Sleep Disorder Detection Using EEG Signals

Shashank S G[1], S Bharihish sai[2], Sudhakar U[3], Tarun D[4], Mr. Bharath K N[5]
[1,2,3,4]Under Graduate Student, Department of Electronics and Communication, Dayananda Sagar Academy of Technology and Management, Bangalore, Karnataka, India
[5]Assistant Professor, Department of Electronics and Communication, Dayananda Sagar Academy of Technology and Management, Bangalore, Karnataka, India
*Corresponding Author: tarundevraj7@gmail.com

Abstract
Sleep disorders are prevalent health concerns affecting millions of individuals worldwide, with adverse impacts on overall well-being and cognitive function. Detecting and diagnosing these disorders accurately is crucial for effective treatment planning and management. This project focuses on utilizing Electroencephalogram (EEG) signals, a non-invasive method for monitoring brain activity, to detect sleeping disorders. By leveraging advanced signal processing techniques and machine learning algorithms, this research aims to develop a robust and accurate system capable of identifying various types of sleep disorders, such as insomnia, sleep apnea, and narcolepsy, based on EEG data. The proposed approach holds the potential to enhance early detection, personalized treatment strategies, and ultimately improve the quality of life for individuals affected by sleep disorders.
Keywords-Ambulatory EEG, automatic scoring, deep learning, electroencephalography, sleep staging.

I. INTRODUCTION

Millions of people worldwide suffer from sleep disturbances, which are a major public health concern and a contributing factor to several health complications. Effective treatment and management of many conditions depend on the capacity to reliably diagnose and track them. Conventional diagnostic techniques sometimes entail subjective evaluations or pricy overnight polysomnography examinations carried out in medical facilities. But technological developments, especially in the area of biosignal processing, present encouraging prospects for more effective and widely available sleep problem identification.

Sleep-disordered breathing, or SDB, is becoming more and more prevalent. By the time they reach adolescence, 25% of children and at least half of adults over 65 have had disrupted sleep. The most prevalent SDBs identified are Obstructive Sleep Apnea, Central Sleep Apnea, Obesity Hyperventilation, and Upper Airway Resistance. These conditions are characterized by breathing interruptions that might have many causes. For instance, breathing stops because of blocked airways in obstructive sleep apnea, the most prevalent sleep disease. The underlying cause of central sleep apnea, which is more prevalent in heart failure patients, is compromised respiratory and cardiovascular control systems.

Providing the user or patient with the greatest amount of ease during ECG measurements is one of the primary objectives of this project, especially for extended use. The capacity to provide interactive healthcare through the use of contemporary technology and communication is known as wireless technology. When there is no direct communication between the patient and the physician, the telemetry system is helpful. The wireless gadget used in the effective remote monitoring system provides accurate, continuous, and real-time data on the heart status of the patient. In this project, we will create a wireless ECG sensor and wirelessly show the sensor's output on a computer screen.

Willem Einthoven created the ECG technique in the early 1900s. One technique for determining the electrical activity of the heart is the electrocardiogram (ECG). The left atrium, right atrium, left ventricle, and right ventricle are the four chambers that make up the human heart. The inferior and superior vena cava are the two main veins that allow blood to enter the human heart. Through veins, the body's oxygen-poor blood is transferred into the right atrium. This blood is oxygen-poor and is sent to the right ventricle, which forces it into the lung. The "Gas Exchange" process in the lungs uses blood that is low in oxygen. The blood is now supplemented with oxygen.

IOT platforms, however, are not widely employed for sleep monitoring these days. Although the healthcare industry is sluggish to adapt, new technologies are developing quickly. The device's ease of use in conjunction with data quality, dependability, and utility are impeding the wider adoption of these technologies. The two primary phases of an ECG are depolarization and repolarization. Repolarization is the mechanical relaxation of the heart chamber, whereas depolarization is the mechanical contraction of the heart chamber, such as the ventricle or atrium.

This project focuses on developing a non-invasive and affordable system for diagnosing different types of sleep disorders by utilizing electroencephalography (EEG) signals, which offer important insights into brain activity during sleep. The electrical activity of the brain is recorded by EEG signals, which make it possible to identify irregularities, sleep disturbances, and various stages of sleep. Our method attempts to provide rapid and accurate detection of sleep disturbances, enabling early intervention and customized treatment strategies by evaluating these signals in real-time.

