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Face Monitoring for Alzheimer's Patients using Accelerometer Data

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Abstract: *Alzheimer's disease is a progressive neurodegenerative disorder that causes memory loss and cognitive decline, making continuous health and behavioral monitoring essential for patient safety. This project presents an IoT-based Alzheimer's Patient Monitoring System designed to track vital health parameters such as heart rate, SpO_2, body temperature, and movement patterns in real time. The system integrates multiple sensors with an ESP32 microcontroller to collect and transmit data seamlessly to a cloud platform.*

The data collected from the sensors are processed and uploaded to the ThingSpeakIoT cloud for continuous visualization and analysis. An emergency switch enables immediate alert messages to caregivers via Telegram, ensuring timely assistance during health emergencies or falls To enhance prediction and decision-making, machine learning algorithms are incorporated to analyze historical data and identify abnormal trends or potential risks. By combining IoT monitoring and intelligent prediction, this system offers a cost-effective, real-time, and scalable solution to improve Alzheimer's patient safety, reduce caregiver burden, and support remote healthcare monitoring

Keywords: *Alzheimer's disease*

I. INTRODUCTION

Alzheimer's disease affects millions globally and is one of the leading causes of disability among the elderly. Patients suffering from Alzheimer's often experience confusion, disorientation, and difficulty communicating their needs, making them highly vulnerable to health complications and accidents. Continuous monitoring of their physical parameters and activities is therefore vital for ensuring their safety and timely medical attention.

The Internet of Things (IoT) has revolutionized healthcare by enabling real-time data acquisition, remote monitoring, and intelligent decision-making. Using an ESP32 microcontroller as the core, this project integrates multiple biomedical sensors to track physiological signals such as heart rate, oxygen saturation, temperature, and movement. The collected data are displayed locally on an LCD and simultaneously uploaded to the ThingSpeak cloud platform for analysis and

Problem Statement

Alzheimer's patients require constant supervision due to their impaired memory, limited awareness, and risk of physical accidents. Traditional caregiving methods heavily rely on human supervision, which can be inconsistent and prone to fatigue. Furthermore, caregivers cannot always monitor vital signs or detect emergencies in real time, which delays responses to potentially life-threatening events.

The lack of a unified, intelligent system for tracking both physiological and behavioral data creates a major gap in current healthcare solutions for Alzheimer's patients. Most existing systems are limited to either single-sensor health monitoring or basic location tracking, without predictive insights or integrated alert mechanisms. This limits their usefulness in long-term, unsupervised patient care.

Therefore, there is an urgent need for a smart, IoT-based system that not only monitors multiple health parameters but also provides predictive analysis, automatic emergency alerts, and medicine reminders.

Objectives

1. To design an IoT-based system using ESP32 for continuous monitoring of Alzheimer's patients.
2. To measure and analyze vital parameters such as heart rate, SpO_2, temperature, and movement.
3. To detect emergency situations such as falls or abnormal readings and send instant alerts via Telegram.
4. To upload all sensor data to ThingSpeak for cloud-based visualization and analysis.
5. To apply machine learning algorithms for predictive health analysis and abnormal behavior detection.
6. To enhance patient safety and reduce the workload on human caregivers.

Benefits of the Project

The proposed Alzheimer's Patient Monitoring System offers a range of benefits across healthcare, patient safety, and caregiver management. By integrating IoT and machine learning, it provides **real-time and intelligent monitoring** of patients without requiring constant human intervention. This ensures that caregivers can remotely access live updates about the patient's condition and respond immediately in emergencies.

The system's **multi-sensor design** allows for comprehensive tracking of physiological parameters, enabling early detection of abnormal health conditions. The emergency button adds another layer of security by allowing patients to call for help quickly.

Moreover, the **cloud connectivity with ThingSpeak** ensures that all collected data are stored and analyzed continuously, helping medical professionals make data-driven decisions. By using **machine learning models**, the system not only monitors but also predicts potential health issues, promoting proactive healthcare. This reduces hospital visits, lowers costs, and provides peace of mind to caregivers. Overall, this project enhances safety, efficiency, and quality of life for Alzheimer's patients through smart technology.

