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Research Article

A Smart Pillow for Health Sensing System

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ABSTRACT

An individual's subjective health is intricately linked to the quality of their sleep. Monitoring vital signs such as body temperature and perspiration during sleep is critical for both clinical diagnosis and sleep assessment. This project utilizes various sensors, including LM35 temperature sensors, accelerometer, pulse sensor, proximity sensor, Arduino UNO, Node MCU, buzzer, and LED. Embedded sensors track the patient's movements, temperature, pulse rate, SpO₂, and sleep patterns throughout the night. Collected data, including sleep duration, interruptions, and quality, is sent to a mobile app for analysis. The Internet of Things (IoT) facilitates automatic oxygen supply activation if needed. IoT-enabled pillows adjust surface and room temperature, ensuring a comfortable sleep environment based on patient preferences. Real-time data on temperature, oxygen level, breathing and pulse rates, and sleeping patterns are displayed on a mobile or PC interface. Consequently, this smart pillow serves as an efficient patient monitoring system, offering portability and ease of use.

Keywords: COVID-19 Pandemic, ICT, Learning, Teaching & TVET

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INTRODUCTION

The health of an individual is significantly subjective to the quality of their sleep. Monitoring essential signs during sleep, such as body temperature and perspiration, is important for both sleep estimation and clinical diagnosis. The need for a smart pillow in a health sensing system is driven by the recognition

that sleep is integral to overall health, and real-time monitoring during sleep can offer valuable insights into an individual's well-being. By incorporating sensors like temperature, pulse, and proximity sensors, a smart pillow can comprehensively track vital signs, sleep patterns, and interruptions, allowing for early detection of potential health issues such as sleep apnea or respiratory disorders. The personalized



health insights derived from continuous monitoring empower individuals and healthcare professionals to make informed decisions about lifestyle adjustments and interventions. Moreover, the integration of Internet of Things (IoT) capabilities in smart pillows facilitates seamless connectivity, enabling remote data access and collaborative health management. With the ability to adjust environmental factors like room temperature, smart pillows contribute to creating an optimal sleep environment, promoting better sleep quality and overall health. In essence, a smart pillow serves as a user-friendly, portable, and efficient solution for proactive health monitoring, emphasizing the critical role of sleep in overall well-being.

LITERATURE REVIEW

The following papers demonstrate the evolving landscape of sleep technology, from advanced monitoring systems to stress detection, reflecting the interdisciplinary nature of sleep research. Wang et al.'s "SleepSense" introduces a novel smart pillow integrating pressure-sensitive FBG-embedded silicone buttons, offering precise sleep monitoring with potential applications in personalized sleep solutions[3]. Kau et al.'s "Pressure-Sensor-Based Sleep Status and Quality Evaluation System" proposes an advanced approach to sleep assessment, leveraging pressure sensors for comprehensive sleep quality evaluations [4]. Zhu et al.'s "Sleep monitoring based on triboelectric nanogenerator" presents a wearable and washable solution for continuous sleep monitoring using triboelectric nanogenerator technology, emphasizing user comfort and convenience [5]. Moshayedi et al.'s "Recognition System for Ergonomic Mattress and Pillow" focuses on recognizing and designing ergonomic sleep products, contributing to optimized sleep environments[6]. Gourlay's "Multidisciplinary development of EEG-based smart headpiece prototype" expands beyond sleep monitoring, introducing an EEG-based headpiece for monitoring

everyday environments with potential broader applications[7]. Jeon et al.'s "Self-x based closed loop wearable IoT for real-time detection and resolution of sleep apnea" addresses the critical issue of sleep apnea with a closed-loop wearable IoT system, offering real-time monitoring and intervention[8]. MB et al.'s "Detection of Stress through Sleeping Habits" explores stress detection via sleeping habits, providing insights into potential early stress detection strategies during sleep[10].

