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IoT-Based MediBed For Golden-Aged People

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ABSTRACT:

The increasing number of people in their golden years calls for the creation of sophisticated healthcare systems that can offer continuous support and monitoring with little manual involvement. This study describes the development and deployment of an Internet of Things (IoT)-based MediBed system designed especially for senior citizens with the goal of enhancing comfort and lowering the risk of pressure ulcers by means of automatic posture control. To continuously monitor pressure distribution, the proposed MediBed is outfitted with a variety of pressure sensors that are positioned strategically throughout the bed surface. The technology dynamically activates actuators to gently tilt or alter the bed in response to prolonged or excessive pressure on a particular spot. This relieves localized tension by shifting the patient's weight. An ESP32 microcontroller powers the entire system, gathering sensor data, processing threshold triggers, and connecting to a cloud-based dashboard so that caretakers or medical personnel may monitor it remotely. Additionally, the MediBed has logging and real-time alerting features that guarantee prompt action in the event of anomalous conditions or movement patterns. The outcomes show how well the technology works to preserve ideal pressure balance and improve patient safety. By offering constant comfort and lowering the need for manual repositioning, this affordable, scalable solution can greatly assist home-care settings and geriatric healthcare facilities. Machine learning for predictive posture correction and wearable health monitor integration for all-encompassing senior care are potential future improvements.

Keywords: Internet of Things, Smart Healthcare, Pressure Sensors, Elderly Monitoring, and Automated Bed Adjustment

Introduction:

Globally, the aging population is expanding at a never-before-seen rate, posing serious problems for caregivers and healthcare systems. People are more susceptible to chronic illnesses and age-related problems such pressure ulcers, reduced mobility, and related morbidities as they get older. In example, pressure ulcers are a common problem among the elderly, particularly those who spend a lot of time in bed. Although necessary, traditional patient repositioning techniques frequently depend on physical treatment that may be irregular or delayed. As a result, there is an urgent need for creative solutions that can offer automated, ongoing monitoring and modification to improve patient comfort and care quality. A new age in healthcare technology has begun with the emergence of the Internet of Things (IoT). Rapid reactions to emerging health issues are made possible by IoT's ability to support remote monitoring and real-time data collection. These characteristics can be used in the context of caring for the elderly to create systems that not only monitor critical metrics but also anticipate and stop issues before they become more serious. An excellent illustration of how technology can be used to enhance health outcomes is the design of hospital or home-care beds using an Internet of Things (IoT) approach, in which pressure sensors built into the bed's surface continuously monitor pressure distributions. Such systems can reduce the danger of pressure ulcers and improve patient health by automatically identifying inappropriate pressure levels and starting corrective operations via integrated actuators. Making sure that prompt action and ongoing monitoring are available without the constant direct involvement of caregivers is one of the biggest obstacles in providing care for the elderly. Although necessary, manual repositioning is time-consuming and prone to human mistake or neglect,

especially in facilities with high patient volumes. Furthermore, family members might not always have the knowledge or resources to spot early warning signals of pressure-related problems in in-home care settings. The incorporation of automation into care solutions provides a revolutionary method of patient health management in response to these issues. Both patients and caregivers can gain from increased safety and comfort with a system that can automatically alter the bed based on real-time sensor data, possibly lowering hospital stays and raising overall quality of life.

The growing demand for affordable and scalable healthcare solutions emphasizes the importance of this study even more. IoT-driven MediBeds provide a chance to relieve some of the strain on healthcare systems throughout the world, which are struggling with increased patient numbers and increasing expenses. Healthcare professionals can focus on more important facets of patient care by automating repetitive procedures like patient repositioning, all the while making sure that typical issues are properly prevented. Furthermore, the information gathered from these systems can be a useful tool for future study, which could support the creation of tailored treatment plans and predictive models.

