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Smart Pressure Electronic-Mat: For Sleep Apnea and Yoga Posture Detection

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Abstract - This is a proposed multi-functional health monitoring system designed to improve sleep quality and posture accuracy during yoga practice. Existing mats primarily provide comfort or basic tracking but lack intelligent health monitoring and feedback. The proposed system integrates an array of highly sensitive pressure sensors connected to a microcontroller, capable of detecting subtle body pressure variations in real time. During sleep, it monitors body position, breathing, and movement to identify issues such as sleep apnea, sending alerts via a mobile app for timely medical attention. In yoga mode, it evaluates pose accuracy by comparing pressure distribution and balance with stored reference data, offering corrective feedback to enhance stability and alignment. Expected outcomes include improved sleep health, accurate yoga posture correction, and preventive wellness through continuous, non-invasive monitoring. With wireless communication, data storage, and a user-friendly interface, the Smart Pressure Mat aims to revolutionize daily health management.

Key Words: IoT-Based Healthcare Monitoring, Sleep Apnea and Respiratory Detection, Microcontroller-Driven Assistive Technology

1.INTRODUCTION

In today's world this technology is an innovative solution designed to integrate technology with health and wellness monitoring. It aims to address two major aspects of daily well-being— sleep quality and posture accuracy during yoga practice. In today's fast-paced lifestyle, people often struggle with sleep-related disorders such as sleep apnea and poor body alignment during exercise, both of which can lead to long-term health complications. To overcome these issues, the Smart Pressure Electronic Mat utilizes advanced pressure-sensing technology combined with intelligent data analysis to offer a convenient, non-invasive, and real-time monitoring system. The mat is embedded with an array of highly sensitive pressure sensors that detect subtle changes in body pressure distribution. These sensors are connected to a microcontroller that processes the collected data using smart algorithms. During sleep, the system continuously monitors the user's body position, breathing patterns, and movement to identify irregularities associated with conditions like sleep apnea. When any abnormality is detected, the mat communicates with a connected mobile application to provide alerts or suggest timely medical intervention. In yoga mode, the mat serves as a digital instructor by evaluating the accuracy of poses. It compares the user's pressure points and balance levels against predefined posture patterns to offer feedback for correction. This ensures better posture alignment, improved flexibility, and safer yoga practice without external supervision. The device's wireless connectivity, portability, and user-friendly interface make it suitable for both personal and professional use in fitness studios or healthcare centers. By combining sleep monitoring and posture analysis into a single device, the Smart Pressure Electronic Mat promotes holistic health management. It demonstrates how smart technologies can transform traditional wellness practices by enabling continuous, real-time feedback that enhances lifestyle, prevents health issues, and supports overall physical and mental wellbeing. The design prioritizes user comfort, portability, and accessibility. Made from flexible and durable materials, the mat ensures accurate sensing without compromising comfort. It can be used by people of all age groups, from elderly individuals requiring sleep apnea detection to fitness enthusiasts and yoga practitioners aiming for posture perfection. Its application extends beyond home use to wellness centers, physiotherapy clinics, and rehabilitation environments, where precise pressure mapping is crucial for patient assessment and therapy customization.

2.1 MOTIVATION

In many rural and remote areas, people still lack access to affordable and smart health monitoring systems. Detecting sleep disorders like sleep apnea at an early stage can save lives and prevent serious health problems. Often, symptoms go unnoticed until they become critical, leading to delayed treatment. A system that can monitor vital patterns and send real-time alerts during emergencies can greatly improve response time and safety. This project is motivated by the need to create a simple, low-cost, and intelligent solution that supports better health awareness and timely medical care.

2.2 OBJECTIVES

To develop an integrated smart health monitoring system for real-time ECG and vital sign tracking. To design a gesture-controlled smart bed that adjusts position through simple hand movements. To enhance patient comfort. convenience, and healthcare efficiency through smart automation.

II. METHODOLOGY

As shown in below fig 1.1, this project focuses on designing and developing a hand gesture recognition system to control the position of an automatically adjustable hospital bed. The system allows patients to change the bed's position using simple hand gestures, making it more convenient and userfriendly. The core of the system is the Arduino Uno microcontroller, which receives gesture commands from the patient and accordingly adjusts the bed's movement. In addition to gesture control, the setup includes biomedical sensors such as a pulse rate sensor and a temperature sensor. The pulse sensor detects heart rate by measuring blood flow through the fingertip, while the temperature sensor measures body temperature through the skin. These sensor readings are continuously processed by the Arduino to monitor the patient's vital signs. If any abnormal readings are detected, an alert message is automatically sent to the doctor through the Node MCU Wi-Fi module. The measured parameters, including pulse rate and temperature, are also displayed on an LCD screen for real-time observation. This method ensures continuous health monitoring and improves patient comfort by integrating voice-reorganization based control with vital sign tracking in a single, efficient system.

