IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

DEVELOPMENT OF AN IOT-BASED SLEEP APNEA MONITORING SYSTEM FOR HEALTHCARE OPERATION

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ABSTRACT

Sleep apnoea syndrome is one of the most common sleep disorders which affects around one out of every 100 people. There is some evidence that sleep apnoea may be linked to hypertension, strokes and heart attacks. The aim of this work is to develop a wearable biomedical system for the continuous and real-time monitoring of the sleep apnoea disease at home. Embedded in a comfortable glove, the proposed wearable device acquires the photople thysmographic (PPG) signal coming from a standard SpO wrapped sensor placed in one of the fingers. Real-time heart rate variability analysis is performed from NN intervals measured in the PPG signal in order to activate an alarm if the number of sleep apnoea events cross a guard level. Through a radio frequency link in the ISM band, the glove communicates with an Internet gateway connected with a remote station for continuous data analysis, monitoring and alarm catch.

Keywords: IoT-Based Sleep Apnea, Oxygen Saturation and ISM band

1. INTRODUCTION

We propose an unobtrusive, wearable, and wireless system for the pre-screening and follow-up in the domestic environment of specific sleep-related breathing disorders. This group of diseases manifests with episodes of apnea and hypopnea of central or obstructive origin, and it can be disabling, with several drawbacks that interfere in the daily patient life. The gold standard for their diagnosis and grading is polysomnography, which is a time-consuming, scarcely available test with many wired electrodes disseminated on the body, requiring hospitalization and long waiting times. It is limited by the night-by-night variability of sleep disorders, while inevitably causing sleep alteration and fragmentation itself. For these reasons, only a small percentage of patients achieve a definitive diagnosis and are followed-up. Our device integrates photo plethysmography, an accelerometer, a microcontroller, and a bluetooth transmission unit. It acquires data during the whole night and transmits to a PC for off-line processing. It is positioned on the nasal septum and detects apnea episodes using the modulation of the photo plethysmography signal during the breath. In those time intervals where the photo plethysmography is detecting an apnea, the accelerometer discriminates obstructive from central type thanks to its excellent sensitivity to thoraco-abdominal movements. Tests were performed on a hospitalized patient wearing our integrated system and the type III home sleep apnea testing recommended by The American Academy of Sleep Medicine. Results are encouraging: sensitivity and precision around 90% were achieved in detecting more than 500 apnea episodes. Least thoraco-abdominal movements and body position were successfully classified in lying down control subjects, paving the way toward apnea type classification. In the last decades, the development of microelectronics was powered by Moore's law, with the focus on integrated circuit densification and aggressive bit integration. However, as of today, the interest is parallelly growing toward the "more than

Moore" paradigm, which is based on the integration of Complementary Metal Oxide Semiconductor (CMOS) technology, radiofrequency (RF) analog and power supply circuits, and a variety of miniaturized sensors in the same chip. In the specific area of medicine, this trend gave birth to the "Health 4.0" revolution, which is characterized by the adoption of electronics components (preferentially wearable and/or implantable) and Information Communication Technology (ICT) to assist medical diagnoses directly from the domestic environment, further promoting the strategy of telemedicine [1–6]. The research in this field is skyrocketing thanks to the enormous benefits that the synergy between ICT and medicine can provide, together with the removal of distances and barriers between patient and doctors and with the adoption of remote data analysis. These benefits span from reduced time spent in hospital, with consequent reduction of costs and optimized personnel employment, to long monitoring times in free-living conditions, thus improving the patient life quality [7]. There are already many examples of this revolutionary synergy on the market, such as shoes with footbeds for gait analysis [8], fall assessment patches [9], body area networks for postural sway evaluation [10], as well as active devices as the diabetes customizable pump, approved by The Food and Drug Administration (FDA) in 2019 [11–13]. Wearable electrocardiogram (ECG) and blood pressure monitors are integrated in commercial products such as smart health watches, and they are used for self-monitoring and self-empowerment, which are other key points of Health 4.0 [14,15]. All these devices allow for a more precise diagnosis and customization of the therapy. For all these reasons, telemedicine is considered one of the key components for improving the health and wellness of the population in the next few years [7]

