

Sleep Apnea Monitoring and diagnosis system

A GRADUATION PROJECT SUBMITTED TO THE

FACULTY OF ENGINEERING

OF

NEAR EAST UNIVERSITY

By

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In Partial Fulfillment of the Requirements for

The Degree of Bachelor of Science

in

Biomedical Engineering

NICOSIA, 2018

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We hereby declare that all the information in this file has been obtained and supplied according with educational regulations and moral behavior. We also declare that, as required by means of these regulations and ethical conduct, we've got absolutely stated and referenced all material and results that aren't original to this paintings.

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ABSTRACT

Sleep apnea cannot be diagnosed by the doctor and usually even the patient will not know that he is affected by this disease, so designing a device that can help the doctor to diagnose the sleep apnea is very important. The aim of our project is to design a device that help the doctor to diagnose the sleep apnea and to alarm the patient and his family when the obstruction of the airways become so severe using a buzzer and LEDs. The device will contain 4 sensors; force sensor for monitoring the chest movement, temperature sensor for measuring the temperature, oximeter to measure the oxygen saturation, and accelerometer to monitor the patient position, these parameters will be displayed on the screen. And if there is any abnormal readings the alarm will turn on.

Keywords: sleep apnea, sensors, touch screen, alarm.

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CHAPTER 1

INTRODUCTION

There are many common respiratory diseases in the world like Pneumonia, Tuberculosis, HAY, fever, Asthma, Chronic obstructive pulmonary disease (COPD), Sleep apnea syndrome, Trachea infections, ...etc.) in which leads to death.

The symptoms of some of these diseases can be a common phenomenon among the people like snoring and they are not considering it as disease as much as a source of discomfort.

But medically, in fact we consider it as a disease caused by a blockage of the airway.

If you suffer from snoring or exposed to continuous sleep during the day, you are most likely to suffer from "Sleep apnea syndrome". It lacks early or appropriate diagnosis and that's why it's known as "hidden disease", when the cessations in breathing occurs several times an hour during night it will cause great pressure on the brain and heart even medical problems will begin to arise such as hypertension, arrhythmia, life expectancy and fatigue during the day.

Hence the early diagnosis and treatment will help the sufferers to improve their quality of sleep and quality of life.

In our project we will shed light on patients who already have sleep apnea by observing their sleep states and development of the disorder from normal phases into danger phases to avoid any problems leading to death or disturbance.

By building and designing an electronic model that diagnosis apnea in continuous manner especially in times of sleep, it will be placed on the patient chest depending on measuring many vital signs/parameters such as sensing chest movement (heartbeat), oxygen saturation by pulse oximeter which is affected by breathing rate, and monitoring the temperature and humidity of the patient by using special sensors.

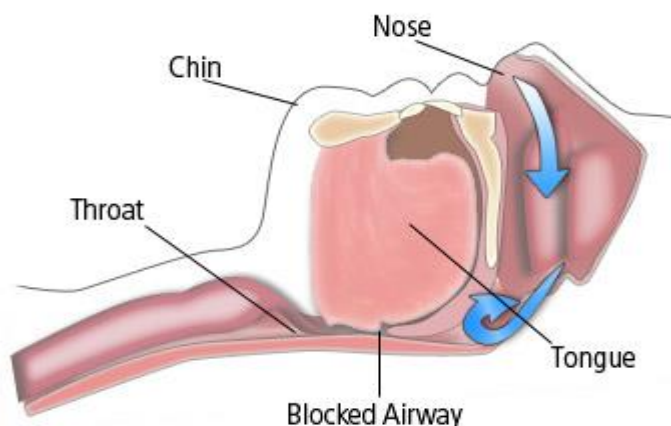


Figure 1: Throat blockage

CHAPTER 2

LITERATURE REVIEW

2.1 Respiratory System:

The primary function of the respiratory system is to supply oxygen molecules to the blood, and to removal of carbon dioxide molecules from the blood.