II. LITERATURE SURVEY

1. **IoT-Based Healthcare-Monitoring System towards Improving Remote Care** · S. Abdulmalek et al. · **2022**
   A broad review of IoT architectures and use-cases for remote health monitoring. Covers sensor selection, edge devices (ESP-class MCUs), cloud platforms and data visualization — useful for architecture choices and ThingSpeak-like cloud integration. PMC
2. **Wearable sensors for monitoring caregivers of people with dementia — a scoping review** · F. Palmese et al. · **2024**
   Systematic mapping of wearables used in dementia care (including monitoring caregiver strain and patient activity). Helpful for choosing wearable sensor modalities and understanding usability constraints for Alzheimer's populations. PMC
3. **Stage-Wise IoT Solutions for Alzheimer's Disease** · S. Salvi et al. · **2025**
   Recent paper discussing IoT-enabled wearables and ambient sensing specifically for Alzheimer's — covers ADL monitoring, gait analytics, and how ML can detect subtle behavioral changes across disease stages. Good for justification of features like medicine reminders and fall-detection. MDPI
4. **Using IoT Technology for Monitoring Alzheimer's and Elderly Patients (prototype study)** · (Authors on ResearchGate) · **2023**
   Prototype system that integrates location, alarm/reminder functionality and IoT telemetry (ESP32/NodeMCU + Telegram). Practical implementation notes for medication reminders and caregiver alerts. ResearchGate
5. **Revitalizing ADXL345 for Enhanced IoT-enabled Fall Detection** · (IJRASET / similar) · **2023**
   Implementation-focused paper demonstrating how to use the ADXL345 accelerometer for tilt-based and dynamic fall detection (hardware wiring, sample thresholds, simple filtering). Useful for implementing/validating your ADXL345 block. IJRASET

System Requirements

Below are**network**, **ML & data**, **security**, and **power** requirements. Use these directly in your SRS (System Requirements Specification).

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A. Network & Cloud Requirements

1. **Wi-Fi connectivity:** ESP32 must connect to a Wi-Fi network with internet access for ThingSpeak and Telegram APIs.
2. **API endpoints:**ThingSpeak HTTP/HTTPS write endpoints (API key) and Telegram Bot API (HTTPS).
3. **Data retention & privacy:** Configure ThingSpeak channel privacy (public/private) and implement access control.

B. ML & Data Requirements

1. **Data collection:** Minimum viable dataset should include timestamped HR, SpO_2, temperature, acceleration (x,y,z), and event labels (fall, medication given, emergency) for supervised training.
2. **Sampling rates:** HR/SpO_2 at 1–2 Hz (or per sensor capability), temperature every 1–5 minutes, accelerometer 25–100 Hz for reliable fall detection.
3. **Model types:** For anomaly detection — Isolation Forest, One-Class SVM, or time-series models (LSTM, CNN) for temporal patterns. Simpler classifiers (Random Forest) for tabular aggregated features are good baseline.
4. **Model deployment:** Inference can run on cloud (ThingSpeak data pulled to ML server) or lightweight models exported and called from the ESP32 (if model small — e.g., decision tree thresholds).

C. Security & Privacy Requirements

1. **TLS/HTTPS:** All communications between ESP32 → cloud → caregiver must use TLS.
2. **API Keys:** Store ThingSpeak and Telegram tokens securely (avoid hard-coding in public repos). Use obfuscation or server-side proxy if possible.
3. **Data minimization:** Upload only necessary fields and allow caregivers to delete logs if required.
4. **GDPR/HIPAA considerations:** If storing identifiable health data, follow local regulatory rules — pseudonymize patient IDs and restrict access.

D. Power & Reliability

1. **Backup power:** Battery backup (Li-Ion) with automatic switchover if mains power fails; include battery level monitoring and low-battery alerts via Telegram.
2. **Watchdog:** Implement software watchdog and auto-reconnect logic for Wi-Fi and cloud endpoints..