Mekid and Chenaoua's 2023 contribution introduces an Internet of Things (IoT)-enabled smart mask that monitors body parameters and location through cloud connectivity, showcasing advancements in wearable health technology[12]. Chen et al.'s exploration of the past, present, and future of sleep quality assessment reflects the continuous evolution in sleep monitoring methodologies, emphasizing the importance of comprehensive approaches[13]. Ma et al.'s 2023 work introduces a highly sensitive and reliable flexible piezoelectric sensor for non-contact sitting motion tracking and physiological signal monitoring, showcasing advancements in sensor technology for diverse applications[14]. Li's IoT Healthcare System based on ESP32, presented at the 2023 IEEE International Conference on Mechatronics and Automation, demonstrates the integration of IoT for healthcare in smart homes[15]. Liu et al.'s 2021 paper focuses on advancing smart cities into the 5G era through multi-field Internet of Things (IoT) applications powered by mechanical energy harvesters, contributing to sustainable urban development[16]. Shijitha et al.'s 2022 research on efficient morphological segmentation of brain hemorrhage stroke lesions employs MultiResUNet, demonstrating advancements in medical image analysis[17]. Kou et al.'s 2022 smart pillow, based on triboelectric nanogenerator arrays, offers a breathable and flexible solution for head movement monitoring during sleep[18]. Xing et al.'s 2022 MXene/MWCNT electronic fabric with enhanced mechanical

robustness on humidity sensing showcases innovations in materials science for real-time respiration monitoring[19]. Sangeetha et al.'s 2022 smart mattress integrated with pressure sensors and IoT functions for sleep apnea detection reflects the intersection of sensor technology and healthcare, promising improved sleep disorder monitoring[20].

Cao et al.'s (2022) parametric study delves into the sleep thermal environment, providing insights into the impact of environmental conditions on sleep quality[21]. He et al. (2022) contribute with a smart flexible vital signs and sleep monitoring belt, leveraging MEMS triaxial accelerometer and pressure sensor technologies for non-intrusive monitoring[22]. Singh et al.'s (2021) analytical study on machine learning techniques delves into the multifaceted applications of machine learning within the realms of blockchain, AI, and IoT, offering valuable perspectives for researchers and practitioners[23]. Lee's (2020) design of a smart pillow system for managing sleep apnea addresses a critical health issue, suggesting potential advancements in sleep apnea management[24]. Rachakonda et al.'s (2020) "Sayopillow" introduces a blockchain-integrated privacy-assured Internet of Medical Things (IoMT) framework, emphasizing secure data handling in stress management considering sleeping habits[25]. Li et al.'s (2020) comparative study explores the intersection of thermal comfort and sleep quality, particularly in hot weather, offering valuable insights for designing innovative mattresses[26]. Song et al.'s (2020) investigation into the effects of phased sleeping thermal environment regulation sheds light on optimizing human thermal comfort and sleep quality[27]. Zimi et al.'s (2020) machine learning-based automatic detection of central sleep apnea events from a pressure-sensitive mat contributes to efficient event detection, while Sadek et al.'s (2020) comparison study introduces a new approach for detecting sleep apnea using a contactless bed sensor. Tamura et al.'s (2018) examination of body

temperature, heat flow, and evaporation in wearable devices provides a foundational understanding of physiological parameters critical for seamless healthcare monitoring[30].

Waltisberg et al.'s (2014) contribution focuses on sleep quality monitoring with a smart bed, offering insights into the use of advanced technologies in capturing and analyzing sleep-related data[31]. Agawane and Mudhalwadkar (2023) present a forward-looking approach with their design of a smart pillow aimed at detecting and managing snoring, addressing a common sleep issue[32]. Ravishani et al.'s (2022) IoT-based smart pillow aims to enhance sleep experiences through connected technologies, reflecting the growing trend of incorporating the Internet of Things (IoT) in sleep-related devices[33]. Dos Reis et al.'s (2020) smart companion pillow project from the EPS@ ISEP 2019 initiative contributes to the field of companion devices, showcasing potential applications beyond traditional sleep monitoring[34]. Ghoneim et al.'s (2020) IoT-based system for monitoring and soothing post-traumatic stress disorder (PTSD) patients extends the scope of sleep technology into mental health, addressing a crucial aspect of holistic well-being[35]. Ali et al.'s (2019) smart pillow for sleep apnea monitoring introduces a specialized device for managing a prevalent sleep disorder[36]. Veiga et al.'s (2018) IoT-based smart pillow for sleep quality monitoring in Ambient Assisted Living (AAL) environments reflects the broader trend of integrating technology for improved healthcare in residential settings[37]. Li's (2019) work on predicting body temperature from a smart pillow using machine learning underscores the potential of AI in enhancing personalized sleep monitoring. Zhang et al.'s (2013) real-time auto-adjustable smart pillow system for sleep apnea detection pioneers early efforts in developing responsive technologies for sleep disorder intervention[39]. Together, these papers collectively contribute to the diverse landscape of sleep