In this work, we focused on a group of pathologies named sleep-related breathing disorders (SRBD), which are characterized by recurrent episodes of pause (apneas) or reduction (hypopneas) of breathing during sleep that last at least 10 s. In the first case, we have an absence or a 90% reduction of the airflow; in the second case, the airflow is reduced by 30% and is associated with a 3% oxygen desaturation in blood or an arousal (alternatively, a 30% reduction with 4% desaturation) [16]. There are five types of sleep-related breathing disorders, according to the third edition of International Classification of Sleep Disorders: the most common is obstructive sleep apnea (OSA), which consists in a physical obstruction of the upper airways; the second type, central sleep apnea (CSA) syndromes, are due to a transient loss of neural output to the respiratory muscles; sleep-related hypoventilation disorders; sleep-related hypoxemia disorder; isolated symptoms; and normal variants [17]. Apneas could be of obstructive or central origin. A third type of apnea, called mixed, is a combination of the first two: the apnea starts as central and then becomes obstructive. OSA affects 1% to 6% of adults and 2% of children. The most common predisposing factor is obesity [18]. Other risk factors are features that can narrow airways and decrease muscle tone, such as anatomical abnormalities (micrognathia, hypertrophy of uvula and soft palate, macroglossia) or functional factors (drugs and alcohol) [19]. A particular type of sleep apnea, called positional OSA, manifests only in a specific sleeping position, usually the supine one. CSA affects less than 1% of subjects [20] and is characterized, in contrast to OSA, by apneas and hypopneas without thoracic and abdominal effort. The most relevant risk factors for central sleep breathing disorders are cardiovascular disease (CVD) and the chronic use of opiods. People who suffer from SRBD, especially OSA, complain of restless sleep, excessive daytime sleepiness, cognitive deficit, and daytime sleep attacks. This may bring to a major risk of driving or work-related accidents. Moreover, OSA is associated with CVD: if not properly treated, people suffering from OSA are more exposed to systemic arterial hypertension, myocardial is chaemia, and cerebrovascular diseases. Even sudden cardiac death could occur in the case of a severe pathology [18,21]. OSA and CSA are two distinct pathologies characterized by different therapeuthic strategies, so classifying the type of apnea is fundamental for diseases management. The most used intervention for OSA is the continuous positive airway pressure (CPAP), which opens the collapsed airways and guarantees their patency. Surgery can be a solution in case of anatomical anomalies [19,22]. For people affected by CSA, therapeuthic options are nocturnal supplemental oxygen, adaptive servo-ventilation, bilevel positive airway pressure (BPAP), and acetazolamide. The diagnosis of SRBD is still a challenge [23]. Up to date, the gold standard to diagnose SRBD is the attended polysomnography (PSG), which consists in recording signals during the night in a sleep laboratory to recognize sleep stages, monitor cardiac activity, and respiratory function [24]. It determines the severity of the disease and evaluates all the sleep disorders [16]. PSG suffers from some limitations that restrain its use.

The internet of things is a rapidly growing field that provides easy access and aids in the simplified operation of various things connected to the internet. IoT is now used vastly in the medical and health care systems. Data collection analysis and monitoring of data can be done with ease using IoT. Obstructive sleep apnea (OSA) is a type of sleep apnea that is becoming the most common respiratory disease. The cessations in breathing must last more than 10 seconds to be considered an apnea event. Apnea is a life-threatening disease [1]. Sleep apnea episodes may occur 5 to 30 times an hour and may occur even up to four hundred times per night for those who suffer severe Sleep apnea, it usually occurs when the patient's upper airway is blocked either partially or even sometimes completely and this sleep disorder is also characterized by continuous reduction of airflow. Sleep Apnea Monitoring System using IoT and Arduino

2. LITERATURE SURVEY

DEVELOPMENT OF AN IOT-BASED SLEEP APNEA MONITORING SYSTEM FOR HEALTHCARE APPLICATIONS - ABDUR RAB DHRUBA,1KAZI NABIUL ALAM,1MD SHAKIB KHAN,1SAMI BOUROUIS,2AND MOHAMMAD MONIRUJJAMAN KHAN

A lot of people die during sleep because of uneven body changes in the body during sleep. On that note, a system to monitor sleep is very important. Most of the previous systems to monitor sleeping problems cannot deal with the real time sleeping problem, generating data after a certain period of sleep. Real-time monitoring of sleep is the key to detecting sleep apnea. To solve this problem, an Internet of Things- (IoT-) based real-time sleep apnea monitoring system has been developed. It will allow the user to measure different indexes of sleep and will notify them through a mobile application when anything odd occurs. The system contains various sensors to measure the electrocardiogram (ECG), heart rate, pulse rate, skin response, and SpO2 of any person during the entire sleeping period. This research is very useful as it can measure the indexes of sleep without disturbing the person and can also show it in the mobile application simultaneously with the help of a Bluetooth module. The system has been developed in such a way that it can be used by every kind of person. Multiple analog sensors are used with the Arduino UNO to measure different parameters of the sleep factor. The system was examined and tested on different people's bodies. To analyze and detect sleep apnea in real-time, the system monitors several people during the sleeping period. The results are displayed on the monitor of the Arduino boards and in the mobile application. The analysis of the achieved data can detect sleep apnea in some of the people that the system monitored, and it can also display the reason why sleep apnea happens. This research also analyzes the people who are not in the danger of sleeping problems by the achieved data. This paper will help everyone learn about sleep apnea and will help people detect it and take the necessary steps to prevent it.