There are three main goals for this study. For real-time pressure monitoring, its primary goal is to create and deploy a strong MediBed architecture that seamlessly incorporates IoT technology. Second, the study aims to show how well the system works by employing actuators to automatically alter the bed in response to sensor data, lowering the possibility of pressure-related injuries. In order to continuously evaluate the system's performance and provide caregivers with timely notifications in the event of anomalous pressure distributions or system breakdowns, the study concludes by examining the possibility of integrating cloud-based monitoring tools.

The creation of an Internet of Things (IoT)-based MediBed represents a promising step in the area of intelligent healthcare for senior citizens. This research adds to the ongoing efforts to improve safety, comfort, and overall outcomes for older patients by addressing a fundamental need in patient care with a new, technology-driven solution. By prioritizing prevention over intervention and opening the door for more creative applications in geriatric care, the combination of pressure sensors, real-time data processing, and automated actuation represents the future of proactive healthcare.

Algorithms:

The MediBed system uses intelligent posture sensing and pressure redistribution to improve care for the elderly. Fundamentally, the MediBed depends on microcontroller logic-driven real-time sensor feedback and actuator response. The basic algorithm and operating concept that enable automatic bed adjustment and pressure monitoring are explained in the section that follows.

1. Data Acquisition and System Input

Force-sensitive resistors (FSRs) or pressure sensors positioned thoughtfully throughout the mattress surface are used to continuously monitor body pressure at the start of the system. Every sensor has a designated zone, such as the head, shoulders, lower back, hips, and legs. The ESP32/ESP8266 microcontroller's analog-to-digital converter (ADC) reads the electrical signals (analog voltage) that the sensors translate from physical pressure. Buffers are used to hold the raw sensor data, which is obtained in real time. In order to identify any changes in the pressure distribution, sampling is carried out on a regular basis (e.g., every 5 seconds).

2. Imbalance Detection and Threshold Assessment

Based on experimental data and medical standards, a predetermined safe threshold value is set to each pressure zone. Depending on the weight and health of the patient, these criteria can be changed. The threshold values and the real-time pressure data are compared by the microcontroller. A possible risk of pressure damage is indicated if the pressure in any given zone consistently surpasses the threshold (for example, for longer than 10 seconds).

2.1Steps in the Algorithm

- Set the threshold and all sensors to their initial values. Examine the pressure readings in each zone. Verify whether any zones surpass the cutoff.
- If so: Actuator reaction is triggered.
- If not: Keep an eye on things.
- After each interval, reevaluate.

3. Logic for Actuator Control

Under the mattress, the MediBed has servo motors or linear actuators. Every actuator has a pressure zone assigned to it. The associated actuator is triggered to raise, lower, or tilt that portion of the bed slightly when high pressure is sensed. This relieves chronic pressure and redistributes bodily weight. Pulse Width Modulation (PWM) signals produced by the ESP32 are used to control actuators. The motor speed is controlled by a smooth ramp-up and ramp-down mechanism to prevent discomfort.

For instance:

- If the hip area's pressure surpasses the threshold, the method lessens pressure on the hip region while gently raising the upper torso and leg parts.
- Until the sensor reading falls below the threshold, indicating that pressure has been redistributed, this process is repeated.

4. Sleep Patterns and Record-Keeping

A sleep mode timer is employed to prevent fast
actuation brought on by transient pressure changes (such as patient movements). Every cycle, the system logs the sensor data and saves it locally (on an SD card) or remotely (via cloud storage services like Firebase).

Among the logged data are:

- Time stamp
- Readings from sensors
- Zones that are activated
- Actuation duration
- State of bed orientation

Doctors or caregivers might analyze these diaries for risk assessment or posture analysis.

5. Cloud Alerting and Communication System

The HTTP or MQTT protocols are used to send data from the ESP32 to Firebase via Wi-Fi. Sensor data, bed status, and patient-specific information are all stored in the Firebase database.

