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doi:10.15199/48.2024.07.13:

Sleep Disorder Monitoring System Using the Internet for Healthcare Applications

Abstract. *Sleep is an indispensable requirement for health, which will refresh a person's body and mind. Sleep quality is essential for a person's lifestyle, eradicating various health complications. Sleep disorder is a significant complication for most people for a more extended period. During sleep time, many people used to die due to abnormal changes in the human body. In this regard, a system for tracking sleep disorders is highly required. Hence, monitoring sleep in real-time is the only way to detect sleep disorders. This paper proposes a sleep disorder monitoring (SDM) system using IoT on a time basis constructed with a Raspberry Pi controller. Various types of sensors are involved in this system to measure parameters such as heart rate, electrocardiogram (ECG), oxygen level, and snoring sound of a person. These measurements are carried out without disturbing that person's sleep. The results are forwarded to a mobile application utilizing a wifi module and displayed on an LCD screen connected to the controller. Moreover, this paper gives an idea about sleep disorders and aids people in detection and prevention.*

Streszczenie. *Sen jest niezbędnym warunkiem zdrowia, który odświeża ciało i umysł człowieka. Jakość snu ma zasadnicze znaczenie dla stylu życia danej osoby, eliminując różne komplikacje zdrowotne. Zaburzenia snu są dla większości ludzi poważnym powikłaniem utrzymującym się przez dłuższy czas. W czasie snu wiele osób umierało z powodu nieprawidłowych zmian w organizmie człowieka. W związku z tym niezwykle potrzebny jest system śledzenia zaburzeń snu. Dlatego monitorowanie snu w czasie rzeczywistym jest jedynym sposobem na wykrycie zaburzeń snu. W artykule zaproponowano system monitorowania zaburzeń snu (SDM) wykorzystujący technologię IoT w trybie czasowym, zbudowany w oparciu o kontroler Raspberry Pi. W systemie tym wykorzystywane są różne typy czujników, które mierzą takie parametry, jak tętno, elektrokardiogram (EKG), poziom tlenu i odgłos chrapania. Pomiary te przeprowadzane są bez zakłócania snu danej osoby. Wyniki przekazywane są do aplikacji mobilnej wykorzystującej moduł Wi-Fi i wyświetlane na ekranie LCD podłączonym do kontrolera. Ponadto artykuł ten daje wyobrażenie o zaburzeniach snu oraz pomaga w ich wykrywaniu i zapobieganiu.* (***System monitorowania zaburzeń snu wykorzystujący Internet do zastosowań w służbie zdrowia***)

Keywords: sleep, IoT, ECG, Raspberry Pi, SDM
Słowa kluczowe: sewn IoT, ECG, Raspberry Pi, SDM

Introduction

Sleep disorder is directly connected to the respiratory system and brain of humans. It shows an abnormality in the process of breathing during sleep. Two types of sleep disorders are obstructive disorder and central disorder. Both diseases can happen simultaneously, which is called a complex sleep disorder. Obstructive sleep disorder is connected with upper congestion in the airway. It occurs due to throat muscle relaxation and less oxygen through the throat passage. This will lead to breathing irritation and intensive complications. The central sleep disorder is more dangerous when compared to the former disease. It happens when the brain fails to forward appropriate instructions for controlling the breathing process [1]. This will stop the breathing process for up to 10 seconds. Both disorders can occur infrequently, creating an emergency treatment situation [2]. The system is to implement sleep disorder monitoring for healthcare applications using the concept of IoT.