At first we need to take a look at the anatomy and physiology of the respiratory system in order to understand how the air goes in and where exactly it's blocked.

The system anatomically starts with nose, pharyngeal cavity, throat/larynx, trachea, bronchi and lungs.

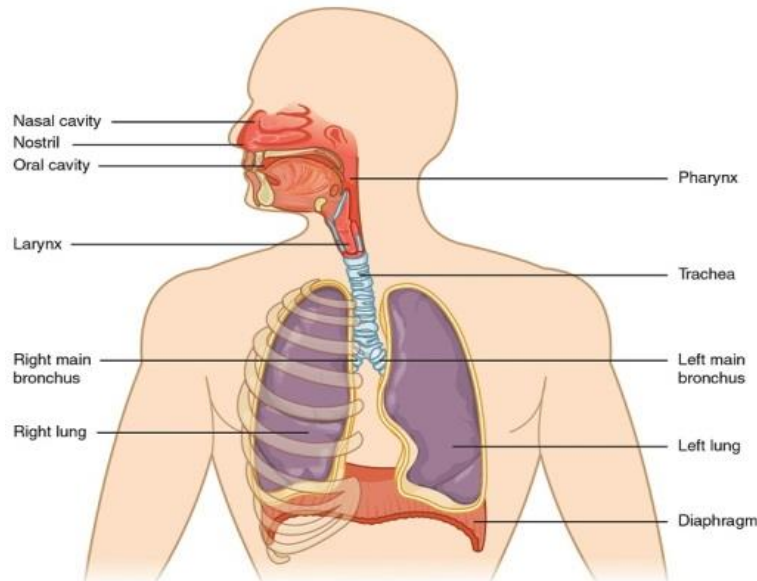


Figure 2: Respiratory system

2.1.1 Respiratory system anatomy:

1) Nose and nasal cavity:

It's the main entrance of air particle for respiratory system and is the first portion of airway; the passage through which air moves in our body. The nose is one of the main structures of the face which protects the interior fraction of nasal cavity; the nose consists of cartilage, bone, muscle, and skin. Nasal cavity which is a hollow space located after the nose. Because the presence of mucus which is covering the wall of the nasal cavity to filter the air and catch dust particles that are entering the nose before it reaches the lung.

2) Pharynx:

It's also called throat. Pharynx located from the end of nasal cavity to the upper end of the larynx. Pharynx is consisting into 3 regions: the nasopharynx, oropharynx, and laryngopharynx. Nasopharynx which is the upper area of the pharynx found behind the nasal cavity. In inhalation process from nasal cavity, the air particle passes into nasopharynx and reaches through oropharynx, which is presence behind the oral cavity the inhaled air reaches into the laryngopharynx which is which transferred to the larynx by the epiglottis.

3) Larynx

Which is known as voice box, it's located in the frontal fraction of the neck and in the top of the trachea and associates the laryngopharynx and the trachea. Larynx consist of many cartilages give it its structure. Larynx also produces different sound because of presence of vocal folds.

4) Trachea

The trachea associates the larynx to the bronchi and enables air to go through the neck and into the thorax. The semicircular shape of the ring enables it to be open all the time. The main function of trachea is extending a clear passage for air to enter and exit the lungs. The wall of trachea also consists of mucus to catch dust and prevent it from reaching to the lungs.

5) Bronchi

At the end of trachea, the passage of the air divides into left and right branches called primary bronchi. Each left and right bronchi will penetrates each left and right lung and then divided into smaller secondary bronchi. In the second bronchi takes the air into lobes of the lungs which is three lobes in the right lung and two lobes in the left lung.

2.1.2 Physiology of respiratory system:

In respiratory physiology, the basic meaning of breathing or (respiratory ventilation) is moving the air into and out of the body tissues which that allow the gas exchange with the internal environment.