technology, showcasing advancements in monitoring, management, and the integration of IoT and machine learning in promoting overall sleep health.

MATERIALS AND METHOD

IoT (Internet of Things) technology has seamlessly integrated into various aspects of our lives, including our sleep routines, and one notable application is the development of smart pillows for health and wellness. These innovative pillows are equipped with embedded sensors that go beyond providing comfort—they actively gather data about your sleep patterns and habits. Throughout the night, these sensors track your movements and sleep patterns, collecting valuable information on factors such as sleep duration, interruptions, and overall sleep quality. This data is then transmitted to a mobile app for in-depth analysis, empowering users with insights into their sleep health. Moreover, the IoT-enabled pillows offer an additional layer of customization by allowing users to adjust the pillow surface temperature according to their preferences, contributing to the creation of a comfortable sleep environment. Users can conveniently monitor their sleep data, set preferences, and receive real-time feedback through a dedicated mobile app. Importantly, these smart pillows also address health concerns by autonomously administering supplemental oxygen in cases where insufficient oxygen levels are detected, showcasing the potential for IoT technology to enhance not only comfort but also health outcomes in our sleep routines.

The hardware components mentioned in the context of IoT-enabled smart pillows contribute to the functionality and capabilities of these innovative devices. Here are details about the key hardware components mentioned:

EMBEDDED SENSORS

- **LM35 Temperature Sensors:** These sensors monitor the temperature of the pillow surface and are connected to the microcontroller (Arduino UNO or Node MCU). The collected temperature data can be transmitted to the cloud for further analysis and user preference adjustment.
- **Accelerometer, Pulse Sensor, Proximity Sensor:** These sensors collect movement, heart rate, and proximity data, respectively, during sleep. The data is processed by the microcontroller and sent to the cloud or a mobile app for comprehensive sleep pattern analysis.

MICROCONTROLLERS

Arduino UNO and Node MCU: These microcontrollers act as the central processing units, collecting data from sensors and managing the overall functionality of the smart pillow. Node MCU, with its Wi-Fi capabilities, facilitates the connection of the smart pillow to the internet, enabling data transmission to cloud servers or mobile apps.

USER INTERFACE AND FEEDBACK

Buzzer and LED: The buzzer and LED indicators can provide real-time feedback to the user. For instance, the buzzer may alert the user to changes in settings or health-related issues, while LEDs can convey information about the device status or user preferences. These indicators can be remotely controlled via the IoT framework.

OXYGEN SUPPLY SYSTEM

Supplemental Oxygen System: In an IoT-enabled context, the system for administering supplemental oxygen can be activated automatically based on real-time data analysis.