E. Testing & Validation Requirements

1. **Unit tests:** For firmware modules (sensor read, filtering, upload).
2. **Integration tests:** Ensure ESP32 → ThingSpeak upload works, Telegram alerts are received, and ML pipeline ingests data.
3. **Field tests:** Simulate falls (safely), send emergency triggers, and compare ML predictions vs. ground truth. Collect false positive/negative stats.
4. **User acceptance:** Caregiver/patient usability testing for notification frequency, message clarity, and LCD readability

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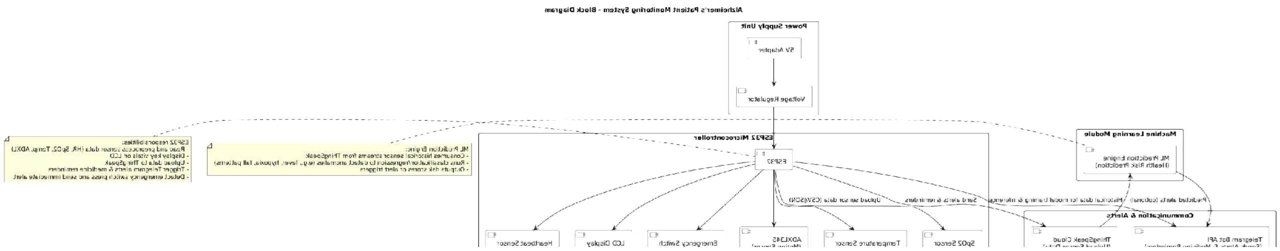
Block Diagram



Description of Block Diagram – Alzheimer's Patient Monitoring System

1. Power Supply Unit

The **Power Supply Unit** provides stable electrical energy to the entire system.

- The **Voltage Regulator** converts and stabilizes the voltage to the required levels (3.3V for ESP32 and sensors).
  This ensures consistent and reliable performance of all components, especially during continuous monitoring.

2. ESP32 Microcontroller (Main Control Unit)

The **ESP32** acts as the **brain of the system**, interfacing with all sensors and peripherals. It collects, processes, and transmits data in real time.

It has built-in **Wi-Fi** and **Bluetooth**, enabling seamless IoT connectivity.

Connected Sensors and Modules:

- **Heartbeat Sensor** – Measures the patient's pulse rate in beats per minute (BPM).
- **SpO_2 Sensor** – Monitors the blood oxygen saturation level to detect hypoxia or breathing irregularities.
- **Temperature Sensor** – Continuously records the patient's body temperature to detect fever or infection.
- **Emergency Switch** – Allows the patient to send an instant emergency message to caregivers via Telegram.
- **LCD Display** – Displays live readings of all vital parameters, ensuring that the patient or nearby caretaker can monitor data locally.

The ESP32 integrates the sensor readings, filters noise, and performs initial threshold-based analysis before sending the data to the cloud.

3. Communication & Alerts Module

This block manages **IoT communication** and **alert transmission**.

- **ThingSpeak Cloud** – The ESP32 uploads all sensor readings to the ThingSpeakIoT platform at regular intervals. This platform visualizes the data using graphs and stores historical records for analysis.
- **Telegram Bot API** – Connected through Wi-Fi, ESP32 sends automatic **Telegram messages** to caregivers or doctors.
  - In case of emergency switch activation or abnormal sensor readings (e.g., high temperature, low SpO_2), the ESP32 immediately triggers an alert message.
  - The system also sends **medicine reminders** to ensure patient compliance with their medical schedule.

This dual communication system ensures both **data storage** and **real-time alerts** for maximum safety.

4. Machine Learning Module

The **Machine Learning (ML) Prediction Engine** operates either on a connected computer or a cloud environment. It uses historical data fetched from **ThingSpeak** for predictive analysis.

Functions include:

- **Training:** Uses previous patient data (temperature, pulse rate, SpO_2, motion) to identify normal and abnormal patterns.

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- **Prediction:** Detects early warning signs such as fever onset, oxygen drop, or irregular movement.

This module adds **intelligence** to the system by converting raw sensor data into actionable insights.

5. Data Flow Explanation

1. **Power Flow:**
   The 5V adapter supplies power → regulated by the voltage regulator → distributed to ESP32 and sensors.
2. **Data Acquisition:**
   Sensors (heartbeat, SpO_2, temperature, ADXL345) continuously sense physiological and movement parameters → send data to ESP32.
3. **Data Processing:**
   ESP32 processes signals, updates the LCD display, and checks for abnormal conditions.
4. **Alert Mechanism:**
   If an emergency switch is pressed or abnormal readings occur, ESP32 immediately sends a Telegram message to caregivers.
5. **Prediction:**
   ThingSpeak data is periodically analyzed by ML algorithms → identifies health risk trends → sends predictive alerts or recommendations.