The breathing process occurs in two stages:

1. First stage : between the lungs and the air in cycles of inhalation and exhalation, where the gas exchange occurs between the blood and the air, by transmission of the oxygen O₂ from the air to the blood and the carbon dioxide Co₂ from the blood to the air.
2. Second stage: called (cellular respiration), which mean between body cells and blood. The cells of the body absorb the oxygen in the blood to break down the foods which is the process of oxidization food molecules to make energy under partial pressure

(The measure of mixture of gasses in the blood or alveoli), and eliminate carbon dioxide as the waste product.

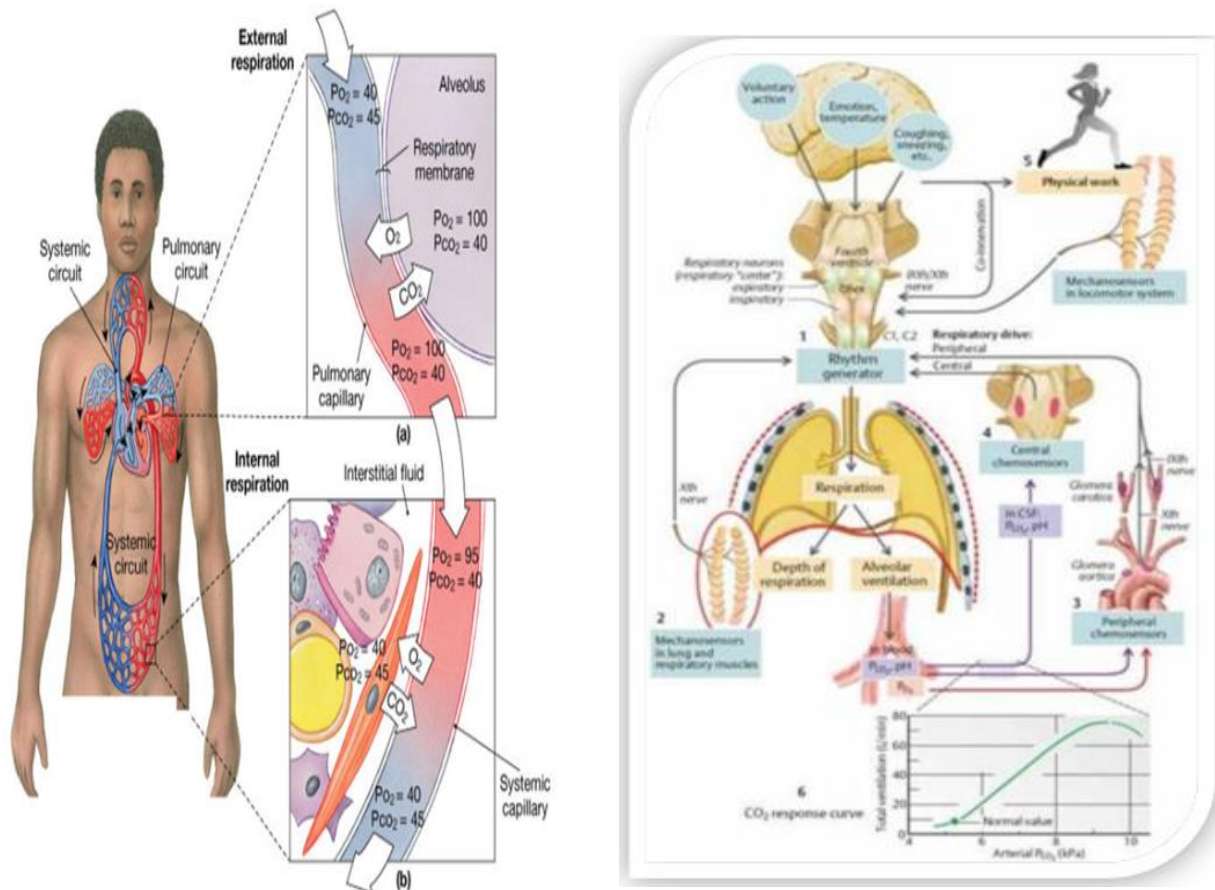


Figure 3 : Respiratory system physiology

2.2 Sleep apnea:

Sleep apnea is a disorder; that most commonly known to cause pauses in breathing or an empty breaths while you are asleep.

