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Smart mattress integrated with pressure sensor and IoT functions for sleep apnea detection

T. Sangeetha [a], D. Kumutha [a,*], M. Divya Bharathi [b], R. Surendran [c]

[a] Department of Biomedical Engineering, Karpaga Vinayaga College of Engineering and Technology, Tamilnadu, India
[b] Department of Computer Science and Engineering, Prince Shri Venkateshwara Padmavathy Engineering College, Chennai, India
[c] Department of Computer Science and Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, India

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ABSTRACT

Obstructive Sleep Apnea (OSA) is the main reason for sleep-associated respiration disorders, wherein respiration stops and begins evolved again and again at some pointing sleep. Sleep-disordered respiration can affect our common health protection and quality of life. This look targets at detecting sleep posture and sleep-disordered respiration through measuring the sensory reaction of a pressure sensor and respiration microphone sensor set up with mattresses, pillowcases, and positional sleep apnea. Three positions use of pressure sensors were used to analyze. The respiration microphone sensor is used for the duration of sleep and to measure breathing levels. In this work, we have got an advanced sleep monitoring system based on an inattentive method. Internet of Things (IoT) is used to transmit information saved in sensors and displayed in internet applications. Helps us without problems displaying gold coins and gold time periods.

1. Introduction

Sleep is one of the maximum large postures for human interest and performs an essential function in restoration and survival. People sleep a median of 8 h a day, which is the 3rd of their lives. Sleep poses have been established to be associated with human fitness. Bad postures can cause health problems or get worse pre-present ailments that can increase the risk of death. For example, four percent are moderate. The stages are considerably related to asthma, which impacts the elderly. In addition, for women who grow to be pregnant late, adopting a spinal role may also reason the pregnant uterus to affect the aorta and inferior vena cava. Loss of a large area of vision (VF) can be related to lateral decubitus posture. Prolonged sleep with one posture can reason or get worse strain ulcers. Pressing may be prevented using special sleeping positions. Good great sloop as a critical plan of keeping the most effective health on the holy time to repair and heal sleeps period in the mattress to an individual's wellbeing causing idiom in the situation of the cardiovascular system endocrine system, immunity in addition to mental well-being. However, a large percentage of the population may be arced through a situation that does now no longer permit the body to got resonate sleep regardless of the individual looking to keep a healthful sleep cycle. Usually recognized as "Sleep Apnea, Sleep is eventually for people even though its primary physiological characteristic stays obscure. Respiration tracking permits the non-stop measurement and evaluation of respiration dynamics and therefore the detection of various.

The early review of obstructive sleep apnea in the clinical literature defined individuals who have been very seriously affected by provided with extreme hypoxemia, hypercapnia, and congestive [1]. Therefore, it's far critical to continuously monitor the sleep status of humans stricken by associated fitness problems. Two sensors are used to measure fitness status [2]. One of the sensors is a breathing microphone sensor and the opposite is a pressure sensor. A respiratory microphone sensor is used to measure respiratory rate, and a pressure sensor is used to measure sleep degrees all through sleep in 3 stages. Slots left proper, and center position. However, the worldwide nurse deficiency is affecting fitness. IoT is used to transmit information saved in the sensors. This sensor assists us to monitor and keep health conditions. The sound asleep posture includes a pressure sensor and RTC. The pressure sensor could calculate the pressure level. The pressure sensor sets unexpected threshold values. To grow the threshold value, the buzzer could be on. The sleeping postures will be updated in the IoT. All data could be displayed on LCD. The IoT can update the sleeping pattern. The pressure sensor is located at the top of the bed, which assists us to measure the sleeping position [3].

* Corresponding author.
E-mail addresses: sangee4contact@gmail.com (T. Sangeetha), skvijaykumu@gmail.com (D. Kumutha), divyamoorthi1022@gmail.com (M.D. Bharathi), surendran.phd.it@gmail.com (R. Surendran).

