Home Based Sleep Apnea Diagnosis System Using Polysomnography Test

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Abstract- *Sleep apnea presents significant challenges in timely diagnosis and treatment, often exacerbated by limitations in accessing polysomnography (PSG) conducted in sleep labs. This study proposes a novel Home-based PSG system to revolutionize the diagnosis and management of sleep apnea.This system utilizes portable, battery-powered devices equipped with various sensors to monitor key physiological parameters such as ECG, heart rate, temperature, SpO2, respiration rate, and posture during sleep. By allowing patients to undergo monitoring in their own homes, the system aims to mitigate disruptions associated with traditional sleep lab settings, ensuring more authentic data collection.A mobile application interface facilitates user-friendly access to PSG data, empowering patients to engage in their sleep health management. Advanced data analysis capabilities enable not only the detection but also the assessment of sleep apnea severity, offering valuable insights for personalized treatment. This innovative Home-based PSG system promises to enhance the accessibility, accuracy, and patient-centricity of sleep apnea diagnosis and treatment, ultimately improving health outcomes and quality of life for affected individuals.*

Keywords- Sleep apnea, polysomnography (PSG), home-based PSG system, ECG, heart rate, SpO2, respiration rate,sleep health management, data analysis, personalized treatment, remote healthcare, patient-centric diagnosis, sleep disorder monitoring, quality of life improvement.

I. INTRODUCTION

Sleep apnea is a prevalent sleep disorder characterized by pauses in breathing or shallow breaths during sleep, leading to disrupted sleep patterns and potentially severe health consequences. However, accessing timely and accurate diagnosis and treatment for sleep apnea remains a significant challenge for many patients due to various factors, including shortages of sleep labs and beds. The conventional method of diagnosing sleep apnea involves Polysomnography (PSG) conducted in sleep labs, which often results in prolonged waits for patients, further delaying their diagnosis and treatment.

Recognizing the limitations and barriers of the current system, this project proposes an innovative solution: a Home-based PSG system aimed at revolutionizing the diagnosis and management of sleep apnea. This system aims to provide a convenient, accessible, and accurate alternative to traditional sleep lab PSG, allowing patients to undergo monitoring and diagnosis in the comfort of their own homes. The Home-based PSG system utilizes state-of-the-art technology, including battery-powered, wireless, and portable devices equipped with various sensors. These sensors measure crucial physiological parameters such as Electrocardiogram (ECG), heart rate, temperature, SpO2 (blood oxygen saturation), respiration rate, and posture throughout the sleep cycle. By continuously monitoring these parameters, the system can accurately detect abnormalities indicative of sleep apnea.

One of the key advantages of the Home-based PSG system is its ability to mitigate the disruptions caused by the unfamiliar sleep lab setting, which often compromise the accuracy of PSG results. By allowing patients to sleep in their natural environment, the system ensures more authentic and reliable data collection, leading to more accurate diagnoses and personalized treatment plans.

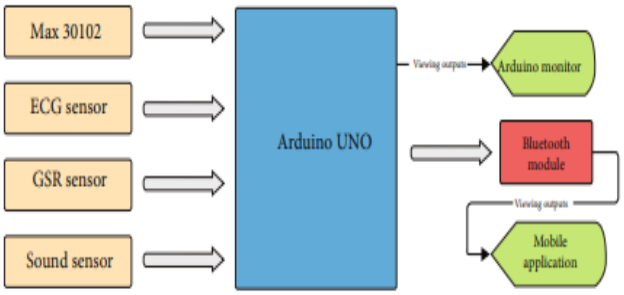
Furthermore, the Home-based PSG system incorporates user-friendly features such as a mobile application interface, accessible through devices like Node MCU. This interface allows patients to easily view and interpret their PSG data, empowering them to take an active role in their sleep health management. Additionally, the system's advanced data analysis capabilities can not only detect the presence of sleep apnea but also assess its severity, providing valuable insights for healthcare professionals to tailor treatment plans accordingly.

II. METHODS AND MATERIALS

Methodology Statements- This section discusses the methods, components and paths that are used to fulfill the goal. The aim of the system is to monitor the entire sleeping

period of a patient with sleeping disorders. This microcontroller-based sleep apnea monitoring system for sleeping disorder patients is combined with three different layers. The main layer is a microcontroller unit which connects the input layer and the output layer. In the input layer, it is combined with four different sensors which will provide the analog signal to the Arduino UNO to measure the different indexes of sleep condition. The output layer is combined with two parts, including the serial monitor of the Arduino UNO and a mobile application to display the digital data converted by the microcontroller.