These pauses may occur and last for seconds or longer for minutes. This may happen up to 30 times in an hour of night sleep. Afterwards the normal breathing is restored back; most likely accompanied by snort or gasping/choking sounds.

Such condition is hard for the doctors to diagnose, whether by a standard physical examination or even by a blood test. The best way to discover the problem is by the bed partner who can notice the symptoms on the sleeping patient.

Snoring and sleep apnea are some common problems which can affect our sleep, health and our daily performance.

Nearly one out of 5 adults suffers such problem (sleep apnea), yet they do not have an idea that they have it; in which it remains undiscovered and untreated. In some cases snoring and sleep apnea happens simultaneously and one can be the cause for the other, most likely.

Where the upper airway might be:

- 1) Too tight, this reduces the flow of air while sleeping.
- 2) Vibrating and sounds like snoring.
- 3) Cracked which results in blockage of breathing.

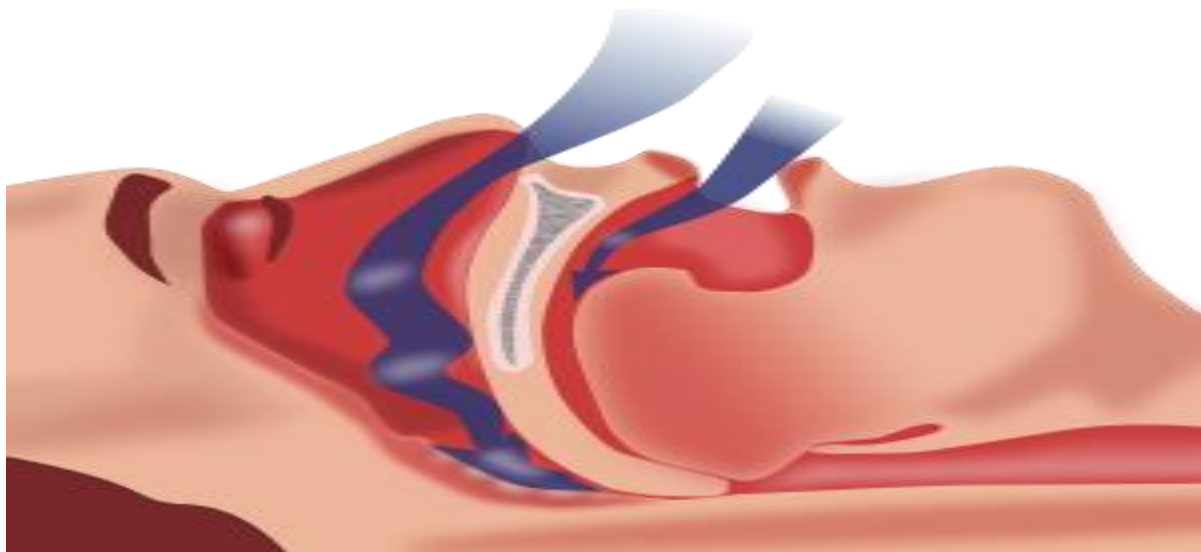


Figure 4: Sleep apnea

2.2.1 Major reasons that lead to blockage of upper breathing airway while sleeping.

These reasons are directly related to the muscular mass which found in the neck, consisting of tongue's muscle and pharynx's muscle; In addition to the fatty mass surrounding these muscles. The main factors contributing in sleep apnea are:

- Relaxation of throat muscles (In high weight patients)
- Gravity (while the patient sleeps on his back)

When tissues completely blocks the upper airway path or prevents the breathing; the patient chokes which leads to waking him (because the brain alerts that the oxygen level has decreased in blood) in order to control on the upper airway path in which he takes his breath again as a

sharp inhalation then goes back to continue sleeping. This phenomenon happens ten to hundred times during a single night, but the patient does not remember that he woke up at night. That entails some potential problems which are:

With every blockage in breathing, the body is forbidden from oxygen and eliminating carbon dioxide while sleeping. As a result of that, blood gases become unstable and the body slowly becomes environmentally toxic. By that time the brain works on waking the patient up to resumes breathing.