To collect thorough information on sleep patterns and disruptions, the suggested methodology combines EEG sensors with extra physiological and environmental sensors, such as accelerometers, sound sensors, and heart rate monitors. The central processing unit gathers, processes, and analyzes data from these sensors using an Arduino-based platform. In order to identify patterns suggestive of various sleep disorders such as insomnia, sleep apnea, restless leg syndrome, and parasomnias, machine learning algorithms are utilized.

Our approach's capability for remote monitoring and intervention is one of its main benefits. The Global System for Mobile Communications, or GSM, modules are integrated into When substantial anomalies are found, the system may instantly notify caretakers or medical experts, allowing for prompt assistance and response. Feedback devices like buzzers and vibrators can also be used to gently wake people up during sleep disturbances, enhancing both the quality of their sleep and their general wellbeing. In conclusion, the goal of this research is to use modern biosignal processing techniques and EEG signals to detect sleep disorders, which is an increasing need for accessible and effective solutions. Our goal is to enable people to take proactive measures toward improved sleep health and quality of life by utilizing technology.

II. OVERVIEW

Sleep disorders, which impact sleep quality, timing, and duration, can significantly impair daytime functioning and overall health. Common disorders include insomnia, sleep apnea, narcolepsy, restless leg syndrome (RLS), and parasomnias. Electroencephalography (EEG) is a pivotal tool in diagnosing these conditions as it records the brain's electrical activity. In sleep studies, EEG helps monitor various sleep stages—wakefulness, NREM (Non-Rapid Eye Movement) sleep, and REM (Rapid Eye Movement) sleep—by detecting characteristic brain wave patterns. For instance, insomnia often shows increased beta activity and reduced sleep spindles, indicating heightened arousal. Sleep apnea is identified by high-frequency EEG bursts following apneic events, he Multiple Sleep Latency Test (MSLT), where early onset of REM sleep is a key indicator. RLS is associated with frequent micro-arousals due to periodic limb movements. In parasomnias, such as sleepwalking, EEG can capture abnormal brain activity during transitions between sleep stages. Thus, EEG is essential in detecting and understanding sleep disorders, facilitating accurate diagnosis and effective treatment.