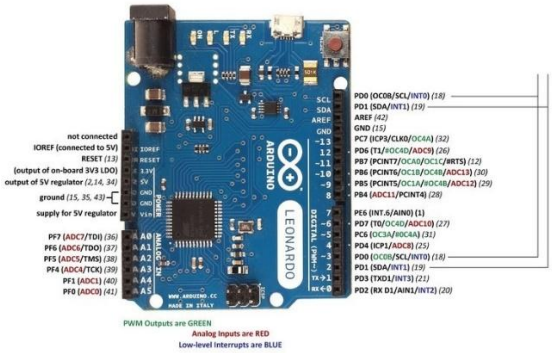
Outline of the System. A block diagram shows the full system in Figure 1. The system consists of input, output, and a microcontroller board Arduino UNO shown in Figure 2. The Arduino board, which is also connected to the output layer, combined with the serial monitor of the Arduino board, and a Massachusetts Institute of Technology (MIT) App Inventor-based mobile application connected to a Bluetooth module show the converted digital data to the viewer. Figure 1 shows the basic workflow of the system. The sensors provide the data to the Arduino UNO simultaneously, and the Arduino UNO passes the converted digital data to the Arduino IDE (Integrated Development Environment)'s serial monitor and also to the mobile application through the Bluetooth module at the same time.



Block Diagram of the System

Modules and Materials. The system is integrated with different kinds of components that are doing different tasks in the system. Some are for the input, some are for the output, and some are used in the system to create a bridge between the inputs and outputs.

Arduino UNO. The Arduino UNO is system's major component, and it is based on the VR Microcontroller Atmega328. This programmable microcontroller has the capacity to connect to other sensors or computers, allowing it to be used in many projects. It has 2 KB of SRAM and 32 KB of flash memory, 13 KB of which is utilized to store the set of instructions in the form of code. It also includes a 1 KB EEPROM. This Arduino board has a total of 30 connections, with 14 digital pins and 6 analog pins for external connection. The A0 to A5 analog pins are used to receive analog data from external devices such as analog sensors. On the board, there are various digital and analog input and output pins that operate at 5 V. These pins have conventional operational current ratings of 20 to 40 milliamps. The DC power jack may provide a voltage ranging from 7 V to 20 V, or the USB connected to an external device can provide a 5 V voltage. Data transmission is the key for IoT devices. To receive, transmit data, and maintain serial communication, two pins called Pin 0 (Rx) and Pin 1 (Tx) work simultaneously. The Rx pin receives data, whereas the Tx pin transmits data. Serial communication can also be done by other input/output (I/O) pins of the board.



Arduino UNO

Sensors. There are several sensors to monitor patient's condition during sleep. To monitor and analyze sleep apnea, the system contains a few sensors that will fulfill the major goals. The heart rate module, SpO2, pulse sensor, ECG sensor, and sound sensor to monitor the snoring sound of the patient during sleep have been used in the system. These five sensors will monitor the patients during sleep and will provide analog data to the Arduino UNO.

MAX30102 Heartrate and SPO2 sensor

Max 30102 Finger Oximeter Heart Rate Module SpO2. The amount of oxygen circulating in the blood is referred to as the blood oxygen level. Oxygen distribution throughout the body is an indicator of detecting a healthy body and an unhealthy body.

Heart Rate Pulse Sensor. Difficulties with breathing and sleep apnea problems are very much related to the heart rate of the patient. The system contains a heart rate pulse sensor to monitor the heart rate of the patient throughout the sleeping period. A high heart rate is one of the major risk factors for sleep apnea. The normal heart rate of a healthy person is in the range of 60-100 beats per minute (bpm).

AD8232 ECG Sensor

AD8232 ECG Sensor. An electrocardiogram, or ECG, is very important in monitoring sleep apnea. An ECG provides information about the heart rate and the rhythm of the heart. It also shows the unusual change in the heart rate. It can provide the state of the heart during the sleeping period, whether there is any kind of enlargement of the heart occurring due to hypertension, and can also detect myocardial infarction.