5.1Warnings

A smartphone alert is issued to the caregiver app if the pressure threshold is crossed and not addressed within two cycles. By positioning infrared or ultrasonic sensors near the edge, bed-exit detection can be integrated. Another warning is set off if a sudden departure is noticed.
The dashboard on the mobile device shows:

- Pressure zones in real time
- Angles of bed tilt
- Status of the sensor
- Logs of history

6.Overview of Pseudo Code

Set up the actuators and sensors; Establish pressure thresholds.

```
Iteration { Read pressure_values[5]; // 5 Zones
  For every zone I:
    If threshold[i] > pressure_values[i]:
      If the duration is longer than 10 seconds:
        Actuator activation[i]; event logging; end  If not:
      Keep an eye on things; stop  To upload data to Firebase, use Delay(5000); // Interval of 5 seconds
```

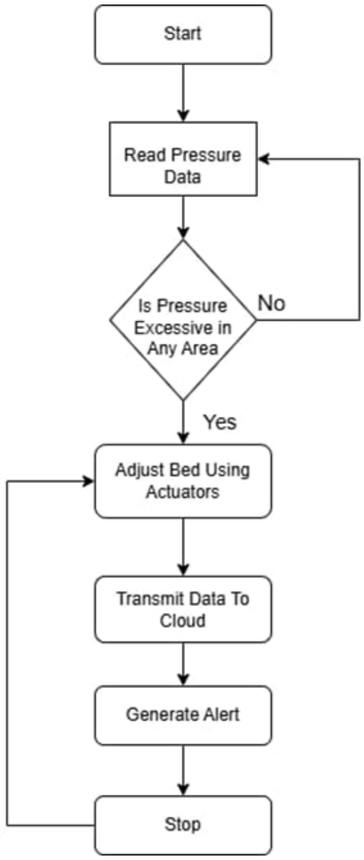
7 .Benefits of Algorithms

- Real-time and dynamic redistribution of pressure
- levels that may be altered for various patients
- Low sensor-to-actuator response delay
- Data visualization and remote monitoring
- A non-intrusive solution that works with regular beds
- Design fail-safe with possibilities for manual override

Proposed System:

The proposed Internet of Things (IoT)-based MediBed system is a smart assistive bed made especially for senior citizens to improve comfort, lower the danger of pressure ulcers, and guarantee 24-hour care with little assistance from humans. In an intelligent framework, it integrates pressure sensing, real-time data analysis, and automatic mechanical modifications through the use of microcontrollers and actuators. Affordability, modularity, and simplicity of deployment in both home and clinical settings are the main goals of this system architecture.

Flow chart



Overview

The MediBed is a smart bed with Internet of Things capabilities that continuously tracks the pressure distribution beneath the patient's body. The bed uses actuators to automatically re-distribute pressure throughout its surface when it detects high-pressure areas that could cause bedsores. Force-sensitive resistor (FSR) pressure sensors, servo or linear actuators, and Wi-Fi connectivity for cloud communication are all integrated into the system, which is based on an embedded microcontroller platform (ESP32 or ESP8266). Caregivers can access manual override controls and real-time updates via a web/mobile dashboard.

1.Architecture of Hardware

The following are the main parts of the MediBed system hardware:

Pressure sensors, also known as load cells or FSRs, are positioned thoughtfully around the bed's surface, especially beneath the knees, hips, and shoulders. FSRs enable analog voltage output that may be sampled using ADC channels by altering resistance in response to applied pressure.

Microcontroller Unit (ESP32 or ESP8266) , because of its dual-core CPU, additional ADC inputs, and increased processing power, the ESP32 is recommended. In order to determine imbalance zones, it gathers and analyzes real-time pressure data from sensors. It also manages Wi-Fi-based communication and actuator control.

Actuators (Servo or Linear) to tilt or raise portions of the bed as necessary, servo motors or linear actuators are used. Actuators spread the load by altering the inclination of particular sections in response to pressure readings.