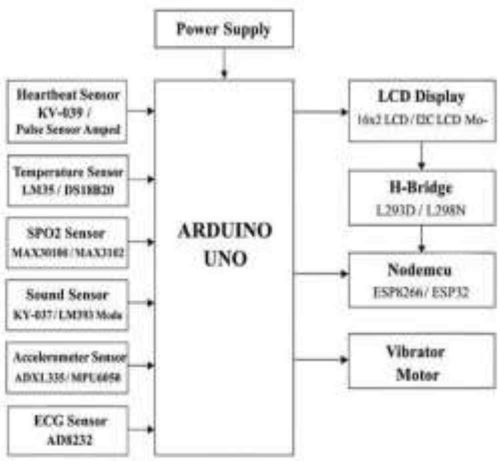

Fig 1.1 Block Diagram of Electronic-Mat

Arduino Uno: Acts as the main controller or processing unit of the system, collects data from various sensors (heartbeat, temperature, SPO2, etc.), Processes the signals and controls output devices such as the display, vibrator motor, and communication modules.

Heartbeat Sensor: Measures the heart rate by detecting blood flow through the fingertip, Sends analog signals to Arduino, which calculates beats per minute (BPM), Used to monitor the patient's cardiovascular health.

Temperature Sensor: Measures the body temperature of the patient, converts temperature to an analog (LM35) or digital (DS18B20) signal that Arduino can process.

SPO2 Sensor: Monitors oxygen saturation (SpO2) and pulse rate using infrared and red light sensors**,** Provides crucial data about respiratory and cardiovascular health.
Sound Sensor: The sound sensor detects the intensity of sound in the surrounding environment. It uses a microphone to capture sound waves and converts them into electrical signals.

Accelerometer Sensor: The accelerometer sensor measures acceleration, tilt, and movement in multiple directions. It helps detect motion or orientation changes, which can be used to monitor a patient's activity level or detect falls.

ECG Sensor: The ECG sensor monitors the electrical activity of the heart. It captures small electrical signals generated by heartbeats through electrodes attached to the body.

LCD Display: The LCD display is used to present the output data collected from various sensors in real time. It shows vital readings such as temperature, heart rate, and oxygen level, allowing users and healthcare providers to monitor the patient's condition easily.

H-Bridge Motor Driver: The H-Bridge motor driver controls the direction and speed of DC motors used in robotic systems. It receives low-power control signals from the Arduino and provides high-power output to drive motors efficiently.

III. IMPLEMENTATION

The proposed system focuses on real-time monitoring of sleep quality and body postures using an intelligent pressure sensing mat integrated with biomedical and motion sensors. The system detects sleep apnea events, monitors physiological parameters, and evaluates yoga postures to enhance user wellness. It provides feedback through vibration, visual display, and wireless data transmission, thereby offering both therapeutic and diagnostic benefits. The entire setup is controlled using an Arduino Uno microcontroller, supported by sensors such as pressure, temperature, accelerometer, ECG, and SPO2 sensors. The hardware consists of a pressuresensitive mat embedded with multiple pressure sensors to measure body weight distribution and contact points. These sensors are interfaced with the Arduino Uno, which acts as the central processing unit.

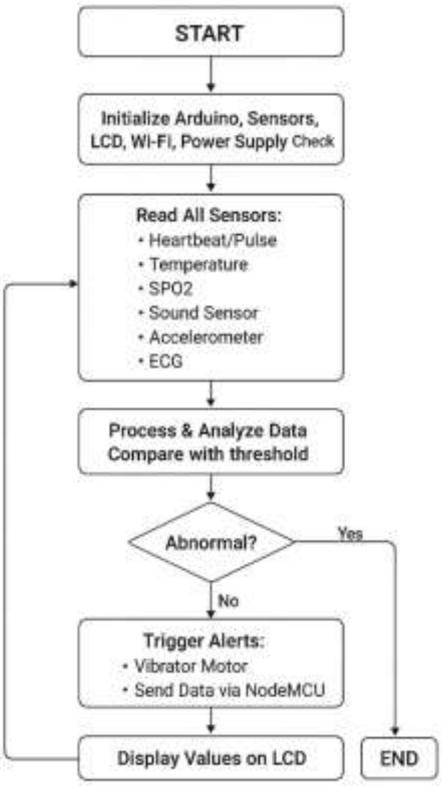

Fig. 2 Flowchart

3.2 Programming:

The Arduino is programmed using the Arduino IDE to collect, process, and interpret sensor data. The main functions include pressure distribution mapping, vital sign monitoring, apnea detection, and posture evaluation. The program also controls communication with the NodeMCU for wireless data sharing