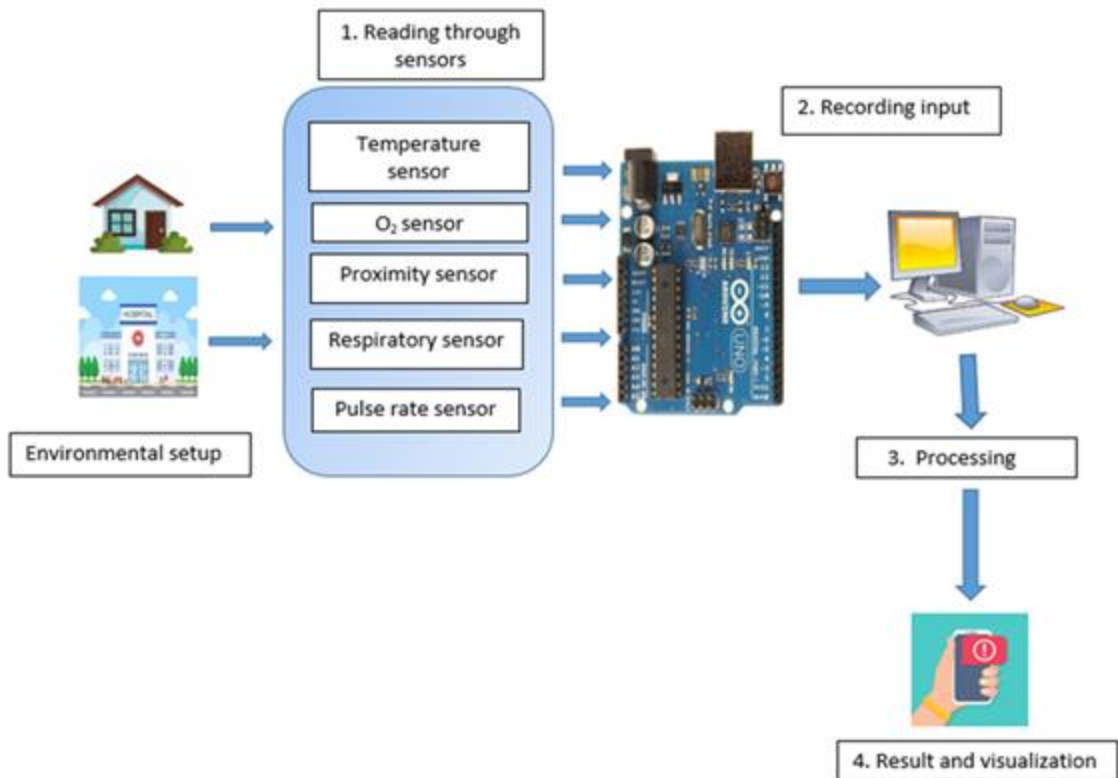


Figure 1: Hardware component integration of Health Sensing system

All hardware components are interconnected and communicate through the IoT architecture. The microcontroller, equipped with Wi-Fi capabilities, establishes connectivity to the internet. The collected data is transmitted to cloud servers for storage, analysis, and accessibility through mobile apps. By embedding these hardware components into an IoT framework, the smart pillow transforms into an intelligent and connected device capable of not only monitoring sleep health parameters but also providing a personalized and responsive sleep environment based on user preferences and real-time data analysis.

RESULTS AND DISCUSSION

Given the comprehensive nature of IoT-enabled smart pillows in monitoring sleep patterns and vital signs, a time-series graph could be particularly informative. A line graph over time could visually represent fluctuations in key parameters such as body temperature, pulse rate, or oxygen levels. This dynamic representation would provide a clear visual understanding of sleep patterns, highlighting variations and trends throughout the night. Additionally, incorporating different colored lines for various parameters would allow for easy comparison and correlation analysis. This type of graph would effectively capture the evolving nature of sleep health, emphasizing the real-time data and insights provided by the smart pillow's IoT capabilities.

The development and implementation of our real-time smart pillow for continuous patient monitoring and sleep apnea detection marks a significant advancement in healthcare technology. The incorporation of sleep patterns and vital signs, including heart rate, patient status, respiratory rate, SpO2 level, temperature, and pulse rate, provides a comprehensive approach to monitoring key health indicators. The integration of an Internet of Things (IoT) system into both domestic and hospital environments introduces additional functionalities. The ability to adjust ambient temperature dynamically enhances patient comfort, while the automatic activation of oxygen cylinders adds an extra layer of safety and responsiveness to critical health situations.

EXPERIMENTAL SETUP

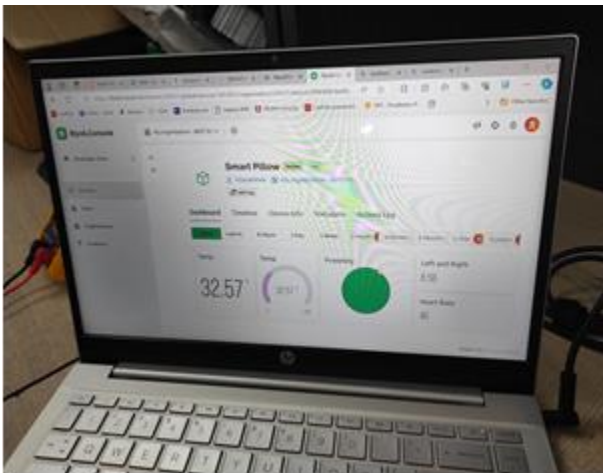


Figure 2: Experimental setup of Health Sensing system.