These events rises the heart beat ratio and causes hypertension , ending with the body losing the automatic response system which leads to increasing breath pausing (apnea) and partially blockage of the airway which makes the breathing cycle incomplete (Hypoapnea).

Sleep apnea influences the sleeping quality and affects the prohibition of sleeping (repetitive brain alerting which means the patient doesn't really sleep well), where sleeping is divided into four levels within two major categories:

- First category is the non REM sleep (sleep is not deep) consisting first and second levels.
- Second category is the REM sleep (deep sleep) consisting third and fourth levels.

It's sentenced that the most important signals of beginning of having sleep apnea in most patients are:

1. Obesity (fatty people are more susceptible to have sleep apnea than normal ones).
2. Snoring.
3. Genetics (the disease might be genetic condition through the family)
4. Narrowing of upper airway path because of (large tongue, flat chin, and extra soft tissues in the throat).
5. Head or neck's shape (might cause a narrower airways)
6. Large almonds.
7. Other congenital malformations (tongue widening or chin reduction).
8. Tongue and throat's muscles might relax more than their initial condition while sleeping as a result of taking stimulations or having alcoholic drinks before sleeping.
9. Nasal congestion - clogged nose - nasal irritants.
10. Syndromes or disorders (thyroid - extremities enlargement - amyloidosis - paralysis of vocal cords - Marfan syndrome - Down's syndrome)
11. Other conditions (immune system abnormalities - hypertension)

But there are still some arguments about if all of these conditions may lead to sleep apnea or just some of them cause that illness. Researches still going on!

2.2.2 Sleep apnea symptoms:

Most common known symptoms that appear on the patient are:

1. Loud snoring.
2. Apnea within periods.
3. Difficulties while waking up at morning.
4. Abnormal drowsiness at daytime and sleeping at improper times.
5. Morning headache.
6. Overweight.
7. Losing concentration.
8. Memory loss
9. Miss judging.
10. Character changes.

2.2.3 Long term effects of sleep apnea:

Repetitive apnea while sleeping is considered as a major factor contributing in hypertension and making it reaches the irregularity situations although while using medications for hypertension regularly, and having heart and blood vessels diseases. It also takes part in body stress and arrhythmia with possibility of heart failure. The resultant damage also reaches the central nervous chains because of the death of nerve cells resulting from lack of oxygen levels. Sleep apnea may also influence the sexual performance in men.

2.2.4 Types of sleep apnea:

1) OSA (Obstructive Sleep Apnea):

It's the apnea resulting from laxity of muscular mass in the throat causing closure of the airway paths. This type of sleep apnea is the most widely common.

It can be found in 5% of adult men and lesser in women before menopause, but after menopause in women the percentage is equalized with men.

This condition happens when the airways are blocked while breathing activities still occurs.

Common for those who exceeds the age of 50.

This type of sleep apnea is our main research axis for diagnosis.