Related Works:

Sleep disorders are very much responsible for various health complications such as high blood pressure, depression, stroke, cardiac problems, etc [3]. Around 7 % of men and 5% of women suffer from sleep disorders, according to a survey. This information affects a hundred million people worldwide, and 80 % of these cases are undiagnosed [4]. It also affects 4 % of the children of different ages with snoring. This variation reflects other parameters with persons affected and unaffected [5]. Various factors, such as obesity, consumption of alcohol, smoking habits, blood pressure, diabetes, etc, are related to this sleep disorder in the form of identification. Central sleep disorder has a high impact on patients who have Parkinson's and strokes. Research says that sleep disorder creates cardiovascular diseases, thereby leading to 20 % of road accidents and costing several lives [6]. The heart-related parameters concerning sleep disorders are heart rate, oxygen level, sleeping time, blood sugar, and cholesterol [7]. In some instances, wearable sensors gather factual time information on sleeping habits and respiration processes [8]. A similar approach is also followed in operation theatres with the signals gained from sensor-dependent mattresses [9]. Various sensors and techniques and peripheral arterial tonometry (PET) are used to detect sleep disorders [10]. In other situations, sophisticated devices record the finger pulse waveforms and check the muscle movements for the detection mechanism [11]. A detection methodology accurately measures sound with high frequencies [12]. An android-based pulse observing system is developed for the measurement of the heart rate of a human being using a single sensor [13]. The results from an SVM-based model system are evaluated with IoT by providing appropriate ECG data from the user [14, 15]. Researchers detect sleep disorders using machine learning techniques [16, 17].

Proposed the SDM System

The system aims to observe the complete sleeping time of humans suffering from sleeping disorders. Figure 1 indicates the outline of the system. The sensors in the system inform Raspberry Controller all simultaneously, and the controller forwards digital data (converted format) both to an LCD Display and to a mobile application employing cloud computing.

Raspberry Pi is almost a minicomputer that can be interfaced with input/output devices such as a keyboard, monitor, scanner, etc. The total arrangement involving the Raspberry controller can be converted into a PC with all features at a meager cost, as shown in the block diagram in Figure 1.

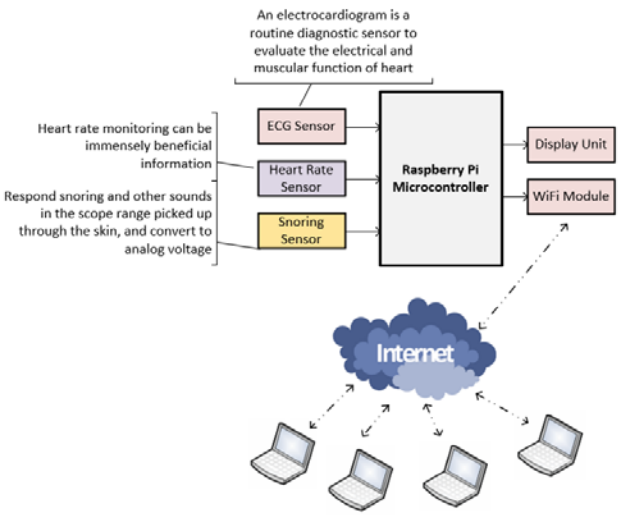

Fig 1. Block diagram of the proposed SDM system

The Raspberry Pi 4 model is employed in the system, which provides the user with a broad range of facilities such as HDMI, RAM with a capacity of 1GB, Ethernet, Bluetooth, and wifi, as shown in Figure 2. The critical feature of this model controller is low power dissipation and consumption. Different sensors are employed in the system to observe the conditions of a patient during sleep time. Sensors used to monitor heart rate, pulse rate, level of oxygen, ECG, and sound are interfaced with the controller. These sensors will monitor patients and send data to the controller.

Fig 2. Raspberry Pi 4 Model

Generally, sleep disorders are correlated with a person's heart rate. A heart rate sensor is used in the system to observe heart rate during sleeping intervals. Generally, the regular heart rate of a healthy person will be between 60 and 100 beats per minute. This value will differ among various persons. Active people may have lower heart rates when compared to other persons. The abnormal and higher value in the heart rate is an essential symptom of sleep disorders. Generally, the heart rate will be much lower during sleep compared to other times of the day. Higher and lower heart rates may occur because of hypertension and a shortage of oxygen in physique. Both are usual signs of sleep disorders. The heart rate sensor is shown in Figure 3. Specifications of this component are 5V and 3.5 mA, respectively.