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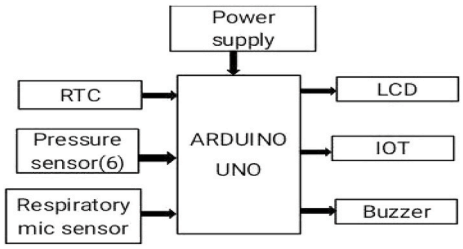


Fig. 1. Block diagram of sleep apnea detection system.

The respiratory mic sensor is located close to the nose and monitors respiration levels. These two sensors play the most important position to monitor health conditions. Sleep is useful for human activities. Sleep postures are one of the remarkable impact aspects of sleeping with quality and good for health. A recognition system is demanding for low-price sleep poses in real-time to immoderate privateers, and an accurate individual experience is desirable [4,5]. We suggest a sleep position identification system primarily based mostly on a pressure sensor sequence that includes a conductive material and conductive wires at a low price. The sensor array is located as a set of beds which includes two rows and three columns. The 10-bit Analog to Digital converter (ADC) can be utilized for the collection of Arduino Nanotechnology [6]. The sampling speed of the entire sensor array is 0.4 frames per second. Six of the five participants' health-associated sleep problems had been diagnosed through the Shallow Convolutional Neural Network (CNN) hosted on a personal computer (PC). The accuracy of the system was 84.80% with the usage of the standard training-check method, and 91.24% using the transfer-primarily based complete situation method.

2. Related works

The Smart Mattress Integrated with e-Textiles was implemented and developed by IoT Functions for Sleep Apnea Management in 2019 [7]. They discussed elaborately the Wireless Blood Pressure Monitoring System Using smartphones for many real-time applications in 2018. The authors discussed GSM Module and Arduino system for monitoring pressure sensors [8]. The author says that IOT Enabled Human Fall Detection with human interaction with the RFID source [9]. In 2016, they introduce the "Wireless monitoring and driving system of household facilities. In 2016, the authors implemented the assessment of the heartbeat by using a camera with an enormous sensor. The Fall Detection System existed with the development of the Arduino Board for human health care [10]. Finally, the survey embedded Ethernet microcontrollers for monitoring and control in the current aspects of smart technologies [11]. In Ref. [12], proposed a prototype device was designed and assembled including a Micro Electro Mechanical System (MEMS) sensor for measuring patients' nasal airflow and a time domain signal processing IC for apenea detection.

3. Implementation

This project consists of a sleeping mattress integrated with a pressure sensor and a respiratory mic sensor to detect the obstructive sleep apnea and sleeping posture of the patient [13–16]. There are two types of module used to find the respiration rate and sleeping pattern. List the sensors used for the proposed system as follows,

a. Pressure sensors. b. Respiratory mic sensor.

In Fig. 1, the block diagram describes the proposed system, which is consisting of RTC, Pressure sensor, Respiratory mic sensor, Arduino UNO, LCD, IoT, and Buzzer. Each unit is clearly explained below with its specified diagram in Fig. 2.

There are 6 sensors corresponding a 2×3 matrices. These sensors are used to calculate sleeping posture like right, left, and middle positions. The pattern can be displayed on the website.

3.1. Program for pressure sensor

The following programs for a pressure sensor and MIC sensor are given below and its implemented using embedded c.

```
#ifndef PH_H
#define PH_H
#include"global.h"
#include"lcd.h"

void F_ph(void)
{
  p1 = digitalRead(D_p1);
  p2 = digitalRead(D_p2);
  p3 = digitalRead(D_p3);
  p4 = digitalRead(D_p4);
  p5 = digitalRead(D_p5);
  p6 = digitalRead(D_p6);
  Serial.print("DATA, DATE,");
  if ((p1 == 0) || (p2 == 0) || (p3 == 0) || (p4 == 0) || (p5 == 0) || (p6 == 0))
  {
    if ((p1 == 0) && (p2 == 0))
    {
      lcd.setCursor(6, 0);
      lcd.print("L");
      Serial.print("L");
      Serial.print(" ,");
      iott("*SLEEPING_POSITION_:_LEFT#");
    }


    if ((p3 == 0) && (p4 == 0))
    {
      lcd.setCursor(6, 0);
      lcd.print("C");
      Serial.print("C");
      Serial.print(" ,");
      iott("*SLEEPING_POSITION_:_CENTER#");
    }
    if ((p5 == 0) && (p6 == 0))
    {
      lcd.setCursor(6, 0);
      lcd.print("R");
      Serial.print("R");
      Serial.print(" ,");
      iott("*SLEEPING_POSITION_:_RIGHT#");
    }
  }
}
#endif
```