III. LITERATURE SURVEY

[1] The paper explores various studies that utilize EEG signals for sleep staging, highlighting the challenges associated with traditional manual scoring methods and the potential of deep learning algorithms in addressing these challenges. It discusses the evolution of deep learning architectures and their successful application in diverse domains, emphasizing their suitability for processing complex time-series data like EEG signals. The survey also examines different approaches for feature extraction and classification in sleep staging tasks, emphasizing the advantages of end-to-end learning frameworks enabled by deep neural networks. Through this extensive review, the paper provides valuable insights into the state-of-the-art methodologies, promising avenues for future research, and the potential impact of deep learning in advancing automatic sleep staging techniques using ambulatory EEG data.[2] This paper acts as a comprehensive handbook for the standardized assessment of sleep stages and their associated occurrences. This manual holds a pivotal position in ensuring uniformity and dependability in interpreting sleep studies, thus aiding in precise diagnosis and treatment of sleep disorders. With meticulous attention to detail and adherence to established scoring standards, it furnishes healthcare providers and researchers with a consistent framework for evaluating sleep patterns and detecting deviations. Its wide acceptance underscores its importance in the realm of sleep medicine, steering clinical practices and research pursuits aimed at enhancing our comprehension and management of sleep-related ailments. Serving as a cornerstone in sleep scoring methodology, this manual continues to shape the terrain of sleep medicine, serving as an indispensable resource for professionals and scholars alike. [3] This research delves into the reliability of EEG measurements over consecutive nights, aiming to ascertain their utility as indicators of sleep quality and stability. By analyzing EEG data collected from a cohort of participants, the authors assess the accuracy and night-to-night fluctuation of frontopolar EEG biomarkers. Their findings shed light on the efficacy of these biomarkers in reliably capturing sleep related phenomena and underscore the importance of considering variability and stability in EEG-based sleep assessments. Through meticulous examination and statistical analysis, the study contributes valuable insights to the field of sleep medicine, informing future research endeavors and clinical practices aimed at utilizing EEG biomarkers for assessing sleep architecture and identifying potential abnormalities.[4] It mainly explores the efficacy of a novel portable wireless sleep monitor as a substitute for traditional polysomnography (PSG). Their research endeavors to ascertain the device's accuracy and reliability in tracking various sleep parameters, such as sleep stages and respiratory events, compared to PSG. Through meticulous experimentation and data analysis, the authors offer valuable insights into the potential of portable wireless sleep monitors in both clinical and research contexts. By highlighting the feasibility and utility of these monitors as PSG alternatives, their findings pave the way for advancements in sleep diagnostics and management. This study contributes significantly to the ongoing exploration of innovative technologies for sleep monitoring, signaling promising avenues for improving sleep assessment practices. [5] At least 50% of the world's elderly population, whose range is fast growing, experience disturbed sleep. Sleep studies have become an extensive approach serving as a diagnostic tool for healthcare professionals. Currently, the gold-standard is Polysomnography (PSG) recorded in a sleep laboratory. However, it is obtrusive, requires qualified technicians, and is time and cost expensive. With the introduction of commercial off-the-shelf technologies in the medical field, alternatives to the conventional methods have been conceived to ensure sleep stages and sleep quality detection which may be now used at home on several nights. Cardio-respiratory and physical activities abide the most promising physiological measurements to detect sleep stages without complete PSG. The statistically proven impacts and budgets related to sleep disorders are phenomenal, showing that the field needs more research. This paper aims at providing the reader with a multidimensional research perspective by presenting a review of research literature on developments made in unobtrusive sleep assessment. Additionally, a categorization of current approaches is presented based on methodological considerations, from data acquisition frameworks and physiological measurements, to information processing. [6] Sleep is associated with important changes in respiratory rate and ventilation. Currently, breathing rate

(BR) is measured during sleep using an array of contact and wearable sensors, including airflow sensors and respiratory belts; there is need for a simplified and more comfortable approach to monitor respiration. Here, we present a new method for BR evaluation during sleep using a non-contact microphone. The basic idea behind this approach is that during sleep the upper airway becomes narrower due to muscle relaxation, which leads to louder breathing sounds that can be captured via ambient microphone. In this study we developed a signal processing algorithm that emphasizes breathing sounds, extracts breathing-related features, and estimates BR during sleep.[7] This paper proposes to improve the breathing disorder-sleep apnea automatic adjustment mechanism, called Breathe Regulator (BR), which uses micro-control and sensor with being supplied by feedback control. The BR is made to adjust the tightness of snoring belt mechanism. First, the used temperature, humidity and dioxide carbon sensors detect patients' respiratory status. And then the detection status is feedback to the micro-controller to adjust and controls the torque motor snoring belt tightness. This BR improved the disadvantages of the traditional methods such as the snoring but not automatically and to adjust the tightness of the situation caused by nasal congestion and the patients unable to breathe.[8] The device consists of two simple sensors; a thermistor placed close to the nose, which detects the changing in airflow during breathing, and a galvanic skin response (GSR) sensor, which measures the conductivity of the skin. The information is extracted by a low power microcontroller, which calculates RR, TA and the activation of the SNA. The information is collected by a smartphone using the low energy Bluetooth feature to guarantee a long lifetime to the device that uses a small coin battery. Different algorithms are described to minimize the payload on the connection, and therefore power consumption too. The amount memory used to store data on the smartphone is approximately 0.01% compared to a continuous recording.

IV. METHODOLOGY

1. Data Acquisition and Preprocessing:

The first step involves acquiring EEG signals using a brainwave sensor connected to an Arduino board via Bluetooth. The brainwave sensor records electrical activity from the scalp, capturing brainwave patterns during sleep. The Arduino board acts as an intermediary, receiving these signals and transmitting them to a connected computer for preprocessing. Preprocessing includes filtering to remove noise and artifacts, such as muscle movements or environmental interference, which can affect the accuracy of sleep apnea detection. Additionally, data segmentation is performed to isolate individual sleep cycles for analysis.