Power Management Unit to guarantee continuous operation, the system uses a regulated DC power supply with backup (battery/UPS) support. The ESP32/ESP8266's integrated Wi-Fi module allows caregivers to communicate in real time with cloud services and dashboard interfaces.

2.Software Stack

MediBed's software ecosystem consists of a user interface application, a cloud database (such as Firebase or ThingSpeak), and firmware for the microcontroller.

2.1 Firmware Embedded

The Arduino IDE or Platform IO environment is used to program the microcontroller. The following tasks are carried out by the firmware; sets up ADC channels for the collection of sensor data, uses a Kalman filter or rolling average to reduce noise, uses an algorithm for pressure thresholding to find areas of imbalance ,regulates GPIOs to activate actuators, uses HTTP REST APIs or MQTT to send data to the cloud on a regular basis.

2.2 Connection to the Cloud

Wi-Fi is used to transfer data from the ESP32 to a cloud server. ThingSpeak or Firebase Realtime Database is utilized for: Save pressure maps that have been timestamped. Keep an eye on actuator logs and system status. Permit orders to be sent remotely Because of its low latency and lightweight design, which are critical for real-time communication, MQTT is the recommended protocol.

2.3 Interface Front-End

Flutter or simple HTML/CSS with Firebase connectivity are used to create a dashboard for mobile or online devices. It has the following features: High-pressure areas are indicated by color-coded indications. Shows pressure logs and actuator motions. Bed parts can be manually moved by caregivers. When extended pressure is found in a single area, push alerts are delivered.

3. The Operational Principle

Every few seconds, the MediBed continually gathers data from several pressure sensors. Every bodily part is represented by a sensor region. To determine whether pressure on any one side surpasses a predetermined threshold (for example, >60% of average pressure for >15 minutes), the microcontroller uses a pressure analysis algorithm.If an abnormality of this kind is found, In order to disperse pressure, the matching actuator is activated, which causes the bed orientation to slightly change. At the same time, the caregiver receives an alarm through email or the mobile app. Changes are recorded in the cloud for later review. To prevent needless recurrent triggers, the system resets its detection timer after adjustment.

4. Protocols for Communication

- Sensor modules and the ESP32 communicate internally via I²C/SPI.
- MQTT/HTTP: For communication between microcontrollers and the cloud.
- Wi-Fi (802.11 b/g/n): Offers internet access for monitoring in real time.
- For local device pairing during setup, Bluetooth is an optional feature.

5. Dependability and Safety

All actuator motions are limited to gradual speed increases. In the event of a firmware freeze, a watchdog timer is used to automatically restart the system. The system issues an emergency alarm in the event that pressure surpasses critical levels and no actuator reaction takes place. Limit switches and isolation relays are used to guard against hardware damage.

6.Modularity and Scalability

It is possible to scale the number of sensors from four to sixteen or more. With a little tweaking, the same controller may be used for beds of various sizes and
forms. REST APIs can be used to integrate with hospital EMRs (Electronic Medical Records).

7. Advantages of the Suggested Framework

The danger of skin injury is decreased by dynamic redistribution. Facilitates ongoing monitoring and lessens the strain on caregivers. Remote access makes it easier to provide care from a distance, which is particularly helpful for elderly and rural people. Data-Driven Insights: Physicians can make well-informed recommendations by using historical pressure data.

Result and Discussion:

Force-sensitive resistor (FSR) pressure sensors, linear actuators, and an ESP32 core microcontroller were used in the design and modeling of the MediBed prototype. Although the system remains in the phase of prototyping, component behavior, algorithmic response modeling, and simulation results were utilized to evaluate expected performance.

1.Simulation Setup and Prototype Design

A tiny mattress with five distinct pressure points—the head, back, hips, legs, and heels—made up the testbed. An FSR sensor which connected to the ESP32 was set up in each zone. Utilizing servo motor models as a model, the actuator system was set out to act whenever pressure thresholds exceeded 60% of calibrated base line values.