Implementation

The implementation of the Alzheimer's Patient Monitoring System involves both **hardware and software integration**, enabling seamless data acquisition, cloud connectivity, and intelligent prediction. The system architecture is designed in modular form, consisting of the **sensor unit**, **controller unit (ESP32)**, **communication unit (ThingSpeak and Telegram)**, and the **machine learning unit** for health prediction.

1. Hardware Implementation

The hardware setup is built around the **ESP32 microcontroller**, which serves as the main processing and communication hub. It is chosen for its built-in **Wi-Fi**, **Bluetooth**, low power consumption, and high processing capability suitable for IoT-based medical applications. The ESP32 is powered through a **regulated 5V power supply**, which is stepped down to 3.3V to match its operating voltage.

The **sensor network** consists of several biomedical and environmental sensors:

- **Heartbeat Sensor (MAX30102)** measures the pulse rate in beats per minute (BPM) by detecting variations in blood flow through infrared light absorption.
- **SpO_2 Sensor** measures the oxygen saturation level in the blood, indicating respiratory efficiency.
- **Temperature Sensor (LM35 or DS18B20)** continuously tracks body temperature to detect fever or infections.
- **ADXL345 Accelerometer** monitors patient movement and detects falls or sudden changes in motion, which are crucial for Alzheimer's patients who often lose balance.
- **Emergency Switch** acts as a manual alert mechanism for the patient to request help instantly.
- **LCD Display (16x2)** provides local, real-time feedback on sensor readings such as heart rate, SpO_2, and temperature.

All sensors are connected to the **analog and I2C pins** of the ESP32. The connections are made through jumper wires on a breadboard or PCB to ensure stability and reliability. Power management and grounding are handled carefully to reduce noise interference in sensor readings.

2. Software Implementation

The software implementation consists of firmware development for the ESP32, cloud integration with ThingSpeak, alert automation using Telegram Bot API, and machine learning model deployment for predictive analytics.

2.1 Cloud Communication with ThingSpeak

The processed data are transmitted to **ThingSpeak**, an IoT analytics cloud platform. Using the **ThingSpeak API key**, the ESP32 uploads sensor values (heart rate, SpO_2, temperature, motion) at fixed intervals through HTTP POST requests over Wi-Fi.

ThingSpeak stores the data in private channels and visualizes it in graphs and dashboards, allowing caregivers and doctors to view patient trends remotely. The stored data also form the dataset for training and validating the machine learning model.

2.2 Telegram Alert System

A **Telegram Bot** is created using the **BotFather** service on Telegram. The ESP32 communicates with this bot via the Telegram API using HTTPS requests.

Whenever an emergency switch is pressed or an abnormal reading is detected, the ESP32 sends an **instant Telegram message** to the caregiver's account. The system also sends **medicine reminders** based on pre-defined schedules stored in code or fetched from the cloud

2.3 Machine Learning Prediction Module

The predictive analysis module is developed in **Python** using libraries like **pandas**, **NumPy**, and **scikit-learn**. Data exported from ThingSpeak is preprocessed to remove outliers and normalized for analysis.Various machine learning algorithms such as **Random Forest**, **Support Vector Machine (SVM)**, and **Logistic Regression** are tested to detect early signs of health anomalies or behavioral changes in the patient. The trained model predicts possible health risks (like dehydration, stress, or fall tendencies) based on continuous trends in the input parameters.

3. Integration and Testing

Once the firmware and communication systems are deployed, the integration phase involves testing data transmission from ESP32 to ThingSpeak, verifying Telegram message delivery, and cross-checking the ML prediction output.
Calibration is performed to ensure accuracy of sensors and reliability of thresholds for healthalerts.

4. Working Overview

1. Sensors continuously sense health and motion data.
2. ESP32 processes and displays readings locally.
3. Sensor data are uploaded to ThingSpeak via Wi-Fi.
4. If an emergency occurs or thresholds exceed limits, ESP32 triggers Telegram alerts.

This complete integration of **IoT and AI** creates an intelligent, low-cost, and user-friendly system suitable for Alzheimer's patient monitoring in real-world scenarios.