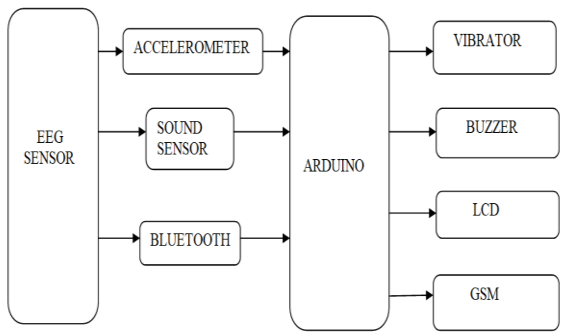

Fig 1: Block Diagram of proposed Methodology

2. Feature Extraction and Classification:

After preprocessing, relevant features are extracted from the EEG signals to characterize sleep patterns associated with sleep apnea. Features may include spectral power densities, coherence measures, or statistical parameters derived from the EEG signal. These features serve as input to a classification algorithm, which distinguishes between normal sleep and sleep apnea events. Machine learning techniques, such as support vector machines (SVM) or artificial neural networks (ANN), are commonly employed for classification. The algorithm is trained using labeled data to learn patterns indicative of sleep apnea and optimize detection accuracy.

3. Real-time Monitoring and Alert System:

The classified EEG data is continuously monitored in real-time to detect instances of sleep apnea during sleep. A LCD display connected to the Arduino board provides real-time visualization of the brainwave values and sleep apnea detection status, allowing users to monitor their sleep patterns conveniently. In the event of a detected sleep apnea episode, an alert system is triggered to notify the user and potential caregivers. This alert system utilizes a GSM module integrated with the Arduino board to send emergency notifications via SMS or call to predefined contacts. Additionally, a buzzer connected to the Arduino board emits audible alerts to awaken the user and prompt corrective actions, such as changing sleep position or seeking medical assistance.

4. Evaluation and Validation:

The performance of the EEG-based sleep apnea detection system is evaluated through comprehensive validation studies. These studies assess the accuracy, sensitivity, and specificity of the system in detecting sleep apnea events compared to established diagnostic standards, such as polysomnography (PSG). Performance metrics, including receiver operating characteristic (ROC) curves and confusion matrices, are calculated to quantify the system's diagnostic capabilities. Furthermore, user feedback and usability assessments are conducted to evaluate the practicality and acceptance of the system in real-world settings. Continuous refinement and optimization of the system are performed based on feedback and validation results to enhance its reliability and effectiveness for sleep apnea detection.

5.Software requirements

Software Development Environment:

The Arduino is a single-board microcontroller, intended to make the application of interactive objects or environments more accessible. The hardware consists of an open- source hardware board designed around an 8-bit Atmel AVR microcontroller or a 32-bit Atmel ARM. Current models feature a USB interface, 6 analog input pins, as well as 14 digital I/O pins which allow the user to attach various extension boards. Introduced in 2005, at the Interaction Design Institute Ivrea, in Ivrea, Italy, it was designed to give students an inexpensive and easy way to program interactive objects. It comes with a simple Integrated Development Environment (IDE) that runs on regular personal computers and allows writing programs for Arduino using a combination of simple Java and C or C++.

The Arduino Integrated Development Environment (IDE) is a cross platform application written in Java, and is derived from the IDE for the processing programming language and the wiring projects. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as Syntax highlighting, Brace matching and Automatic Indentation, and is also capable of compiling and uploading programs to the board with a single click.

V. IMPLEMENTATION

Detecting sleep apnea using EEG (Electroencephalography) involves several components working in tandem to monitor brainwave activity and alert users in case of abnormalities. The system incorporates Bluetooth-based connectivity between an Arduino microcontroller and a brainwave sensor for real-time data acquisition. The Arduino serves as the central processing unit, receiving EEG data from the sensor and analyzing it for patterns indicative of sleep apnea.

The brainwave sensor records electrical activity in the brain, providing valuable data on sleep stages and identifying potential instances of apnea. Through Bluetooth connectivity, this data is transmitted wirelessly to the Arduino for processing. The Arduino then interprets the EEG signals, employing algorithms to detect irregularities associated with sleep disturbances such as apnea episodes.