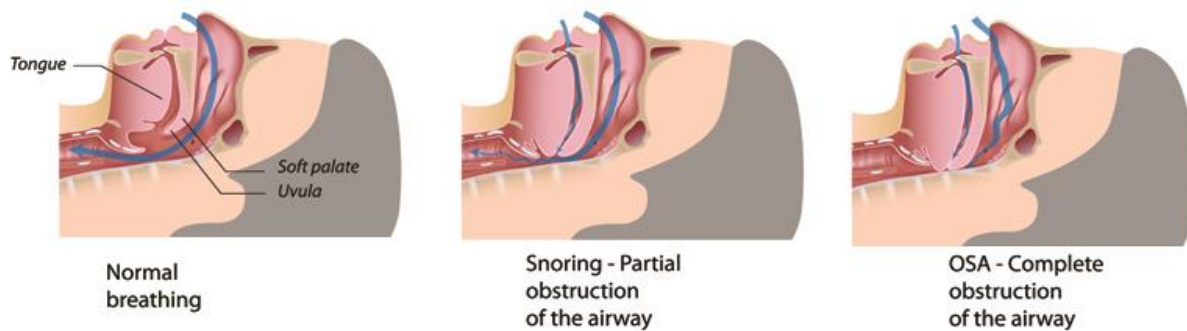


Figure 5: OSA

2) CSA (Central Sleep Apnea):

This type of sleep apnea occurs by medical problems that effect on the brain stems. When the brain fails to send the signals to the muscles responsible for controlling the breath, such type is not commonly known to happen.

Apnea occurs when the patient loses the ability to breathe automatically due to disturbance in the central nervous system (stopping breathing or irregular breathing during sleep).

It can be a result of some diseases such as brain disease (cerebrovascular accident – chronic respiratory disease – brain tumor).

3) Mixed sleep apnea (MSA):

- It's breathlessness a result of disorder in control central of brain and result of relax the muscles of throat.
- Less common.
- It's a combination of both obstructive and central sleep apnea.
- The patient with this type of sleep apnea suffers of snoring, so the treatment will help to get rid of blockage of the airway but can't be completely stopped the sleep apnea.
- The treatment combination between of CSA and OSA.

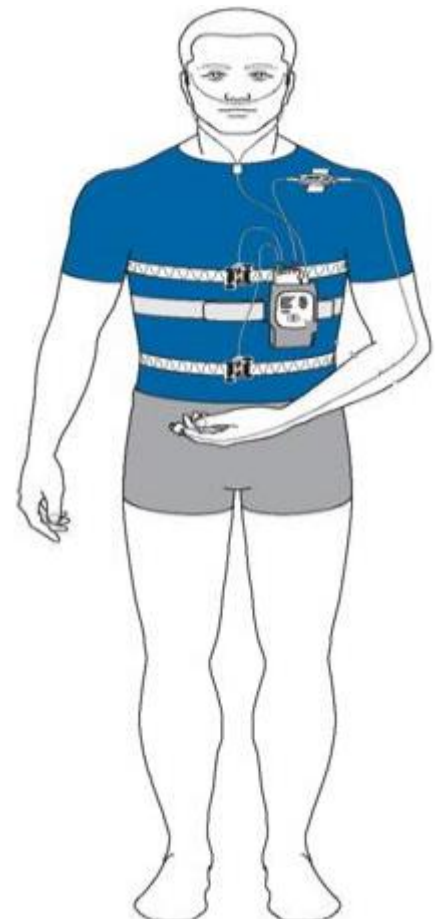


Figure 6: Diagnosis

2.2.5 Diagnosis:

The diagnosis should be performed by physiotherapist, Lung specialist, and neurologist. The diagnosis not easy

because of the causes of sleep disorder, also the diagnosis should include all the medical history and physical examination.

Polysomnography is the most common test to determine if the patient has sleep apnea or not.

In some cases, the simplest diagnosticians can identify the disease. However, if the test does not confirm whether the person is infected so polysomnography should be used.

To do polysomnography, the patient must sleep one night in laboratory, so that the electrodes will placed on the head and on the outer edge of the eyelids and on the chin and also put belts around the chest and abdomen, also a nose sensor is placed to measure air flow, and oximetry is placed to measure the level of oxygen in the blood.

This diagnosis describe the eye movement, muscles activity, breathing, oxygen concentration in the blood, air flow and the brain electrical activity, then all this information will be collected and evaluated.

