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Adaptive Therapeutic Mattress for Bedsore Prevention and Relief

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Abstract - Bedsores, also known as pressure ulcers, are a major issue for bedridden patients caused by prolonged pressure, heat, and moisture. This paper presents an IoT-based therapeutic mattress using an ESP32 microcontroller to automate multi-modal therapy and real-time monitoring. The system integrates vibration therapy, infrared (IR) therapy, and a Peltier module for temperature regulation. Sensors such as load cell, temperature, and moisture sensors continuously monitor the patient's condition. The ESP32 transmits data to the ThingSpeak cloud, which sends email alerts to caretakers during abnormal conditions. An OLED display shows real-time parameters, and an emergency button allows the patient to notify the caretaker instantly. The system provides a cost-effective, IoT-enabled therapeutic approach to prevent bedsores and enhance patient comfort.

Keywords: Bedsores, IoT, ESP32, Peltier Module, Vibration Therapy, IR Therapy, ThingSpeak.

1. INTRODUCTION

Bedsores, also known as pressure ulcers or decubitus ulcers, are a major health problem affecting patients who are confined to bed for extended periods due to illness, injury, or surgery. These wounds occur when continuous pressure on specific body parts, such as the back, hips, heels, and shoulders, restricts blood circulation and leads to tissue damage. In severe cases, bedsores can result in infection, pain, and prolonged recovery time. Conventional monitoring methods rely heavily on manual inspection by caretakers, which is time-consuming and may lead to delayed intervention, especially in hospitals with limited staff. With the development of the Internet of Things (IoT) and embedded technology, healthcare systems have become smarter, more reliable, and automated. IoT enables continuous remote monitoring of patient parameters, allowing timely alerts and preventive actions. The integration of embedded sensors with microcontrollers ensures real-time data collection and intelligent decision-making for patient safety.

This project presents an **IoT-based therapeutic mattress** that prevents bedsores by continuously monitoring body temperature, moisture, and posture using sensors interfaced with an **ESP32 microcontroller**. The system integrates **vibration therapy**, **infrared (IR) therapy**, and a **Peltier cooling module** to maintain comfort and improve blood circulation. The **ThingSpeak IoT platform** transmits real-time data and sends email alerts to caretakers during abnormal conditions. An **OLED display** shows live readings, and an **emergency button** lets the patient alert the caretaker instantly.

The proposed system reduces manual dependency, supports home-care monitoring, and enhances patient comfort. It provides a cost-effective, energy-efficient, and scalable solution that combines smart sensing and therapeutic automation to prevent the development of bedsores.

2. LITERATURE REVIEW

Several research studies have focused on smart systems for preventing and managing bedsores using sensors and automation. Brienza and Kottner (2018) emphasized the importance of continuous monitoring and early detection. Rajesh Pandey et al. (2018) proposed a smart bed using pressure sensors but without integrated therapy or IoT features. Abdelmoghith et al. (2020) introduced an IoT-based healthcare monitoring system, while Pongthanisorn et al. (2020) developed an elderly care system using non-contact sensors for fall and bedsore prevention. Recent works like Saleh et al. (2021) and Kommey et al. (2021) focused on automated electro-therapy and posture-based systems but remained costly and lacked real-time alerts. Some recent studies have also suggested AI-based predictive models for pressure ulcer detection, but they are still in experimental stages. Researchers have also explored wearable sensors and smart textiles for real-time monitoring, yet these systems often suffer from limited durability and comfort issues. A few designs integrate wireless communication modules like Wi-Fi and Bluetooth for patient data transfer, improving mobility but increasing power consumption. To overcome these gaps, the proposed ESP32-based IoT therapeutic matrix integrates temperature, moisture, and posture sensing with vibration, infrared, and cooling therapies, enabling real-time monitoring and email alerts through ThingSpeak for both hospital and home-care use.

3. PROBLEM STATEMENT:

Bedridden patients often develop bedsores due to prolonged pressure, increased temperature, and moisture accumulation. Existing solutions are expensive and lack integrated, real-time therapeutic monitoring and alert mechanisms.

4. METHOLOGY

The system is designed to function efficiently with low power consumption and high reliability for continuous patient care. It operates automatically to monitor patient conditions and provide necessary therapy without manual intervention

ESP32 Microcontroller: Acts as the main controller for processing sensor data, controlling therapy modules, and sending real-time data to ThingSpeak via Wi-Fi. It ensures smooth communication between sensors and actuators while maintaining reliable IoT connectivity.

