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# Design and Development of Smart Mattress Using Iot Functionalities for Sleep Apnea Management

A E Yogita[1], Daniya Naaz[2], Hadiya Sultana S[3], Javeria Banu[4]
*Corresponding Guide: Sindhu T N*
[1,2,3,4]*Student, Sri Siddhartha Institute of Technology, Tumakuru, Karnataka*

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**ABSTRACT**: OSA abbreviated for Obstructive Sleep Apnea is a serious sleep disorder. Individuals with OSA often remain unaware that their upper airway is obstructed, leading to breathing difficulties. Therefore, continuous sleep monitoring in everyday life is crucial. Sleep apnea (OSA) is characterized by airway blockages during sleep, leading to temporary pauses in breathing. Our project introduces Sleep Smart, an innovative fabric mattress topper equipped with textile pressure sensors. This topper monitors sleep patterns, and respiration rate, and detects potential OSA episodes. By leveraging smart textile technology, this project aims to advance the field of sleep monitoring. We intend to create a discreet, wireless system called Sleep Smart, which integrates various sensors, including textile pressure sensors, temperature and humidity sensors, optical sensors, piezoelectric sensors, heart rate, and SpO2 sensors. These features enable real-time monitoring of sleep habits and respiration rates from the comfort of one's bed, utilizing IoT capabilities. The project has three main goals: 1. Design and develop the mattress pad, 2. Perform analysis on the pressure data, and respiration rate, read oxygen level in blood, and real-time monitoring through webcam, 3. Recording and monitoring sensor data on an IoT application and cloud for storage. This project highlights significant research progress and outlines future objectives.

**KEYWORDS:** Obstructive sleep apnea, embedded system, e-textiles, IoT.

## I. INTRODUCTION

Individuals with sleep apnea often face episodes of shallow breathing or complete pauses in their breathing while asleep. In cases of Obstructive Sleep Apnea, the upper airway is blocked during sleep, typically without the person's knowledge of their breathing issues. To diagnose OSA effectively, monitoring various parameters like respiratory function, sleep patterns, and heart activity is essential. In this project, we have developed a sleep monitoring system called Sleep Smart.

This system employs intelligent textile pressure detectors integrated into a wireless embedded platform with IoT functionality. Sleep Smart aims to develop a fabric mattress pad embedded with these sensors, intended to track sleep patterns and breathing rates, thus evaluating the risk of Obstructive Sleep Apnea (OSA). The Sleep Smart pad includes a fabric sensor matrix, resistor arrays, and an embedded system with IoT and wireless capabilities. Algorithms will be developed to identify OSA events during sleep and assess overall sleep quality. Additionally, an IoT framework will be established to provide personalized visualization of sleep quality and OSA data via a tablet application. Technology enhances textiles' ability to sense their environment and respond to external stimuli while maintaining their inherent properties. This adaptive capability is a hallmark of smart fabrics.

Through the use of soft computing and portable devices, these fabrics have seen a surge in demand. Textiles are evolving into integrated circuits for smart wearables. While these wearables don't replace traditional clothing, they have carved out their market segment without standardization. E-textiles or smart wearables can detect touch, strain, pressure, temperature, and humidity thanks to sensors based on capacitance, resistance, and optics, all connected to a control device that processes these signals into information. Continuous advancements are being made with new dyes, techniques, electronics, and fiber compatibility while adhering to core principles.

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## II. LITERATURE SURVEY

Smart mattresses integrated with e-textiles using lot is a rapidly growing field in the healthcare and wellness industry. This technology aims to provide users with a comfortable and personalized sleeping experience by monitoring various health metrics and adjusting the mattress accordingly. A literature search on this topic reveals several studies and articles. Some of the notable ones are:

**1. "Development of a Smart Mattress for Monitoring Sleep Quality Using Pressure-Sensitive Conductive Fabric Sensors"** by D. Han et al. This paper presents a smart mattress system that uses conductive fabric sensors to monitor various sleep parameters such as heart rate, breathing rate, and sleep position. The system also includes an IoT platform for data analysis and visualization.

**2. "Design and Implementation of a Smart Mattress with a Flexible Pressure Sensor Array"** by H. Jang et al. This paper proposes a smart mattress system that uses a flexible pressure sensor array to monitor the sleeping posture and movements of the user. The system also includes an IoT platform for data analysis and personalized sleep recommendations.