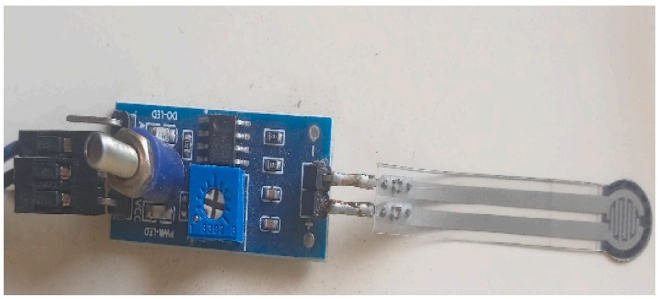


Fig. 2. Pressure sensor.

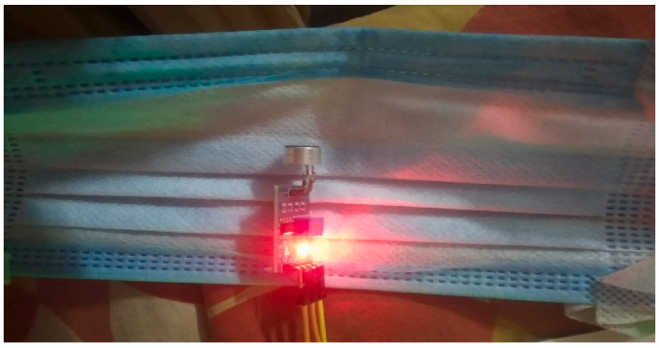


Fig. 3. Respiratory MIC sensor.

3.2. Respiratory MIC sensor

This sensor is covered with a mask. It helps to determine the respiration rate. Arduino's 5th pin is connected to the sensor. If increasing the breathing level, then it will be displayed on an LCD in Fig. 3.

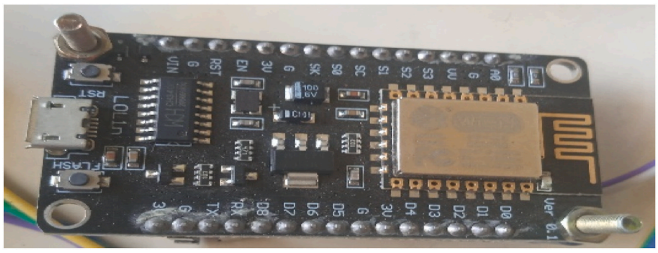


Fig. 4. IoT chip.

Fig. 5. Real-time clock.

3.3. Program for respiration MIC sensor

```
#ifndef RESP_H
#define RESP_H
#include"global.h"
#include"lcd.h"

void F_resp(void)
{
  for (int i = 0; i < 20; i++)
  {
    if (i < 10)
    {
      lcd.setCursor(14, 0);
      lcd.print('0');
      lcd.setCursor(15, 0);
      lcd.print(i);
    }
    if (i > 9) {
      lcd.setCursor(14, 0);
      lcd.print(i);
    }
    r = digitalRead(D_resp);
  {
    count++;
    lcd.setCursor(11, 0);
    lcd.print(count);
    lcd.print("  ");

  }
  delay(1000);
}
avg = (count * 3);
Serial.print(avg);
Serial.println(" ,");
iott("@" + String(avg) + "#");
count = 0;

if (avg < 12)
{
  E_RESP_STATE = RESP_LOW;
  digitalWrite(D_buzzer, !digitalRead(D_buzzer));
}
if ((avg > 12) && (avg < 20))
{
  E_RESP_STATE = RESP_NORMAL;
  digitalWrite(D_buzzer, LOW);

 }
 if (avg > 20)
 {
   E_RESP_STATE = RESP_HIGH;
   digitalWrite(D_buzzer, !digitalRead(D_buzzer));
 }
 delay(500);
}
#endif
```

3.4. Internet of Things (IoT)

IoT board is an essential hardware structure used to build models of the inventions of the designer in Fig. 4. The power supply can be given through the cable. RTC and LCD pins are connected to the IoT [17,18].

