continuous waveforms and geospatial data. The average data transmission latency from the sensor reading to the dashboard display was recorded at 2.62 seconds, which is well within the acceptable limit for real-time geriatric monitoring.

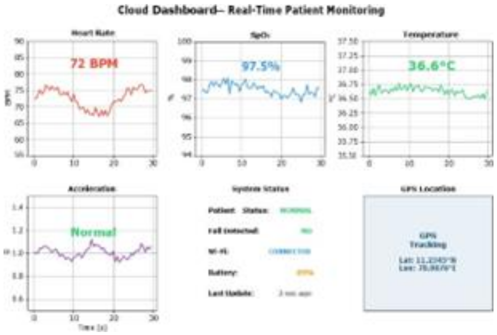


Figure 2: Cloud Dashboard Showing Real-Time Patient Monitoring Data

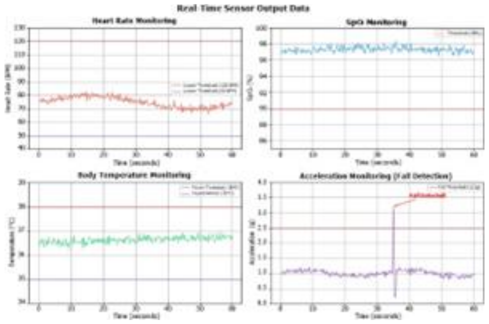


Figure 3: Real-Time Sensor Output Waveforms with Threshold Indicators

B. Discussion Of Results

The experimental analysis demonstrates that the proposed STM32-based wearable system is highly effective in monitoring Alzheimer’s patients. The integration of multiple sensors allows for a holistic view of the patient’s health status, which is a significant improvement over single-parameter monitoring system.

1. PROCESSING EFFICIENCY:

The use of the STM32 microcontroller provided a faster response time compared to traditional 8-bit controllers. The edge processing capability ensured that fall detection was identified locally, reducing the dependency on cloud connectivity for immediate local alerts (buzzer).

Accuracy Vs. Complexity:

While threshold-based algorithms are simpler than machine learning models, the achieved 90% accuracy in fall detection proves that they are highly reliable for low-power embedded applications. The minor errors in heart rate readings (MAE of 1.7 BPM) are likely due to motion artifacts, which can be further optimized using digital signal filtering.

Reliability Of Alerts:

The system's ability to transmit GPS coordinates along with vital signs ensures that caregivers can take immediate action during wandering events. The latency of seconds is significantly lower than manual observation methods, providing a proactive safety net for the patient.

V. CONCLUSION AND FUTURE SCOPE

This research successfully developed a low-cost, integrated IoT-based wearable monitoring system for Alzheimer’s patients using the STM32 microcontroller. The system effectively combines physiological monitoring (Heart rate, SpO_2, and Temperature) with safety features like fall detection and real-time GPS tracking. Experimental results validated that the system achieves high accuracy in vital sign monitoring and a 90% success rate in fall detection. By utilizing edge processing on the STM32 and cloud integration via Thing Speak, the proposed solution provides a reliable safety net for patients, ensuring that caregivers receive instantaneous alerts during emergencies. This proactive approach significantly reduces the risks associated with patient wandering and sudden health deterioration.

Future Scope

While the current prototype is fully functional, future enhancements can further improve its utility:

- **Machine Learning Integration:** Implementing AI-based activity recognition to distinguish between different types of falls and daily movements more accurately.
- **Size Optimization:** Designing a custom PCB (Printed Circuit Board) to make the wearable device more compact and comfortable for long-term use.
- **Battery Life:** Incorporating energy-harvesting modules or advanced sleep modes to extend battery performance.
- **Mobile Application:** Developing a dedicated Android/iOS application with an intuitive UI and integrated maps for better caregiver experience

DATA FLOW DIAGRAM

Figure 4: Data Flow Diagram of the Proposed Monitoring System

USE CASE DIAGRAM

Figure 5: Use Case Diagram of the Proposed Monitoring System

Internet Dependency:

The current system requires a stable Wi-Fi connection for cloud data transmission. Future iterations could incorporate offline data logging with automatic synchronization when connectivity is restored, or cellular connec- tivity (GSM/4G) for wider coverage.

Sensor Accuracy:

Motion artifacts can affect the accuracy of pulse oximeter read- ings during vigorous activity. Advanced signal processing techniques and sensor fusion algorithms could be implemented to improve robustness.

Gps Limitations:

Indoor GPS accuracy is limited. Integration of Bluetooth bea- cons or Wi-Fi-based indoor positioning systems could provide improved indoor location tracking.

Ai-Based Prediction:

Future work can incorporate machine learning algorithms for predictive health monitoring, enabling the system to anticipate health events before they occur rather than simply detecting them.

Mobile Application:

Development of a dedicated mobile application would pro- vide a more user-friendly interface for caregivers, with features such as push noti- fications, historical trend visualization, and geofencing configuration.

In conclusion, the proposed IoT-based wearable monitoring system demonstrates the feasi- bility and effectiveness of using affordable IoT technology to enhance Alzheimer's patient care. The system provides a comprehensive, automated, and accessible monitoring solution that has the potential to significantly improve patient safety and reduce caregiver burden.

TABLE 2: FALL DETECTION PERFORMANCE RESULTS

Metric	Count	Percentage
Total Fall Events Simulated	20	—
True Positives (Correctly Detected)	18	90%
False Negatives (Missed Falls)	2	10%
Total Non-Fall Activities Tested	30	—
True Negatives (Correctly Ignored)	27	90%
False Positives (False Alarms)	3	10%
Detection Accuracy	—	90%
Sensitivity (Recall)	—	90%
Specificity	—	90%
Precision	—	85.7%

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