A REVIEW ON BIOFEEDBACK SYSTEM FOR OBSTRUCTIVE SLEEP APNEA IN GERIATRIC POPULATION - AUTHOR- MONISHA R1 , PREMKUMAR R2

Sleep apnea is significant sleep disorder which causes soft tissue muscle relaxation during breathing which narrow the airway tract, where breathing is cuttoff temporarily and obstruct air flow. During each halt there will be no movement in throat muscles. In the most common form, this follows loud snoring and there cause abrupt awakening causing gasping or choking. Main three types of sleep apnea include, Obstructive sleep apnea (OSA) the more common form that occurs when throat muscles relax (Fig. 1), Central sleep apnea which occurs when your brain doesn't send proper signals to the muscles that control breathing and Complex sleep apnea syndrome which occurs when someone has both obstructive sleep apnea and central sleep apnea. Whereas Obstructive Sleep Apnea (OSA) is the most common form. It affects males about twice as often as females. OSÁ has been diagnosed more in 55 and above age group [1,2]. Approximately 1 billion of the world's population of 7.3 billion people, between the ages of 30 and 69 years, are estimated to have the most common type of sleep-disordered breathing, obstructive sleep apnoea (OSA) [3] Prevalence surveys have estimated that about 4% of the middle-aged men and 2% of the middle-aged women are afflicted by OSA in developed countries. 1- 2.1% in females) [4]. There are few existing methods to treat OSA such as Polysomnography and apnea monitor, each technique has unique pros and cons like Apnea monitor requires technician to assist the patients whereas the cost of polysomnography is high. In order to address the existing drawbacks, the proposed system will be incorporated with multiple features to monitor, oxygen saturation level, Abrupt awakening and Cessation of airflow. Pause in breathing is monitored using a respiration sensor and the corresponding therapeutic support will be provided when the breathing is paused. Accelerometer sensor is used to monitor the abrupt awakening of the patient and decrease in oxygen saturation levels are monitored continuously by the SpO2 sensor along with Heart rate calculation. The acquired parameters are encrypted and transmitted to practitioner via inbuilt IoT module. The objective of the review paper is to analyse existing methodology and its drawbacks.

VALIDITY OF PERIPHERAL OXYGEN SATURATION MEASUREMENTS WITH THE GARMIN FĒNIX® 5X PLUS WEARABLE DEVICE AT 4559 - AUTHOR - LISA M. SCHIEFER,GUNNAR TREFF,FRANZISKA TREFF

Decreased oxygen saturation (SO_2) at high altitude is associated with potentially life-threatening diseases, e.g., high-altitude pulmonary edema. Wearable devices that allow continuous monitoring of peripheral oxygen saturation (SpO_2), such as the Garmin Fēnix® 5X Plus (GAR), might provide early detection to prevent hypoxia-induced diseases. We therefore aimed to validate GAR-derived SpO_2 readings at 4559 m. SpO_2 was measured with GAR and the medically certified Covidien Nellcor SpO_2 monitor (COV) at six time points in 13 healthy lowlanders after a rapid ascent from 1130 m to 4559 m. Arterial blood gas (ABG) analysis served as the criterion measure and was conducted at four of the six time points with the Radiometer ABL 90 Flex. Validity was assessed by intraclass correlation coefficients (ICCs), mean absolute percentage error (MAPE), and Bland–Altman plots. Mean (±SD) SO_2, including all time points at 4559 m, was 85.2 ± 6.2% with GAR, 81.0 ± 9.4% with COV, and 75.0 ± 9.5% with ABG. Validity of GAR was low, as indicated by the ICC (0.549), the MAPE (9.77%), the mean SO_2 difference (7.0%), and the wide limits of agreement (−6.5; 20.5%) vs. ABG. Validity of COV was good, as indicated by the ICC (0.883), the MAPE (6.15%), and the mean SO_2 difference (0.1%) vs. ABG. The GAR device demonstrated poor validity and cannot be recommended for monitoring SpO_2 at high altitude.