**3. "Smart Mattress with E-textile Sensors for Monitoring Sleep Quality and Heart Rate Variability"** by L. Gu et al. This paper presents a smart mattress system that uses e-textile sensors to monitor sleep quality and heart rate variability. The system also includes an IoT platform for data analysis and visualization.

**4. "Smart Mattress System for Monitoring Sleep Quality Using Wearable Sensors and Internet of Things (IoT)"** by S. Khan et al. This paper proposes a smart mattress system that integrates wearable sensors and IoT technology to monitor sleep quality and provide personalized sleep recommendations.

Overall, the literature survey suggests that smart mattresses integrated with e-textiles using IoT have the potential to revolutionize the sleep industry by providing users with a personalized and comfortable sleeping experience. However, more research is needed to improve the accuracy and reliability of these systems.

## III. METHODOLOGY

**1. Hardware Setup:**

- Install the Sensors, 16x2 LCD, and Arduino microcontroller.
- Connect the sensors, LCD, and Arduino according to the hardware specifications.
- Set up the IoT module and ensure it can communicate with the Arduino for remote monitoring
- Integrate code to send data to the IoT module for remote monitoring and control.

**2. Testing:**

- **Unit Testing:**
- Test the functionality of the Sensors, LCD, and IoT module individually.
- Verify the Arduino code for reading Sensors, displaying information on the LCD, and communicating with the IoT module.

- **Integration Testing:**
- Test the interaction between all components, ensuring seamless integration and proper functionality.

- **Real-world Testing:**
- Evaluate the system's performance in real-world scenarios, such as different lighting conditions and varying vehicle speeds.

**3. User Interface Development:**

Develop a user interface on the LCD to display access status, instructions, and system status, ensure the user interface is intuitive, and provide clear information to users.

**4. Deployment:**

Install the system at the desired location, ensuring proper calibration and configuration. Provide user training and support for administrators and users. Monitor system performance post-deployment and address any issues that arise.

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**5. Maintenance and Monitoring:**

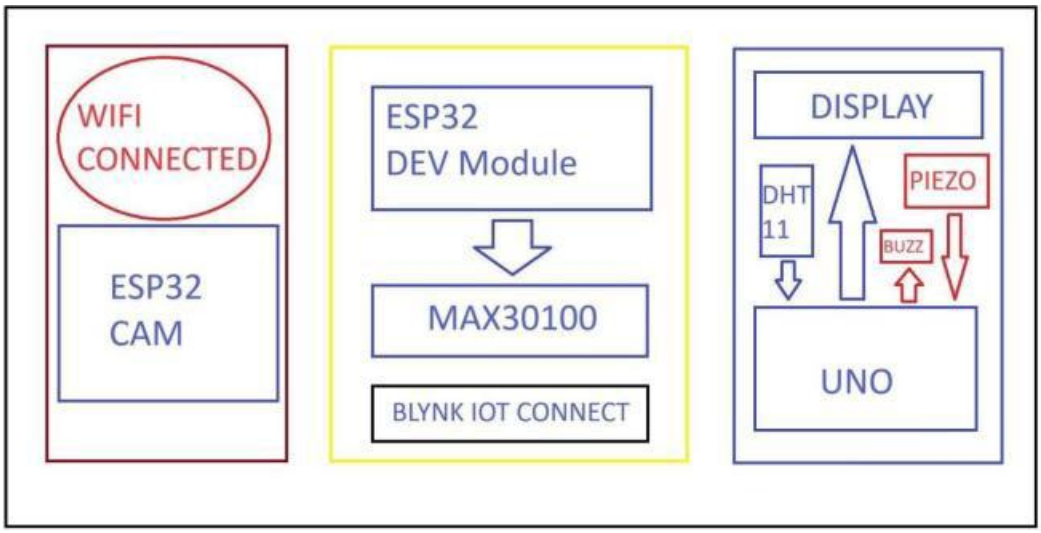
Implement a maintenance schedule to regularly check and update system components. Monitor system performance and address any issues promptly to ensure continuous operation. By following this methodology, we can monitor the Sleep Apnea patients and get the information about the patient in the Blynk IoT app.