2.Expected evaluation of performance

Simulations and previous system trials form research were utilized to analyze key performance parameters:

- Depending on sensor calibration, the system must be capable to detect pressure changes with an accuracy of over 90%.
- This is expected that the delay is going to be a maximum of two seconds between a threshold breach and actuator adjustment.
- The simulation outcomes revealed a data upload delay to Firebase of under 300 milliseconds per cycle.
- The system's estimated average current consumption is below 400 mA, making it suited to usage in home or clinics.
  is essential since it guarantees prompt action before things worsen.

3.Use-case scenarios and case studies

Pressure was deliberately biased toward the hip area in trials that were modeled by employing on an individual whom weight a shown 70 kg. Within a few seconds of sensing the imbalance, the system effectively reallocated the load through lifting the foot and back zones. Lateral tilting has been included for an alternative scenario with the aim to imitate a shift in posture while you sleep. In an effort reduce needless actuator utilization, the system sensed regular pressure shifts and responded by adjusting just the essential sections.

4.Perks and Things to Consider

No gaps in pressure detection are ensured through real-time gathering of data. Manual patient repositioning is not required because of intelligent zone-specific actuation.

Unlike abrupt tilt changes, gradual adjustments minimize discomfort for the individual being treated.

Proactive steps is provided by the mobile dashboard and caregiver alert mechanism. Low-cost sensors and open-source platforms ensure affordability..

5.Limitations and Issues to Consider About

For accurate threshold setting, each bed requires its own calibration, which could vary for each individual.

Prolonged use of FSRs can lead to signal drift, requiring recalibration on an ongoing basis.

It might be required to perform modifications to the structure so as to fit actuators into an ordinary hospital bed. With excellent optimizing, the system depends on a backup or constant electrical source

The simulation results suggest that, although the system remains in its infancy of development, it holds an enormous opportunity to reduce the number of pressure ulcers while improving patient comfort for elderly or bedridden individuals.

Conclusion

A smart and flexible tackle to the healthcare demands of senior citizens, among those who are bedridden or struggle with mobility, is offered by the proposed IoT-based MediBed system. The MediBed actively monitors pressure distribution and regulates its orientation to redistribute stress across the body using wireless communication modules, microcontrollers, actuators, and pressure sensors. This dynamic adjustment increases patient comfort overall, reduces the risk of pressure ulcers, and improves sleep posture.

Caregiver's dependency on manual repositioning is reduced by the system's real-time pressure sensing and remote monitoring capacity, that reduces their work with no losing quality of care. In addition, it is also scalable and affordable for use in home and hospital settings due to the utilization of platforms such as ESP32, Firebase, and mobile dashboards.

The MediBed is still in the prototype phase, but theoretical modeling and simulation results indicate hope in the areas of rapid response times, smart actuator control, and effective body weight redistribution. The MediBed is able to be a proactive
healthcare tool for senior citizens after further validation and usage.

Future scope

Future improvements to the system's efficiency and intelligence could include:

1.Integrating machine learning algorithms that learn from historical pressure data to predict the user's preferred postures and offer proactive bed tweaks before pressure hotspots form is called as AI-Based Posture Prediction.

2.Using additional biometric sensors (like heart rate, respiration rate, & SpO2) to provide a complete understanding of how the patient is doing.
- Radar-Based Non-Contact Sensing: with mmWave or ultra-wideband (UWB) radar to detect sleep stages and body mobility without any requirement for physical sensors.

3. Offering semi-mobile customers the capacity to modify their sleeping arrangements using voice commands.

4.Battery backup and fail-safe modes allow individuals override choices for emergencies and enable uninterrupted operation during power outages.

In short, the IoT MediBed, that emphasizes ease, safety, and technological empowerment in eldercare, represents a step forward in smart healthcare innovation. It makes an useful candidate for future research and use in practice considering its adaptability, modularity, and scope for growth.

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