SLEEP APNEA DETECTION IN FOG BASED AMBIENT ASSISTED LIVING SYSTEM- AUTHER - ACE DIMITRIEVSKIA, NATASA KOCESKAB, EFTIM ZDRAVEVSKI A , PETRE LAMESKIA, BETIM CICOC, SASO KOCESKIB AND VLADIMIR TRAJKOVIKA

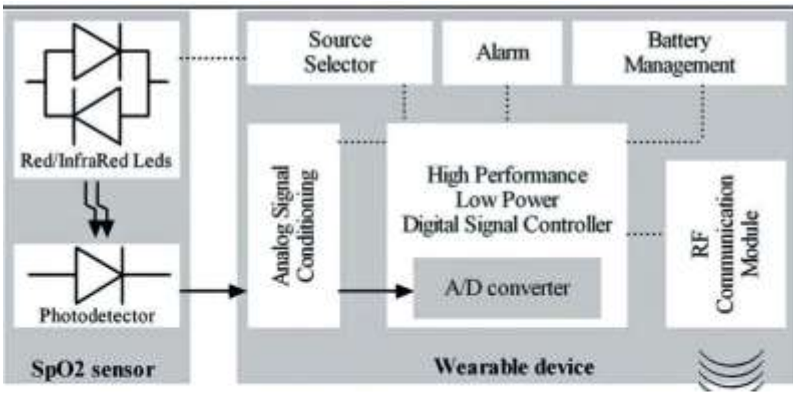
Ambient Assisted Living environments use different sensors and actuators to enable their endusers to live in their preferred environments. Unlike smart homes, where a target audience is usually a family unit, standard Ambient Assisted Living end users are care receivers and care providers. This article describes an approach based on the fog computing paradigm to detect sleep apnea in an Ambient Assisted Living context unobtrusively. The edge nodes process and detect local activities of daily living events and have direct control of the local environment. The fog nodes are used to further process and transmit data. The cloud is used for more complex and anonymous data computation. This research shows that sensors, which are unobtrusive and do not interfere with users' daily routines, can be successfully used for pattern observation.

DETECTION OF SLEEP PARALYSIS BY USING IOT BASED DEVICE AND ITS RELATIONSHIP BETWEEN SLEEP PARALYSIS AND SLEEP QUALITY - AUTHOR – **MUHAMMAD SHOAIB AKHTAR, TAO FENG**

When a person wakes up in the middle of the night, they are paralyzed. Despite the fact that most episodes are associated with extreme terror and some might cause clinically significant suffering, little is understood about the experience. This study will analyze existing research on the relationship between sleep paralyses and sleep in general. Many studies have connected poor sleep quality to an increased risk of sleep paralysis. Awake yet unable to act, sleep paralysis occurs. This might happen between awake and sleeping. The problem is approached in three steps: Data collection, data storage, calculation and machine learning prediction of sleep paralysis. The data came from the Smart Device. The dataset has several (independent) and dependent variables (Outcome). This device has been put to the test. Each exam has its own set of features and predicted outcomes. To assess the system's validity, we executed a posture recognition accuracy test. The device was hidden on top of the bed. The controller is in charge of measurement and data collection. Experiments were conducted by collecting pressure data from a patient lying down. The person acted out his sleeping positions on a mat for a while. Machine learning has been used to predict sleep paralysis. By comparing sleep postures to the outcome, we were able to show the link between sleep qualities and sleep paralysis. Machine learning approaches have been used to predict sleep paralysis. Comparing sleeping positions with the results showed the link between sleep quality and sleep paralysis. Sleep paralysis correlates with poor sleep quality. The Random Forest model has the highest accuracy of 91.9 percent in predicting sleep paralysis in the given dataset. SVM with Linear Kernel was 80.49 percent accurate, RBF was 42.68 percent, and Polynomial was 47.56 percent.

3. EXISTING SYSTEM

The authors raised awareness of the limited data on the accuracy of these devices, both for stand-alone finger oximeters and smart phone systems that do not have regulatory agency approval, especially when saturation falls below 90%. Additionally, in the future, the availability of new technologies, such as contact-less SpO_2 analysis, e.g., via video processing, might add even more convenient methods to self-monitor SpO_2 levels at high altitude provided sound methodological studies prove their validity in real-world mountaineering conditions. Our study has some limitations worth mentioning. SpO_2 readings from wrist-worn devices might be influenced by skin tone, and this factor was not assessed in our study. However, there was no effect of skin tone on any SpO_2 variables in the study of Hermand.