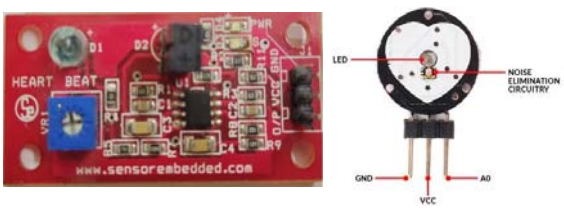

Fig. 3 Heart rate sensor module

The oxygen level indicates the quantity of oxygen circulating in the blood. This distribution of oxygen shows the healthiness of a human being. It also marks the uniform distribution of oxygen from the lungs to cells. Complications in the lungs are one of the vital reasons for low levels of oxygen in the body. Another reason is irregularity in the process of breathing. The oxygen saturation of a healthy person and a person with a sleep disorder will be 95% minimum and around 90% maximum, respectively. A pulse oximeter comprising a sensor is used in the system to measure the oxygen level, as shown in Figure 5. This sensor can measure the value of SpO2 by connecting it to a person's fingertip. The specifications of this sensor are 3.4 V to 5 V.

ECG is an indispensable parameter for tracking sleep disorders, giving information about heart rhythm. It also indicates abnormal variations in the heart rate. It shows the heart state during sleeping time and signs the complication of hypertension, which may lead to enlargement in the size of the heart. This parameter also differs from person to person. Generally, a healthy person will have a stable form of ECG compared to an inactive person. Figure 4 shows the ECG sensor for monitoring.

Fig. 4 ECG sensors

Fig. 5 Sound sensor

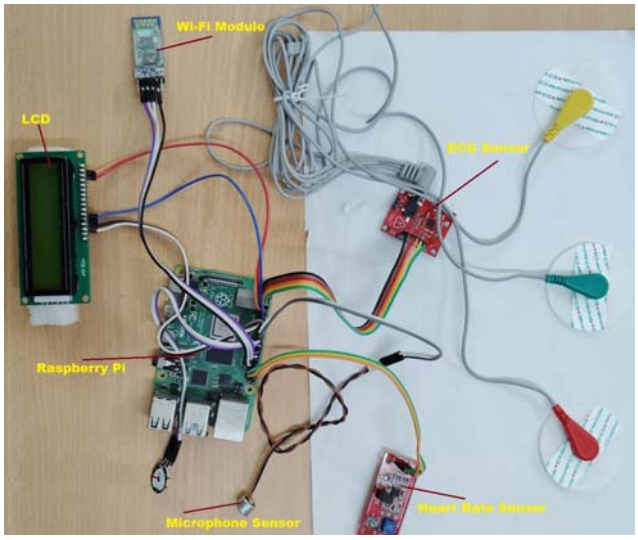

Fig. 6 The SDM system test board circuit

Snoring is another important symptom of sleep disorders. It shows complications in breathing. Snoring sound intensity can be measured using a sound sensor during sleeping. The sensor includes a microphone and relevant circuitry for converting sound signals to electrical signals. The sound sensor is shown in Figure 6. The Raspberry Controller consists of a wifi module by which communication can be established with an Android application. Once the wifi module is synchronized with the mobile application, information will be available in the Android application for the user. The wifi module becomes the gateway between the controller and the Android application. Figure 5 shows a flowchart for a complete monitoring system.