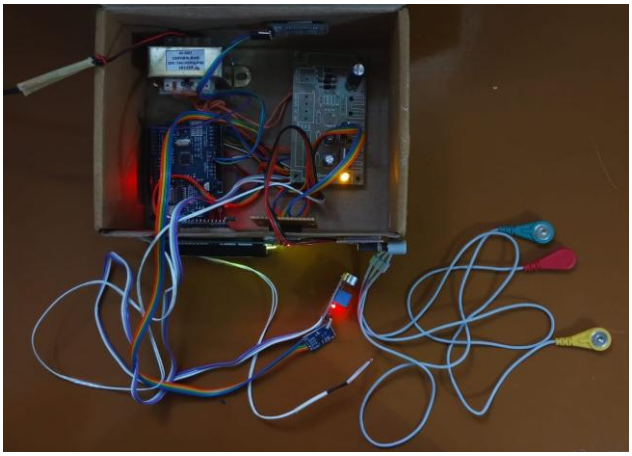
HC-05 Bluetooth Module

Bluetooth Module. Serial communication is the key to this IoT-based paper. For that, the system contains a Bluetooth module HC-05. This Bluetooth module is the gateway between the Arduino Uno and android application. Operated in two moods, this Bluetooth module sends or receives data to another device in one mode, and another mode is working in AT command mode to set device's settings as default. After pairing with the Bluetooth device, the digital data will be visible in the mobile application for the user. Figure 13 shows the pin out of the HC-05 Bluetooth module. The devices operate in a voltage range of 4 V to 6 V and a current of 30 mA. The TX (transmit) and RX (receive) pins of the Bluetooth module operate serial communication. To transmit serial data, the TX pin operates, and the RX pin works to receive data from the microcontroller. The TX pin of the Arduino is connected to the RX pin of the Bluetooth module, and the RX pin of the Arduino is connected to the TX pin of the Bluetooth module. In the system, after pairing with the Bluetooth module, the mobile application, digital data is transmitted to the app from the Arduino.

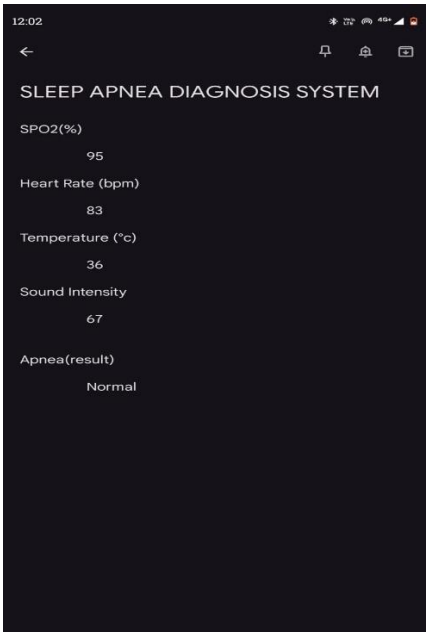
MIT App Inventor 2. This system contains a mobile application to show the real-time data transferred from the Arduino via Bluetooth. This application shows all of the parameters related to sleep apnea continuously. In the system, the name of the application is "sleep apnea monitoring device." This mobile application was created using MIT App Inventor 2 [22]. It allows the user to create an application and also has the functionality to create a gateway between the hardware devices. This mobile application shows the digital data converted by Arduino UNO. To do that, the Bluetooth module HC-05 is connected to the Arduino.

III. DESIGN AND IMPLEMENTATION

Hardware Design. The home-based PSG system offers a groundbreaking solution for monitoring vital parameters during sleep, specifically targeting sleep apnea. Its portable design allows patients to undergo sleep studies at home, enhancing comfort and convenience. Equipped with an array of sensors, the system detects abnormalities in vital parameters such as heart rate, oxygen saturation, and respiratory rate. Through real-time analysis via a mobile application, users receive visual representations of their sleep stages and any detected anomalies, including sleep apnea events.Leveraging advanced signal processing and machine learning, the system accurately identifies patterns indicative of sleep apnea severity, aiding in diagnosis and treatment planning. This innovative approach not only improves patient experience but also provides cost-efficient alternatives to traditional PSG methods. In essence, this system represents a significant advancement in sleep medicine, bridging the gap between clinical accuracy and patient-centered care.



Software design (result). The mobile dashboard output presents a condensed view of the home-based PSG system's data on a mobile device. Users can conveniently access summaries of their sleep stages and vital parameters, along with notifications for any detected anomalies, such as sleep apnea events. The mobile application provides a seamless experience, enabling users to monitor their sleep health on the go and stay informed about their sleep quality.



IV.CONCLUSION

The proposed Home-based PSG system offers a groundbreaking solution for diagnosing and managing sleep apnea. Through portable, battery-powered devices with multiple sensors, patients can undergo monitoring at home, overcoming barriers associated with traditional sleep labs. A user-friendly mobile app interface grants easy access to PSG data, empowering patients to engage in their sleep health management actively. Advanced data analysis not only detects sleep apnea but also evaluates its severity, providing personalized insights for treatment planning. This system aims to enhance patient-centric care in sleep apnea diagnosis and treatment, improving health outcomes and quality of life.

V. SCOPE FOR FUTURE WORK

The Home-based PSG system holds promise for further advancement. Miniaturization efforts can lead to more wearable and comfortable devices, enhancing patient compliance. Integration with emerging technologies like AI and IoT could enable intelligent data analysis and real-time feedback, improving detection accuracy. Longitudinal monitoring and predictive analytics may anticipate sleep apnea episodes, while telemedicine integration can facilitate remote monitoring and timely interventions. Optimizing user experience through mobile app enhancements and community support features can enhance patient engagement.

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