The buzzer generates a sound from an incoming electrical signal when it is greater than 350 C then the proximity sensor will turn a blue colour. Also when the object is been detected the setup will detect some

vital parameters like O2 level, breathing rate and heart rate of the patients. Using the output

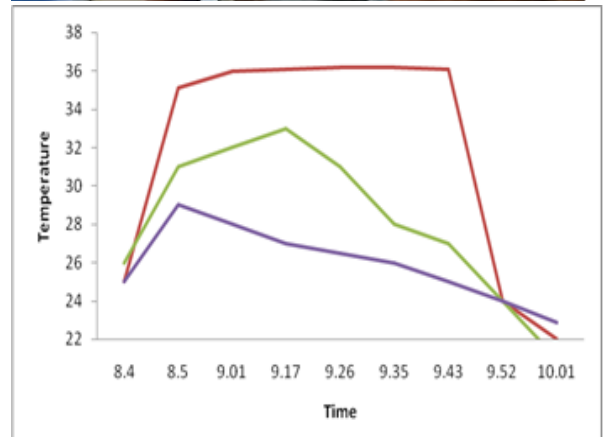
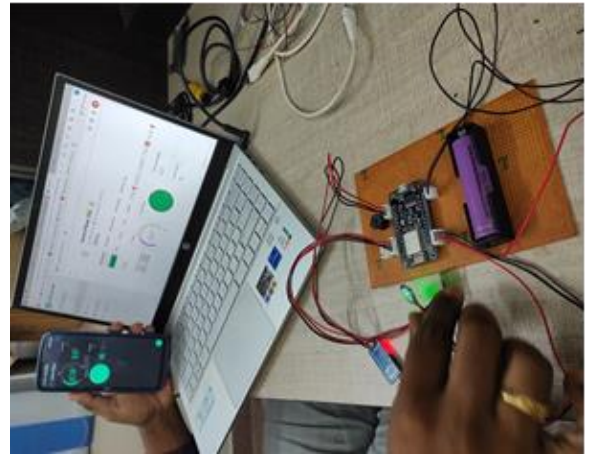


Figure 3: Measurement of Temperature

A notable feature of our technology is the patient gesture detection system, which facilitates seamless interaction between patients and healthcare professionals. This aspect not only enhances communication but also allows for a more personalized and responsive healthcare experience. Importantly, the affordability of this technology makes it accessible to a broad range of individuals, including immobile patients and those who are proactively interested in monitoring their daily health status. The cost-effectiveness contributes to the

scalability and widespread adoption of the system. The results demonstrate the successful integration of diverse health monitoring features and IoT capabilities in a single, inexpensive device. The potential applications of this technology extend beyond hospital settings, catering to the needs of individuals in various environments. The positive implications for both patient care and proactive health management underscore the significance of this innovation in advancing healthcare solutions.

CONCLUSIONS

The integration of IoT technology into smart pillows represents a transformative leap in the landscape of sleep health and monitoring. By seamlessly combining embedded sensors such as LM35 temperature sensors, accelerometers, pulse sensors, and proximity sensors with microcontrollers like Arduino UNO and Node MCU, these devices evolve beyond mere comfort providers into intelligent systems that actively track and analyze sleep patterns and vital signs. The IoT framework facilitates real-time data transmission to cloud servers, empowering users with personalized insights and feedback through mobile apps. The ability to adjust pillow surface temperature and autonomously administer supplemental oxygen showcases the adaptability and potential health interventions these pillows can offer. In essence, IoT-enabled smart pillows redefine the sleep experience, becoming integral components of proactive, connected, and user-centric approaches to sleep health and well-being.

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