3.5. Real -time clock (RTC)

Real-Time Clock (RTC) board enables to use of a real-time clock and calendar in applications. In this system, inputs like RTC and force sensors, the output of the system is LCD. Time is set between 1 and 4 min. Consider the count of 1 h practically in Fig. 5.

Fig. 6. Buzzer.

Fig. 7. Liquid crystal display.

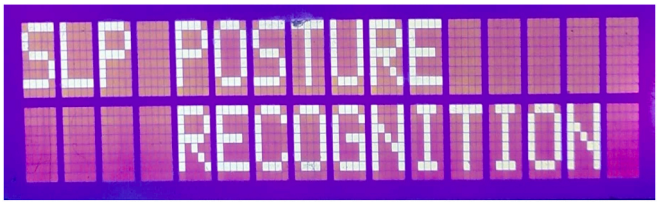


Fig. 8. Sleeping Posture identification.

3.6. Buzzer

Buzzer produces the beep sound. It can connect with the 6pin of the Arduino. In this system, the patient did't sleep after 1 min, then the buzzer will be on automatically. In Fig. 6, as the same after 4 min you did't wake up, then the buzzer will be on.

3.7. Liquid Crystal Display (LCD)

It has 16 × 2 corresponding rows and columns that denote the respiration rate and sleeping time. It will be reflected on a website like sleeping posture and respiration rate and respective graphs in Fig. 7.

The following two important steps to identifying the sleep apnea detection system are.

1. Sleeping Posture
2. Breathing Level

3.7.1. Seeping posture

The force sensor will calculate the pressure level. The pressure sensor sets a sudden threshold value. To increase the threshold value, the buzzer will be on. The sleeping postures will be Updated in the IoT [19]. All information will be displayed on LCD.

The above Fig. 8 shows the identification of the sleeping posture of an apnea patient.

3.7.2. Breathing level

In this project, we have used the Arduino UNO microcontroller which acts as the brain of our system; hence the entire system program is stored in it. C program is coded on the Arduino UNO. The system consists of a pressure sensor, RTC, a buzzer, and Arduino microcontroller for automated detection of sleeping patterns updated in IoT [20]. If any threshold value increases automatically, an alarm will be produced using a buzzer. These processes will be displayed on an LCD and all these values will be monitored in IoT. The respiratory MIC sensor is used to detect the breathing level [21]. To determine the breathing level, periodic breathing is defined as the presence of at least 3 apneas lasting 3 s or more, separated by normal respiration within a 20-s period [22–25]. This may be present in up to 20% and 5% of sleeping time in preterm and term infants, respectively. The respiration rate level is defined as a ratio of

RR = Number of breath count per minute

or (Breath count for 30 s) × 2

Breath level: The repertory mic sensor will detect the breathing level. The LCD will update the breathing level value in Fig. 9.

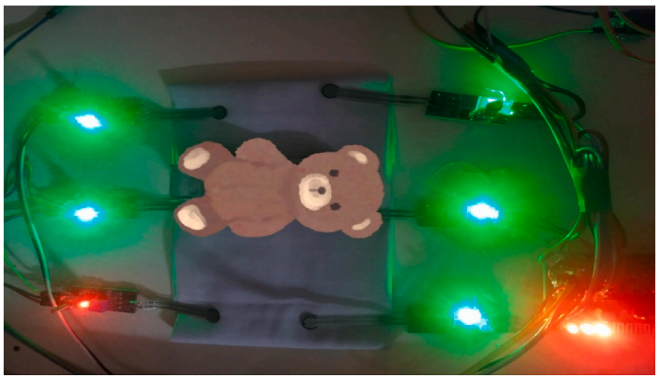


Fig. 9. Sleeping in the center position.

Table 1
Components requirements.