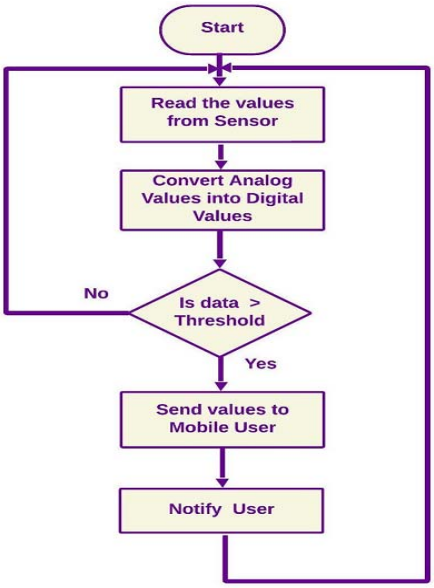

Fig. 7 Flowchart of the proposed SDM system

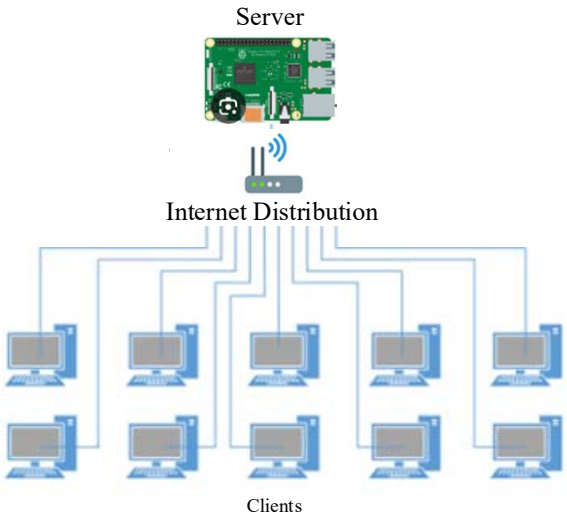

Fig. 8 Server network connecting to other end device nodes

The server installation is by the overall design of the wireless network of the sleep disorder monitoring system. The developer has designed the server installation regarding hardware and applications used in server networking development. The server network installation through the Internet of Things platform can be installed using an Ethernet cable connected directly to the switch, and there must be a single distribution device so that client machines can connect to the server, as shown in Figure 8.

The Results and Discussions

The system examined people from different age groups with additional health complications to detect sleep disorders. The previous medical information and history of diseases may also lead to sleep disorder problems. The system examined the patients and gave results concerning all relevant parameters, which can be viewed in the Android application. The complete arrangement of the system includes a Raspberry controller integrated with all applicable sensors and mobile applications. The resultant values appear both on LCD and in Android applications. The system executes to monitor sleep disorders successfully. Figure 8 shows the system prototype, and

Figure 9 indicates the mobile application. This can be worn in an effortless manner that does not disturb the patient's sleep under all circumstances.

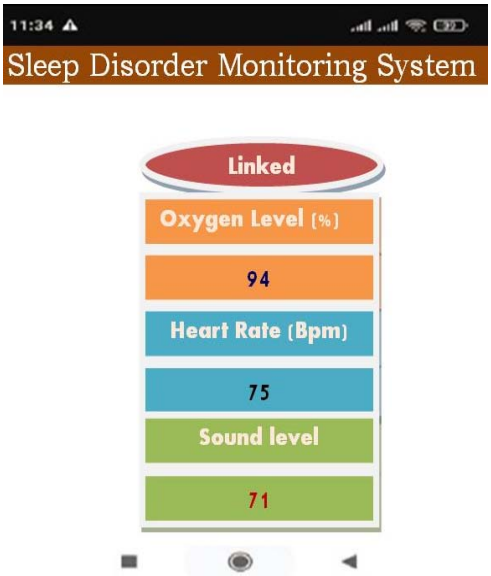

Fig. 9 The output display of the SDM system

Figure 9 shows the parameters of the sleep disorder monitoring system, which consists of oxygen level, heart rate, and sound level. The sampling of the heart rate sub-system of sleep disorder monitoring is shown in Figure 10.

Figure 10. The samples of heart rate monitoring of each node

The proposed monitoring can continuously detect people's heart or pulse rates. The importance of the proposed device, which will be developed in future work, is to make the prototype more compact and wearable use for the patient. Moreover, it is highly accurate because this device is a valuable tool in monitoring people's health.

Conclusions

This paper enunciated the application of IoT-based systems for effectively monitoring sleep disorders. This system uses a Raspberry controller integrated with relevant sensors and an Android application for viewing. The measurement parameters are heart rate, level of oxygen, ECG, and snoring sound of a patient. Nearly five persons are subjected to examination for analysis, and this system provides optimum results for arriving at decisions on sleep disorders. This monitoring method will aid ordinary people in detecting sleep disorders in an early situation. Moreover, it will also help them eliminate their sleeping complications. Other Sensors, such as humidity and temperature sensors, can be included as future enhancements even though these parameters have a minor impact on sleeping disorders.

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