Temperature Sensor (DS18B20): Measures the patient's body surface temperature. When the temperature exceeds the set limit, it activates the Peltier module to provide a cooling effect and maintain comfort.

Moisture Sensor: Detects moisture or pus from bedsores. If abnormal levels are detected, it triggers an alert to the caretaker and helps in identifying early signs of skin irritation.

Load Cell with HX711 Amplifier: Monitors the patient's position by detecting pressure distribution. If the patient remains in one position for a long time, it alerts the caretaker to reposition and prevent sores.

Peltier Module: Provides a cooling effect when the detected temperature crosses the threshold, maintaining skin comfort and preventing heat-induced irritation, thereby protecting the patient's skin from inflammation and promoting a soothing therapeutic environment.

Vibration Motor: Gives gentle vibrations at regular intervals to improve blood circulation and reduce continuous pressure points on the patient's body, helping to relieve stiffness, enhance muscle relaxation, and prevent the early formation of bedsores.

Infrared (IR) Therapy Module: Enhances blood flow and provides muscle relaxation through infrared light exposure, promoting faster healing and comfort.

Emergency Button: Allows the patient to manually alert the caretaker in case of discomfort or emergency. When pressed, it activates the buzzer and sends a notification.

OLED Display: Displays real-time sensor readings such as temperature, moisture, and system status, allowing quick local monitoring.

Buzzer: Produces an audible alert for abnormal sensor values or when the emergency button is pressed to draw immediate attention.

ThingSpeak IoT Platform: Collects sensor data from the ESP32, updates it on the cloud, and sends email notifications to the caretaker. It also provides a real-time dashboard to track patient conditions remotely.

Power Supply: Ensures stable and continuous power to all modules and sensors for reliable operation, preventing voltage fluctuations and maintaining consistent system performance even during prolonged usage.

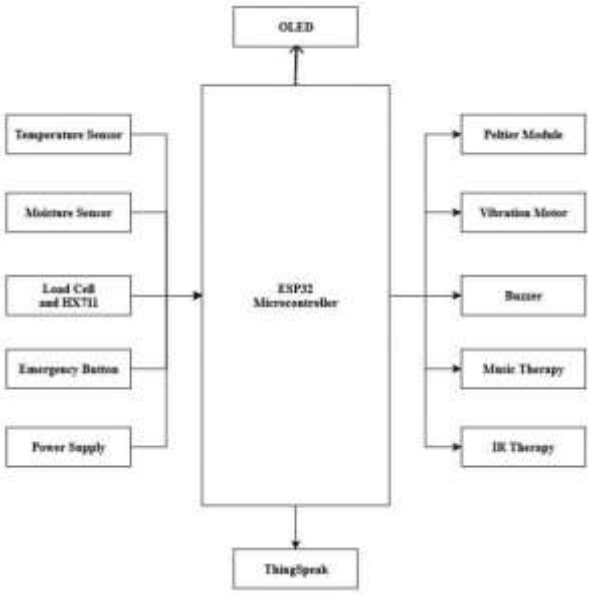


Fig -1: Block Diagram of the proposed system.

5. Objectives :

The main objectives of the study are as follows:

a. To develop an IoT-based smart therapeutic mattress for bedridden patients.

b. To monitor real-time parameters such as pressure, temperature, and moisture.

c. To automate vibration, infrared, and cooling therapies based on sensor feedback.

d. To alert caretakers through ThingSpeak in case of abnormal conditions.

e. To design a cost-effective and user-friendly solution for hospital and home use.

6. APPLICATION:

1. Hospitals and Nursing Homes:

The system can be implemented in hospitals and nursing homes to monitor bedridden patients continuously. It helps nursing staff reduce manual supervision by automatically detecting abnormal conditions and providing therapeutic actions such as vibration, infrared, and cooling therapies.

2. Home Care for Bedridden Patients:

This model is ideal for patients receiving long-term care at home. Through the ThingSpeak IoT platform, caretakers or family members can remotely monitor temperature, moisture, and posture conditions and receive instant alerts in case of emergencies.

3. Rehabilitation Centers:

Rehabilitation and physiotherapy centers can use this system to improve blood circulation and prevent pressure ulcers in patients with limited mobility. The vibration and IR therapies help stimulate muscles and promote faster recovery.

4. Elderly Care Facilities:

Elderly individuals often suffer from limited mobility, making them prone to bedsores. This smart therapeutic mattress provides comfort and safety by maintaining proper skin temperature and alerting caretakers when intervention is needed.

5. Post-Surgical Recovery Units:
Patients recovering from major surgeries require long hours of bed rest. The system helps prevent sores by maintaining optimal temperature and posture, improving recovery comfort, and reducing medical complications related to skin damage.