Applications of the Alzheimer's Patient Monitoring System

1. **Home-Based Patient Monitoring**
   Enables family members or caregivers to continuously monitor Alzheimer's patients in a home environment. Real-time alerts through Telegram reduce dependency on manual supervision.
2. **Hospitals and Rehabilitation Centers**
   Useful for healthcare institutions to track multiple patients simultaneously through cloud dashboards, improving nursing efficiency and early risk detection.
3. **Elderly Care Facilities**
   Alzheimer's patients in assisted living or old-age homes can be monitored remotely by medical staff, ensuring timely help in case of a fall or health anomaly.
4. **Emergency Response Systems**
   The built-in panic switch and fall detection features make it ideal for elderly patients living alone, enabling quick medical response and potentially saving lives.

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5. **Medication Compliance Tracking**
   Automated medicine reminders ensure timely intake of medication, reducing cognitive strain on Alzheimer's patients and improving treatment adherence.

Expected Outcome

The **Alzheimer's Patient Monitoring System** is designed to deliver a **comprehensive, intelligent, and automated health supervision platform** for elderly and Alzheimer's patients. Upon successful implementation, the system is expected to achieve **real-time monitoring, emergency alerting, and predictive health analysis** through the seamless integration of sensors, cloud computing, and machine learning.

1. Real-Time Health Monitoring

The system will continuously measure key physiological parameters such as **heart rate, SpO_2 (oxygen saturation), body temperature, and movement patterns**through respective biomedical sensors. These real-time readings will be displayed locally on the **LCD module** and simultaneously transmitted to the **ThingSpeakIoT cloud platform**, allowing caregivers and healthcare professionals to remotely visualize patient health trends at any time.This ensures **24×7 remote observation** without the need for physical presence, offering a practical solution for Alzheimer's patients who often need continuous care.

2. Intelligent Alerts and Notifications

One of the core expected outcomes is the system's ability to generate **automatic alerts**. When any sensor reading crosses a predefined threshold — for instance, a **high heart rate**, **low oxygen level**, or **fall detection by the ADXL345 sensor** — the **ESP32** will instantly trigger a **Telegram message** to the caregiver or family member. Additionally, the system will also send **medicine reminders** through Telegram, ensuring that the patient adheres to prescribed medication schedules. The integration of an **emergency switch** allows the patient to manually send distress signals, making the system not only automated but also user-responsive in critical conditions.

3. Predictive Health Analysis using Machine Learning

A major expected outcome of this project is the development of an intelligent **Machine Learning (ML)** model trained on the collected health data. This model will analyze patterns in the patient's historical readings to predict potential health risks such as irregular heartbeats, temperature anomalies, or behavioral instability (detected via motion data).. This predictive capability transforms the system from a **reactive** to a **proactive healthcare tool**.

4. Improved Patient Safety and Caregiver Efficiency

Through automated alerts, remote visualization, and predictive insights, caregivers can respond promptly to medical emergencies, reducing response times drastically. The expected result is **enhanced patient safety**, fewer hospital admissions, and reduced caregiver workload.Alzheimer's patients—who are prone to disorientation, wandering, or memory lapses—can now be **monitored safely even in unsupervised conditions**.

5. Data Logging and Analytics

The project will generate and store time-stamped data for all physiological and behavioral parameters on the ThingSpeak cloud. This data will serve as a valuable dataset for **long-term behavioral studies**, **clinical assessments**, and **AI model retraining**. The cloud dashboard will present this data in the form of **interactive visual graphs**, providing deep insights into patient health trends and improving the accuracy of predictive analytics.

III. CONCLUSION

The Alzheimer's Patient Monitoring System demonstrates an effective application of IoT and machine learning in healthcare automation. By integrating various biomedical and motion sensors with the ESP32 microcontroller, the system continuously monitors vital signs and environmental conditions. The inclusion of cloud connectivity via ThingSpeak ensures real-time data accessibility and remote monitoring by caregivers and healthcare professionals.

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In conclusion, the proposed system represents a scalable, low-cost, and reliable healthcare monitoring framework. Future enhancements can include GPS integration for location tracking, voice-based alerts for patients, and deep learning models for improved prediction accuracy. This approach aligns with the growing need for smart healthcare systems in aging societies and promotes proactive, data-driven medical care.

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