4. PROPOSED SYSTEM

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. The values indicate how the heart rate of a person changes from the start of sleep to the end of sleep. In the experiment, we measured the value of heart rate every second throughout the period and checked the highest, lowest, and value that clicked most of the time. After checking the values, we took the decision to calculate the average heart rate in each hour.

5. HARDWARE COMPONENTS

5.1. ARDUINO UNO

Arduino is a prototype platform (open-source) based on an easy-to-use hardware and software. It consists of a circuit board, which can be programmed (referred to as a microcontroller) and a ready-made software called Arduino IDE (Integrated Development Environment), which is used to write and upload the computer code to the physical board. Arduino provides a standard form factor that breaks the functions of the micro-controller into a more accessible package. Arduino is a prototype platform (open-source) based on an easy-to-use hardware and software. It consists of a circuit board, which can be programmed (referred to as a microcontroller) and a ready-made software called Arduino IDE (Integrated Development Environment), which is used to write and upload the computer code to the physical board.

The key features are,

Arduino boards are able to read analog or digital input signals from different sensors and turn it into an output such as activating a motor, turning LED on/off, connect to the cloud and many other actions.

You can control your board functions by sending a set of instructions to the microcontroller on the board via Arduino IDE (referred to as uploading software).

Unlike most previous programmable circuit boards, Arduino does not need an extra piece of hardware (called a programmer) in order to load a new code onto the board. You can simply use a USB cable.

Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program.

Finally, Arduino provides a standard form factor that breaks the functions of the micro-controller into a more accessible package.

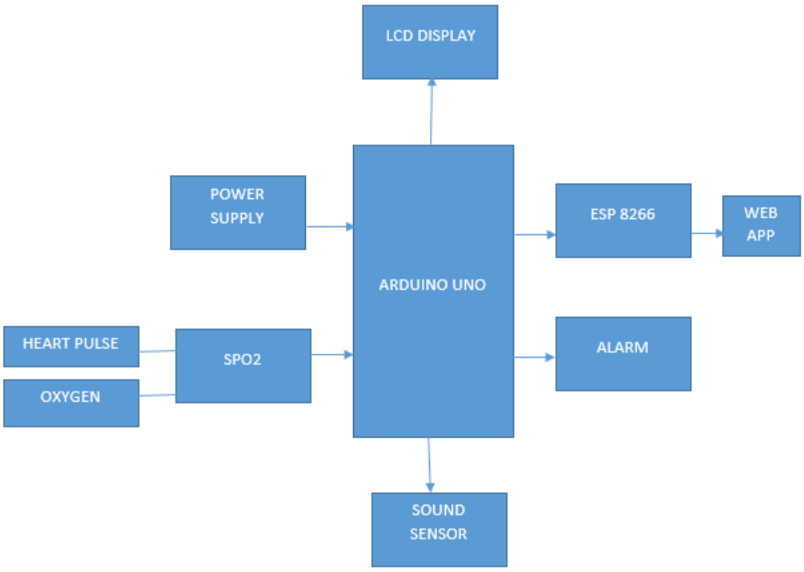
5.1.1 BOARD TYPES

Various kinds of Arduino boards are available depending on different microcontrollers used. However, all Arduino boards have one thing in common: they are programmed through the Arduino IDE. The differences are based on the number of inputs and outputs (the number of sensors, LEDs, and buttons you can use on a single board), speed, operating voltage, form factor etc. Some boards are designed to be embedded and have no programming interface (hardware), which you would need to buy separately. Some can run directly from a 3.7V battery, others need at least 5V. Here is a list of different Arduino boards available.

Types of Arduino boards,

Arduino UNO (ATMEGA328)
Arduino Leonardo (ATMEGA32U4)
Arduino mega (ATMEGA2560)

6. BLOCK DIAGRAM



7. RESULT & CONCLUSION

This research shows how IoT devices can monitor sleep apnea. To implement the system, we used a basic microcontroller and some of the major health-related sensors. The mobile application has been created with a very simple app developing web application. After monitoring five people, the system gives quite satisfactory results for making decisions about sleep apnea. From the given results, it is clear that two people do not have any symptoms of any kind of sleep apnea. One person who is in the age range of 36-50 has major issues with sleep conditions. The system successfully detects sleep apnea for that person. The system also detects obstructive sleep apnea in a person. After analyzing the results, it is clear that the person whose age is 50+ is a patient with OSA. That kind of monitoring will help people to detect sleep apnea at the early stage. Thus, this research can help people to learn about sleep apnea, the way to detect it, and it will also help people to eliminate all their sleeping problems.

8. REFFERENCE

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