1. It has a single mattress that does patient stress analysis indicated through hardware.

2. It consists of 5 sensors in a single mattress which acts as an all-in-one solution to the existing system. The spO2 sensor monitors the oxygen level, heart rate sensor to measure heart rate, valuation of body temperature using a DHT level sensor, body humidity measure sensor, identification of sleeping position using a pressure sensor, and a camera installed to monitor the patient.

3. Choosing sensors capable of accurately measuring pressure distribution and contact area between the body and the mattress was a crucial decision.

4. To make an informed choice, We evaluated various options, including pre-made mattress sensor arrays, limit switches, FSRs (force-sensitive resistors), and piezoresistive materials.




**SYSTEM ARCHITECTURE**

A systems development project is considered economically viable or beneficial for an organization if the expected benefits surpass the estimated costs. Although some expenses—such as time, budget, and personnel resources utilized during the design and implementation stages, as well as continuing costs for infrastructure, support, training, and maintenance post-implementation—are relatively easy to identify, accurately estimating costs can be difficult, particularly with new technologies and complex systems. In these high-risk situations, using sophisticated cost-benefit analysis tools is crucial for making well-informed financial feasibility evaluations.

The proposed system can leverage existing hardware and software technologies. Essential requirements include a hardware and software architecture meeting minimum specifications to support an operating system capable of hosting Java toolkit and media player applications. The project timeline allocates specific durations to phases such as analysis, design, implementation, and testing, totaling approximately two months for project completion.

**Piezo Electric Sensor**

A piezoelectric sensor is a device that converts mechanical stress or pressure into an electrical signal using the piezoelectric effect. It is commonly used for measuring vibrations, pressure, and acceleration. These sensors are widely used in various applications, including industrial equipment, medical devices, and consumer electronics.

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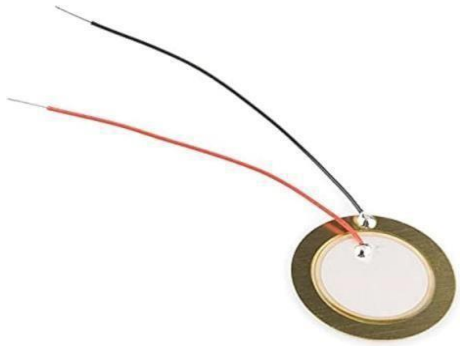
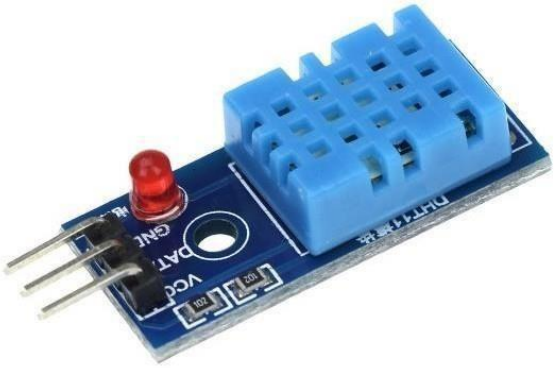


**PIEZO ELECTRIC SENSOR**

**DHT Sensor**

DHT stands for Digital Humidity and Temperature. The DHT sensor is an affordable digital sensor designed to measure temperature and humidity. It can be conveniently interfaced with microcontrollers like Arduino or Raspberry Pi to provide real-time readings of humidity and temperature.



**DHT SENSOR**

**Arduino Uno**

The Arduino Uno stands out as a widely embraced microcontroller board renowned for its simplicity and adaptability in crafting interactive electronic projects. Its foundation on the ATmega328P microcontroller makes it a staple for hobbyists and prototyping enthusiasts. With a multitude of digital and analog pins, the Uno enables the seamless connection of sensors, actuators, displays, and more, facilitating the creation of diverse projects. The inclusion of a USB interface for programming and power supply enhances accessibility for beginners and provides advanced functionalities for experienced developers. The Arduino Integrated Development Environment (IDE) simplifies coding with its user-friendly interface based on C and C++ languages. Boasting a straightforward design and extensive community support, the Uno serves as an ideal platform for learning electronics and coding, enabling users to manifest their ideas.