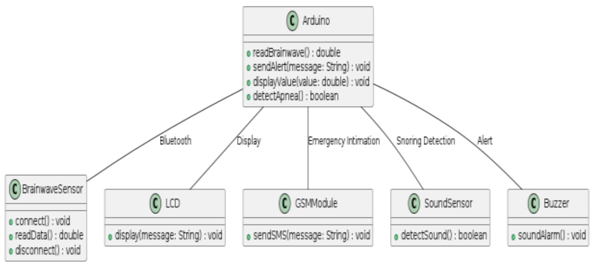

Fig 2: Implementation of system

To provide users with immediate feedback, an LCD display is integrated into the system, showing real-time brainwave values and any detected anomalies. This display offers users insight into their sleep patterns and alerts them to potential issues that may require further attention. In the event of a significant apnea episode, timely intervention is crucial. Hence, a GSM module is incorporated into the system to enable emergency intimation. Upon detecting a severe apnea event, the Arduino triggers the GSM module to send an alert message to predefined contacts, notifying them of the situation and prompting appropriate action. Additionally, to ensure immediate awareness and response, a buzzer is integrated into the system for audible alerts. When an apnea episode is detected, the buzzer emits a distinct sound, alerting the user and prompting them to take necessary measures, such as adjusting their sleeping position or seeking medical assistance if required. By combining EEG monitoring with Bluetooth connectivity, real-time data display, GSM-based emergency notification, and audible alerts, this system offers a comprehensive approach to sleep apnea detection and management, enhancing user awareness and facilitating timely intervention to mitigate potential risks associated with this sleep disorder.

VI. APPLICATIONS

The application of EEG signals in sleep disorder detection is multifaceted, spanning clinical, research, technological, and public health domains. Clinically, EEG is essential for accurate diagnosis and personalized treatment planning, enabling healthcare providers to identify specific disorders like insomnia, sleep apnea, narcolepsy, restless leg syndrome, and parasomnias by analyzing brain wave patterns. This precision allows for tailored interventions, such as cognitive-behavioral therapy for insomnia or CPAP therapy for sleep apnea. In research, EEG aids in understanding sleep architecture and evaluating treatment efficacy by providing detailed insights into sleep stages and their impact on health. Technological advancements have led to the development of wearable EEG devices for real-time, long-term sleep monitoring and automated systems that use machine learning to analyze EEG data, enhancing diagnostic accuracy and efficiency. Public health initiatives benefit from EEG-based screening programs for early detection of sleep disorders in at-risk populations, while educational tools using EEG data help individuals understand and improve their sleep quality. Thus, EEG is a crucial tool in the detection, understanding, and management of sleep disorders across various applications.

VII. CONCLUSION AND FUTURE SCOPE

EEG signals play a critical role in the detection and management of sleep disorders. By providing detailed insights into brain activity during different sleep stages, EEG enables accurate diagnosis and personalized treatment for conditions like insomnia, sleep apnea, narcolepsy, restless leg syndrome, and parasomnias. Its application extends beyond clinical settings to research, technological innovation, and public health, offering a comprehensive approach to understanding and addressing sleep disorders. The integration of EEG in sleep studies has significantly advanced our knowledge of sleep architecture and the impact of various disorders, leading to improved treatment outcomes and overall health.

The future scope of sleep disorder detection using EEG signals is vast and promising. Advancements in EEG technology will likely lead to more comfortable and accessible wearable devices for continuous, long-term monitoring, enhancing data accuracy and patient compliance. Artificial intelligence and machine learning will revolutionize the analysis of EEG data, enabling sophisticated, automated detection of sleep disorders, thereby increasing diagnostic speed and accuracy. Integration of EEG with other biometric data, such as heart rate and oxygen saturation, will provide a comprehensive assessment of sleep health, while the expansion of telemedicine will facilitate remote diagnosis and management, making sleep studies more accessible and reducing the need for hospital visits. Personalized medicine approaches will tailor treatments to individual genetic makeups and specific sleep patterns, enhancing intervention effectiveness. Additionally, large-scale public health initiatives utilizing EEG could identify sleep disorders in broader populations, especially in underserved areas, promoting early detection and intervention and improving overall public health outcomes.

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