2.2.6 Treatment:

Non-invasive methods are the most common treatment for sleep apnea which they are:

- 1- Continuous positive airway pressure (CPAP), the most common treatment, which is involve wearing a mask to keeps the flow of air flowing through the nose during sleep and this flow keeps the airway open.

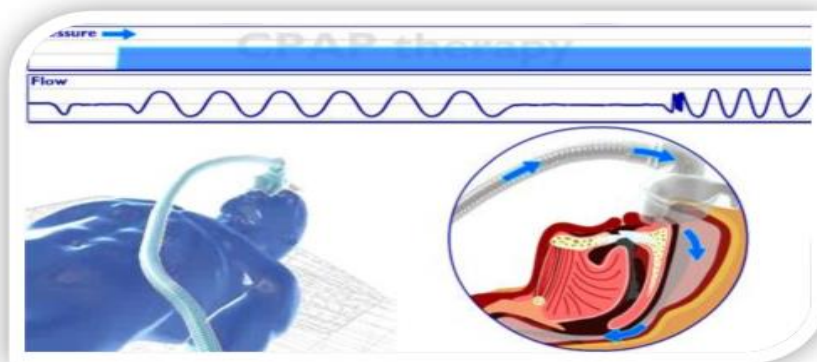


Figure 7: CPAP

- 2- Weight Loss: The weight reduction of 10% helps to reduce the disease.
- 3- Changing the sleep habits: like sleeping on one side instead of sleeping on the back may reduce the disease.

- 4- Behavior modification: such as avoiding alcohol may sometimes help to reduce the disease.
- Surgical methods are non-common methods of treatment , includes :
 - 1- Sonoplasty: An operation that uses radio frequency radiation energy to reduce or remove soft tissue in the upper respiratory tract.
 - 2- Uvulopalatopharyngoplasty (UPPP): used to remove the soft tissue at the back of the throat and palate, thus expanding the airway in the throat.
 - 3- Correcting of facial / throat malformations may help to reduce of disease.
 - 4- Nose Surgery: such as a deviation of the nose which can reduce of disease.

2.3 Asthma disease

It is a chronic disease that affects the airways of the lungs and is caused by inflammation and tightness of the respiratory tract, Which prevents airflow to the airways, leading to repeated episodes of shortness of breath with a wheezing (chest wheezing) accompanied by cough and phlegm after inhalation of substances that cause allergic reactions or irritation of the respiratory system. These seizures vary in intensity and frequency from one person to another, one of the most common diseases among children.

CHAPTER 3

MATERIALS AND METHODS

3.1 Aim of the project:

The aim of our project is to build a device that is capable of real-time monitoring and detecting of sleep apnea and warning the patient's family when it happens by continuously monitoring a set of parameters associated with sleep apnea.

The system will contain multiple sensors to measure heart rate, air flow and chest movements. These sensors will send the detected signals to a microcontroller; in which it will process them and show them on a screen. The processed signals will be able to trigger an embedded alarm system once sleep apnea occurs.

3.2 Materials:

3.2.1 Power Supply:

We don't have to use voltage source in our project because our Arduino takes 5 voltages to work taking it directly from the battery. Because the value of the voltage is small, this will protect the patient from electric shock hazard.



Figure 8: 9v Battery

3.2.2 Arduino:

Which is the microcontroller of our device, we will connect the sensors to the Arduino, where we can write the codes for them. Arduino is perfect for our project because it is cost

effective and easy to program, the Arduino will get the input signals from the sensors to be processed and gives back an output which is digital output or analog output. And we can program it to activate an alarm when a certain input signal is obtained.