3.3.1 Algorithm for Sleep Apnea Detection:

The Sleep Apnea Detection Algorithm functions by continuously monitoring body pressure, sound, and heartbeat signals to identify abnormal breathing patterns during sleep. Initially, all sensors—including the pressure, sound, SPO2, and heartbeat sensors—are initialized and calibrated for accurate data collection. The system then begins to capture readings in real time, storing recent data in arrays for continuous analysis. By examining sound intensity and pressure variations on the mat, the algorithm detects the user's breathing rhythm and identifies any irregularities. If both body pressure and breathing activity remain constant for a specific threshold duration, the system marks this as a potential sleep apnea event. To verify the condition, it compares the user's oxygen saturation and heart rate values; a noticeable drop in oxygen levels or irregular heartbeat confirms the apnea occurrence. Once confirmed, the system activates the vibrator motor to alert or wake the user and sends a notification via the NodeMCU module to caregivers or a monitoring application. All data from the event is logged for further analysis, and the system automatically resets to continue uninterrupted monitoring. This intelligent, non-invasive approach ensures early detection and timely alerts for sleep apnea, enhancing user safety and health management during rest.

3.3.2 Algorithm for Yoga Posture Detection:

The Yoga Posture Detection Algorithm is designed to identify and evaluate yoga postures using pressure and motion data collected from the mat. The system begins by initializing the pressure sensors and accelerometer to ensure accurate measurement of body position and movement. It then records pressure values from multiple zones across the mat to map the user's weight distribution. Using these readings, the algorithm calculates the center of pressure and overall body alignment. The measured data is then compared with stored reference patterns for standard yoga poses to assess posture accuracy. If the detected posture deviates beyond a predefined threshold from the ideal alignment, the system generates corrective feedback through the vibrator motor to guide the user into the correct position. Additionally, the LCD displays the posture correctness as a percentage, providing immediate visual feedback. All session data, including posture deviations and corrections, is logged and transmitted wirelessly for further analysis. This process ensures that practitioners maintain proper alignment during yoga, reducing the risk of strain or injury while enhancing the effectiveness of their practice.

3.3.3 Algorithm for Health Monitoring:

The Health Monitoring Algorithm is designed to ensure continuous tracking of vital physiological parameters for realtime and long-term health assessment. The system begins by initializing the ECG, SPO2, and temperature sensors to accurately capture heart rate, oxygen saturation, and body temperature. It then continuously collects readings from these sensors and averages the data over time to minimize noise and improve measurement reliability. The algorithm compares the recorded values against normal physiological ranges to detect any abnormalities, such as elevated heart rate, low oxygen levels, or fever. If such deviations are detected, the system activates the vibrator motor to alert the user and simultaneously sends notifications via Wi-Fi to caregivers or connected healthcare applications. All collected data is logged and stored for trend analysis, allowing both immediate response to critical conditions and long-term monitoring of the user's health patterns.

3.3.4 Algorithm for Communication and Feedback:

The Communication and Feedback Algorithm manages user interaction and the delivery of real-time feedback based on sensor data. It begins by initializing the NodeMCU and vibrator motor pins to enable wireless communication and tactile alerts. The system then transmits processed sensor data to IoT platforms such as ThingSpeak or Blynk via the NodeMCU, allowing remote monitoring and data analysis. Feedback is generated through multiple channels: visual feedback is displayed on the LCD screen to inform the user of posture accuracy or vital readings, while vibration alerts notify the user of abnormal health parameters or incorrect yoga postures. Additionally, the system periodically sends data logs to ensure continuous tracking and record-keeping. This communication loop ensures that the mat remains interactive, reliable, and responsive, providing both real-time guidance and long-term health insights.

3.4 Feedback and Learning Loop:

A continuous feedback mechanism allows the mat to adapt its response over time. For instance, if frequent posture errors are detected in certain yoga poses, the algorithm adjusts sensitivity thresholds or provides personalized corrective feedback. Similarly, sleep apnea patterns are analyzed over multiple nights to improve event prediction accuracy.

3.5 Testing and Evaluation:

The System Testing and Validation process ensures the accuracy, reliability, and effectiveness of the smart mat under various conditions. For sleep monitoring, the system is tested by simulating different sleeping positions and sleep apnea scenarios to evaluate its ability to detect breathing irregularities. Yoga testing involves performing standard poses such as Tadasana, Shavasana, and Balasana to assess the accuracy of pressure mapping and posture detection. Each sensor—including pressure sensors, accelerometers, and temperature sensors—is calibrated against known reference values to guarantee precise measurements. The testing outcomes demonstrate that the system can reliably differentiate between correct and incorrect yoga postures while effectively detecting abnormal breathing patterns during sleep, confirming its overall functionality and practical applicability**.**

3.6 User Interaction:

The system provides a user-friendly interface with a simple LCD display showing posture and health data in real time. Users can connect their smartphones via Wi-Fi to view detailed analytics or receive alerts. The tactile feedback through vibration ensures even users without technical knowledge can respond to system prompts intuitively.