**ARDUINO UNO**

## IV. RESULTS AND DISCUSSIONS

Numerous smart mattresses currently on the market are equipped with IoT (Internet of Things) technology. These mattresses utilize a range of sensors and smart functionalities to track sleep patterns effectively. They offer personalized insights and recommendations aimed at enhancing overall sleep quality.

**Eight Sleep Pod Pro:** Utilizing advanced sensors, this smart mattress monitors sleep patterns and offers insights into sleep quality, including metrics such as heart rate, breathing rate, and movement. Additionally, an accompanying app delivers personalized recommendations aimed at improving sleep.

**Sleep Number 360 Smart Bed:** Equipped with advanced sensors, this mattress monitors your movements and automatically adjusts its firmness to align with your preferred sleep position. Additionally, an accompanying app offers insights into your sleep patterns and provides personalized recommendations for improving sleep quality.

**Nectar Sleep Mattress:** This mattress employs a blend of sensors and temperature control to monitor your sleep patterns and regulate the mattress temperature for optimal comfort. Additionally, it includes an app that offers personalized insights into your sleep and provides recommendations to enhance your overall sleep experience.

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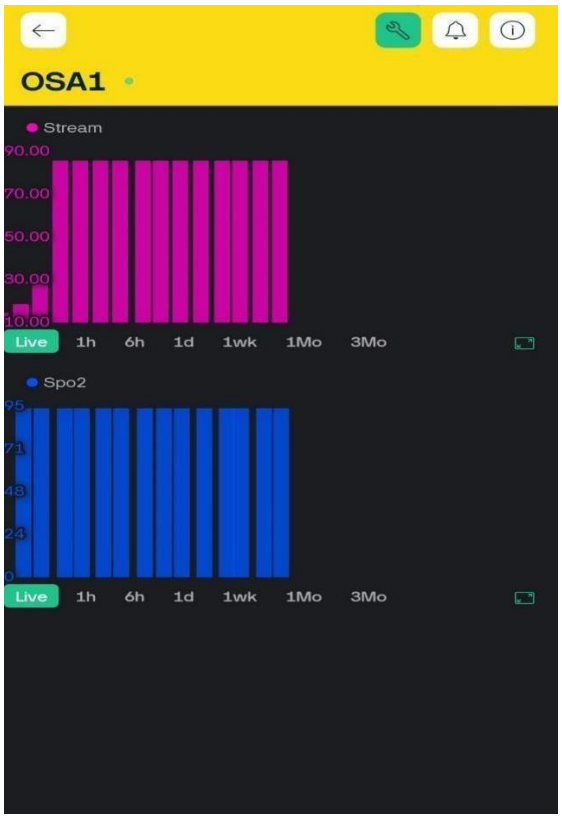
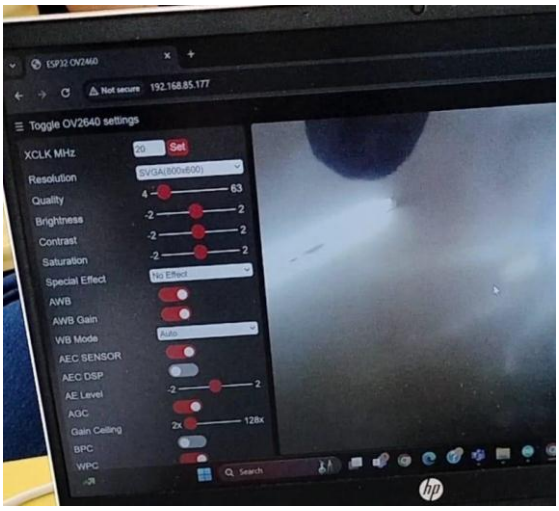



**BLYNK IOT APPLICATION RESULTS**


**TEMPERATURE AND HUMIDITY RESULTS**




**WEBCAM RESULTS**

## V. CONCLUSION

In conclusion, the utilization of this IoT-based multiple monitoring system not only ensures the continuous tracking of patient data but also enhances security. By monitoring vital physiological parameters from sleep to wakefulness, this system enables detailed health case studies and facilitates research through comprehensive data aggregation. Storing patient data securely in the cloud creates a safe environment for ongoing monitoring. Therefore, an affordable and robust sleeping posture identification system equipped with advanced features and technologies holds significant promise for improving patient care.

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