S.No	Name of the components	Quantity	Amount (rs.)
1.	Real time clock	01	520
2.	Pressure sensor	06	1194
3.	Respiratory mic sensor	01	158
4.	Power supply	01	138
5.	Arduino atmel mega	01	1349
6.	Buzzer	01	140
7.	LCD	01	190
8.	IOT	01	375
9	Others		100
Total			5064

4. Results and discussion

The results are compared with different comparable sleep posture identification systems, and the usage of pressure sensors, and the primary advantages of proposing the low-price bedsheet and thin thickness. The proposed system makes use of conductive threads and the pressure-sensitive conductive sheet. The components **and** requirements **used in the prposed work** is displayed in Table 1. The organizational device that guides another feature of the system is real-time processing. Compared with different comparable systems, the data collection module in our system gives real-time data conversation among sensors and machines to gain knowledge of system.

Real-time processing additionally can be carried out using temporal difference, spatial difference, or Address-event Representation (AER) techniques in image sensing to further reduce processing complexity and system power. Address Event Representation (AER) is an imperative neuromorphic inter-chip communication protocol that allows for real-time virtual massive connectivity between a large number of neurons

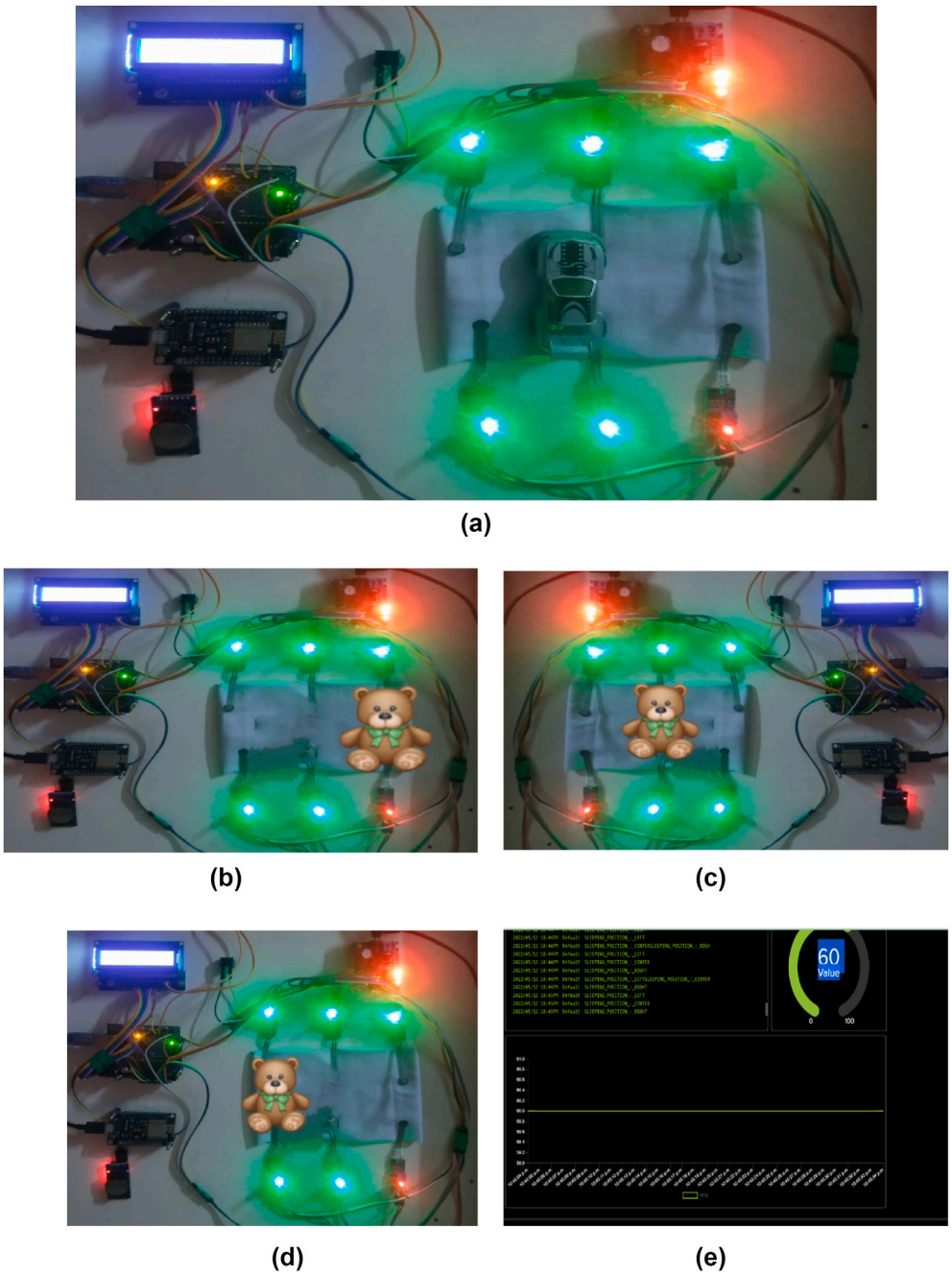


Fig. 10. Prototype of sleep apnea detection and sleeping posture detection.

located on different chips. It is likewise possible to combine a wi-Fi link into the system to update the cable. The advantages of the proposed system are affecting by individual sleeping time and posture is monitored in the IoT and provides a fast response.

Fig. 10 shows the overall system of the project. It displays the connection of the sleeping posture recognition system and breathing level with the pressure sensor and respiratory mic sensor.

The above Figures 10 (a), (b), (c), (d) illustrations that the sample of the sleeping posture of an apnea patient.

Fig. 11 Sleeping position is used to identify the different levels of sleeping position of an apnea patient for a particular period and the position may be right, left, or center. Sleeping position identification is a essential role in apnea detection.

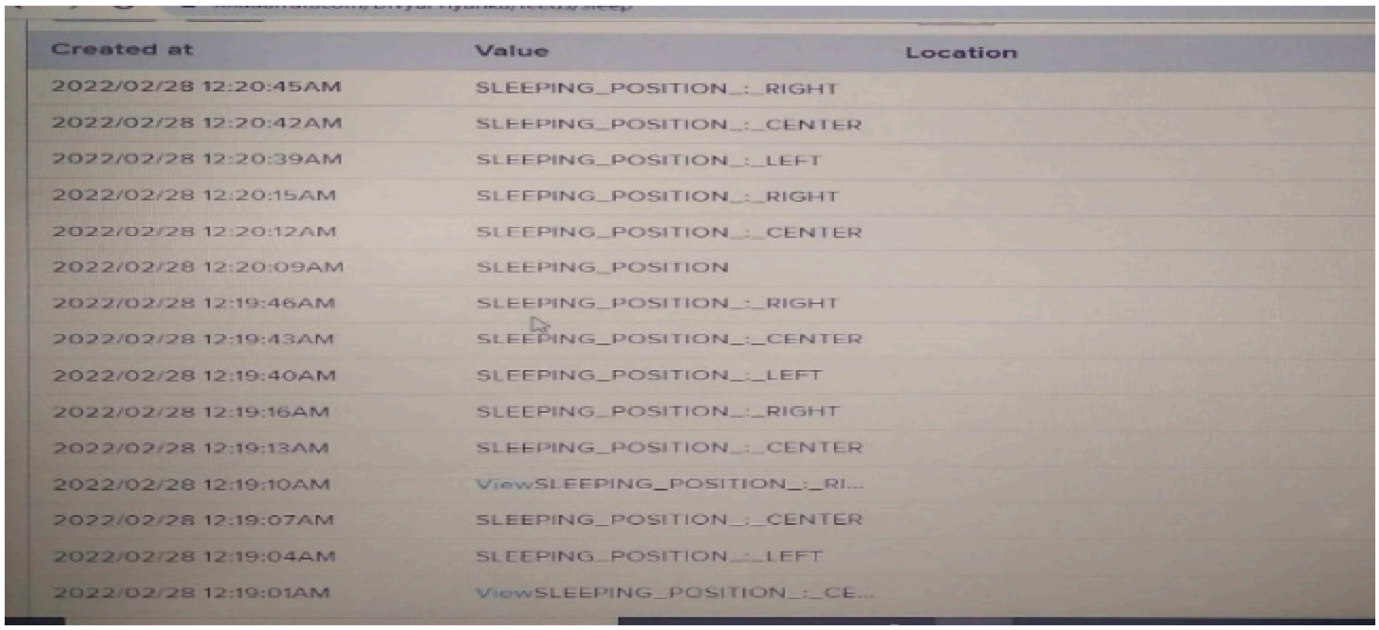
The condition of the body changes during the sleeping period, always the system is fixed to monitor the sleeping period in various aspects. For that, it monitored the patient in three positions and updated every hour, and analysed how different parameters changed every hour.