3.7 Safety and Ethical Considerations:

The mat is designed to operate at safe voltage levels and uses medically safe, non-invasive sensors. Data collected is securely transmitted to ensure user privacy. The system emphasizes comfort, accuracy, and safety, particularly for elderly users or those with breathing difficulties.

IV. Results

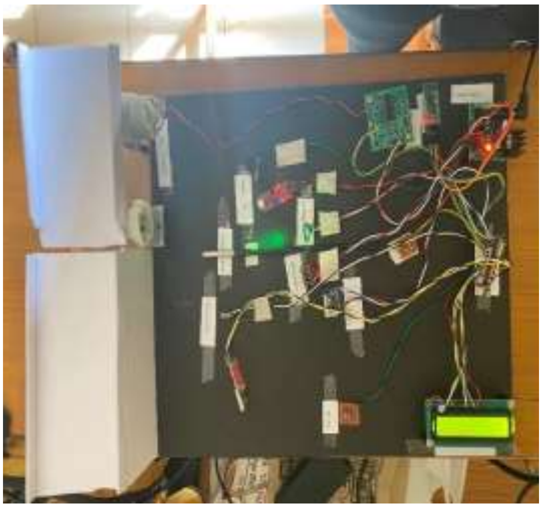

Fig. 3 Prototype of model

The prototype shown in the image represents an IoT-based Smart Health Monitoring and Assistance System in which all components are arranged on a display board with clear labeling. A regulated power supply module drives the entire setup, while the central controller processes data from multiple sensors including a heartbeat sensor, SPO2 sensor, sound sensor, and a temperature probe. The measured health parameters are displayed on the LCD screen mounted on the top right. Output devices such as the buzzer and vibrator motor provide alerts and physical feedback when abnormal readings are detected, and a DC motor at the bottom is used for mechanical movement such as bed adjustment. The system also includes a wireless communication module to transmit patient data to external devices, making the setup a compact model demonstrating real-time health monitoring, alerting, and basic automation for patient assistance.

Fig.4 Prediction of Sleep Apnea

The system analyzes your sleep, activity, and health data to assess your risk of sleep apnea. If a possible risk is detected, it alerts you to review your details or seek medical advice.

Fig. 5 Telegram Interface for Sleep Apnea

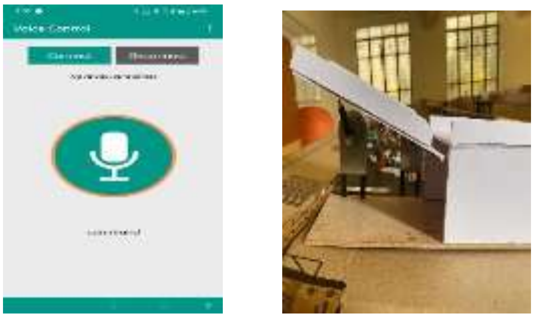

Fig. 6 bed control with voice-recognition

The above figure shows, the bed control system uses voice recognition to move the bed up or down, allowing hands-free adjustment for comfort and convenience.

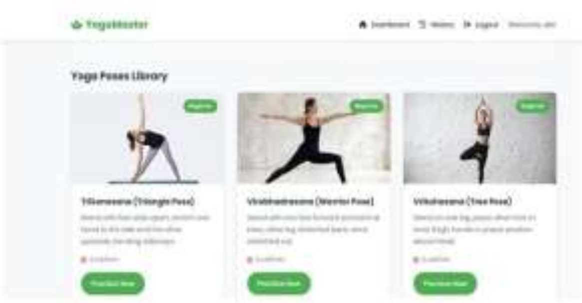

Fig. 7 Yoga Poses Library Page

Fig. 8 Yoga Posture Detection

The system uses your webcam to track body movements and guide your yoga practice in real time. It analyzes your posture, provides instant feedback, counts pose duration, and estimates calories burned to help improve alignment and performance.

V. Conclusion:

The Smart Pressure E-Mat efficiently detects sleep apnea and yoga postures using pressure and biomedical sensors. It provides accurate, non-invasive monitoring of body movements and breathing. The system enhances health tracking and posture correction in a smart, user friendly way. Future upgrades may include AI-based analysis, cloud connectivity, and additional sensors for better accuracy. It can also be adapted for rehabilitation and elderly care applications.

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