7. RESULTS – SYSTEM DEMONSTRATION

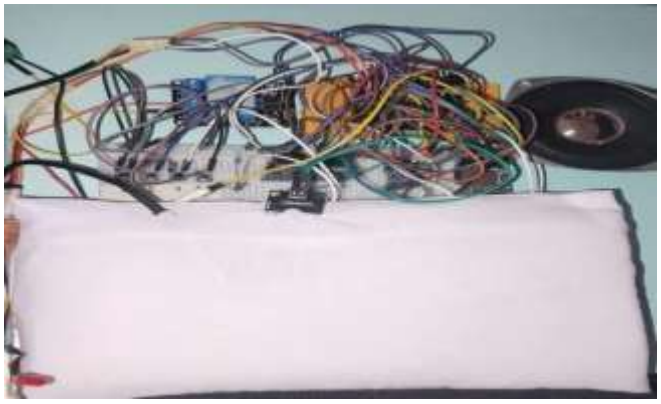
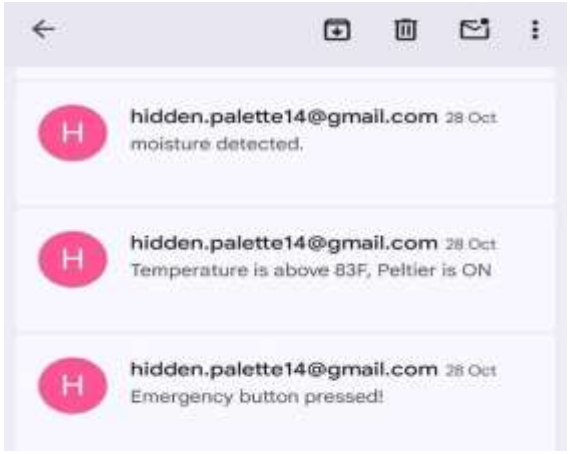


Fig -2: Hardware setup.

The system was tested under various simulated conditions to verify its accuracy and stability. The sensors effectively detected temperature, moisture, and posture changes, and the Peltier module activated automatically when the temperature exceeded the limit. The vibration and infrared modules improved blood circulation and patient comfort. Real-time data were displayed on the OLED and updated on ThingSpeak, which generated email alerts during abnormal conditions. The system operated reliably, responded quickly, and proved efficient in preventing bedsores through continuous monitoring and timely alerts.



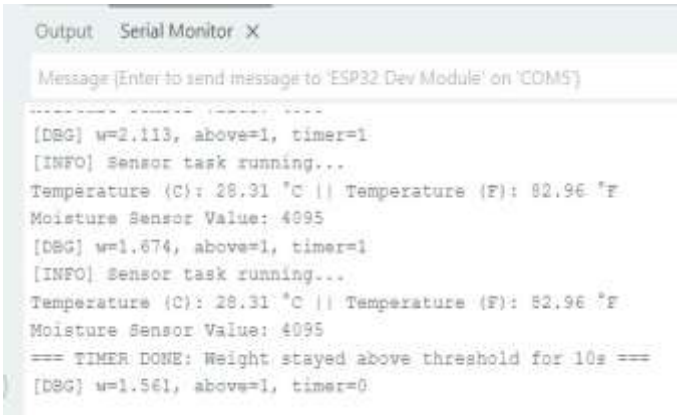


Fig -3: result outcome.

Patient health data is stored and visualized on cloud platforms (ThingSpeak), accessible remotely by healthcare professionals. Enables continuous monitoring from mobile devices, improving response time and healthcare decision- making.

8. CONCLUSIONS

The proposed IoT-based adaptive therapeutic mattress provides an effective and integrated solution for preventing and managing bedsores in bedridden patients. By combining temperature, moisture, and posture sensing with automated vibration, infrared, and cooling therapies, the system ensures continuous monitoring and timely intervention. It significantly reduces manual dependency, enhances patient comfort, and helps caretakers respond quickly to abnormal conditions. The use of the ESP32 microcontroller and the ThingSpeak IoT platform ensures reliable data transmission, real-time visualization, and automatic email notifications.

The system is cost-effective, energy-efficient, and easily scalable for both hospital and home-care applications. It can be implemented in healthcare centers, nursing homes, and rehabilitation units to provide round-the-clock care and early detection of pressure ulcer risks. Overall, the project demonstrates how IoT and embedded technologies can be effectively utilized to improve patient safety, comfort, and quality of healthcare services.

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