Fig. 12 shows that the wake-up condition is denoted by a respiration high level. One hour is a count of 1 min, thus the display shows the value of four then the wake-up condition occurs.

Fig. 13 shows that respiration is low and apnea detection. The patient breathing level was less than 1.20 min as per count. It displays apnea symptoms in Table 2.

Fig. 14 mentions that to detect the respiration rate, it will be projected on the website link in graph format. This graph shows the relationship between respiration rate and time. The respiration rate is automatically stored and displayed on the web page.

Fig. 15 is used to detect the sleeping posture, and it will be projected using the website link in graph format. This graph shows the sleeping posture of the patient and the sleeping time will be recorded and



Created at	Value	Location
2022/02/28 12:20:45AM	SLEEPING_POSITION_:_RIGHT	
2022/02/28 12:20:42AM	SLEEPING_POSITION_:_CENTER	
2022/02/28 12:20:39AM	SLEEPING_POSITION_:_LEFT	
2022/02/28 12:20:15AM	SLEEPING_POSITION_:_RIGHT	
2022/02/28 12:20:12AM	SLEEPING_POSITION_:_CENTER	
2022/02/28 12:20:09AM	SLEEPING_POSITION	
2022/02/28 12:19:46AM	SLEEPING_POSITION_:_RIGHT	
2022/02/28 12:19:43AM	SLEEPING_POSITION_:_CENTER	
2022/02/28 12:19:40AM	SLEEPING_POSITION_:_LEFT	
2022/02/28 12:19:16AM	SLEEPING_POSITION_:_RIGHT	
2022/02/28 12:19:13AM	SLEEPING_POSITION_:_CENTER	
2022/02/28 12:19:10AM	ViewSLEEPING_POSITION_:_RI...	
2022/02/28 12:19:07AM	SLEEPING_POSITION_:_CENTER	
2022/02/28 12:19:04AM	SLEEPING_POSITION_:_LEFT	
2022/02/28 12:19:01AM	ViewSLEEPING_POSITION_:_CE...	

Fig. 11. Sleeping position.

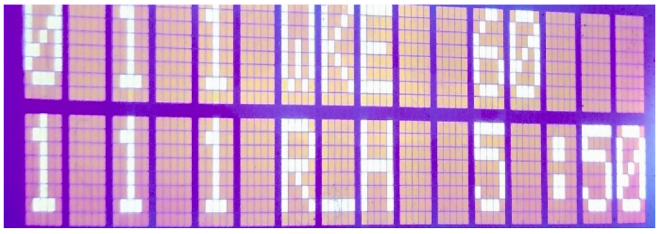


Fig. 12. Respiration High Level and wake-up condition.

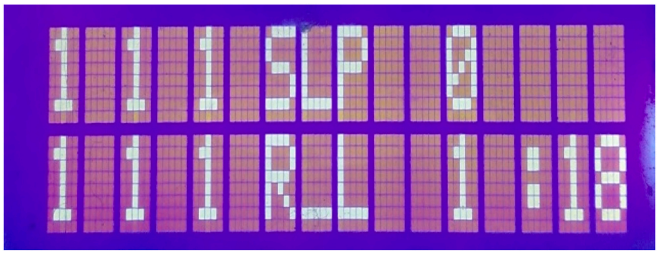


Fig. 13. Respiration Low Levels may be symptoms of apnea.

Table 2
Respiration rate results.

S. No	Age	Breath count/minute	Symptoms
1.	2 months to 1-year	More than 50 breaths per minute.	A lesser breath count were identified as APNEA.
2.	(1–12) years	More than 40 breaths per minute	
3.	over 12 years old	More than 20 breaths per minute	

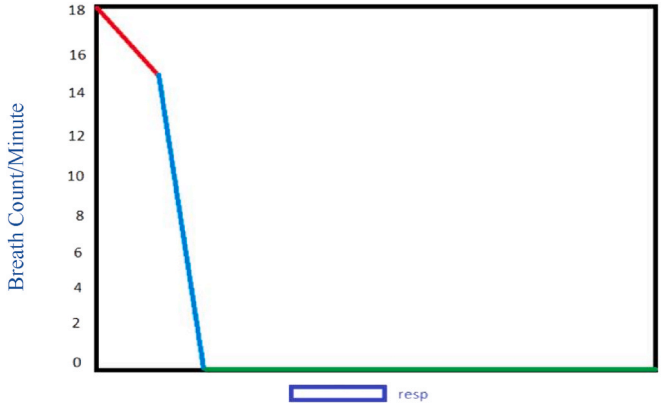


Fig. 14. To detect the respiration rate, it will be projected on the website link in graph format. Breath count/minute.

displayed in the graph format.

5. Conclusion

Thus, an actual sleeping posture identification system with excessive low cost is excellent and they are implemented with better efficiency. It reduces the complexity of sleeping pattern identification and tracking the breathing level using certain sensors. Particularly, for adults who suffer from it and cause essential complications that can affect their health. Hence, it modified the overall health status of the human being a very accurate manner. Then, we implemented to recognize the patient fall detection system using an accelerometer and RFID technology. Furthermore, elder human activity detects the possibility of cardiovascular parameters, such as heart rate (HR), Respiration Rate (RR), and Heart Rate Variability (HRV). In the future, if the patient is detected with wrong respiration, there will be an automated delivery of pressure. Hence, emergency prevention is used to halt the technique if required and the prevention timing is recorded for future use. Currently, Obstructive Sleep Apnea has grown to be the main disease all around the world. This work may be advanced and implemented in actual time primarily based totally on user requirements. The analog to digital

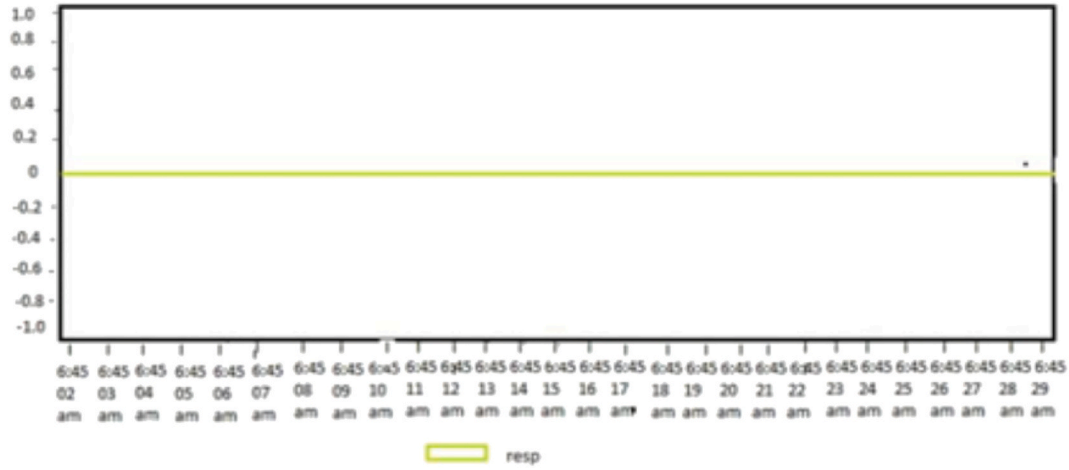


Fig. 15. To detect sleeping posture, it will be projected on the website link in graph format.

conversion of the information is very beneficial for future diagnosis. GSM module produces an audio alert to the patient.

CRediT authorship contribution statement

T. Sangeetha: Conceptualization, Methodology, Software. **D. Kumutha:** Data curation, Writing – original draft, Software, Validation. **M. Divya Bharathi:** Visualization, Investigation. **R. Surendran:** Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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