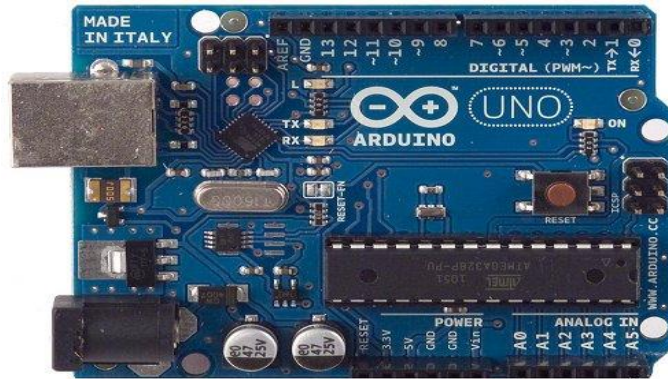


Figure 9: Mega Arduino

3.2.3 temperature sensor:

This type of sensors is used to measure patient's temperature. When the patient stops breathing his temperature will increase and he will get sweaty so we will need a sensor for measuring the temperature, by attaching the sensor to the patient belt where it can get measurements from the skin. It has a minor disadvantage that it monitors temperature periodically not continuously, because of the complex network of transistors in it. But this can be avoided by programming a smaller delaying times in sensing the temperature and humidity in the Arduino code.

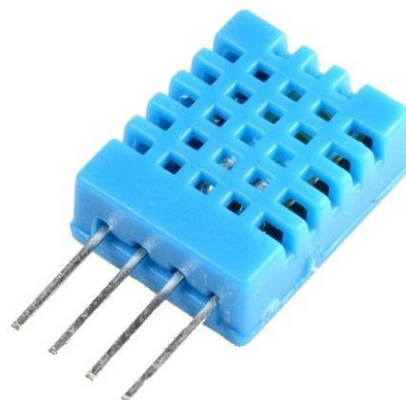


Figure 10: DHT sensor

3.2.4 Pulse oximetry:

It's a device that uses a red and infrared light to measure the saturation of oxygen in your blood and to also measure heart rate. The pulse oximetry sensor consists of:

- 1- Two diodes; these diodes emit light; one red and one infrared light. In infrared light source, oxyhemoglobin absorbs it more than deoxyhemoglobin and for red light it's vice versa.
- 2- There's also a photodetector to calculate the percentage of light which it's transmitted. This kind of sensor is placed on the fingertip. And in that way the different measuring of oxygen saturation and heart rate should be calculated. When the patient places his finger between the light sources and the detector; these LED sources start to emit light through the finger. A small fraction of light is absorbed by the finger and another fraction passes through the finger to the photodetector. Each heartbeat from the patient heart should increase the volume of the artery which is the oxygenated blood passing through it. By this way absorption of light by the finger will increase and less fraction of light hits the photodetector.

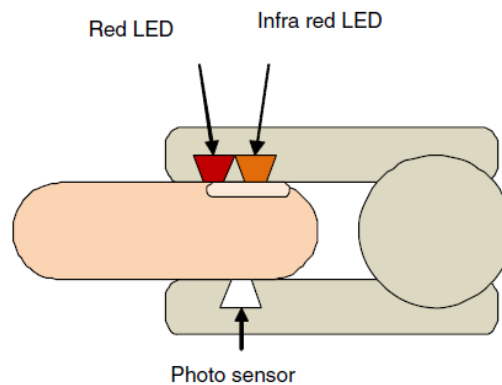


Figure 11: Oximeter

3.2.5 Force sensor:

The force sensitive resistor (FSR) which uses a strain gage to monitor the chest movement which is an indication for the patient breathing process. The sensor will be placed between patient's chest and the belt to measure the applied pressure of the chest on the strain gage. This sensor uses the voltage division concept which states that the voltage on each resistor in a series connection will be equal to the voltage source, so when the pressure increases on the strain gage (inhalation) its resistance will increase which will lead the voltage on the strain gage to increase, and when this pressure decreases (exhalation) the strain gage resistance decreases will

decrease which will make the resistance decrease. We use this type of sensor because of its high sensitivity, low cost and durability



Figure 12: Force sensor

3.2.6 Accelerometer:

- An electromechanical device, we used it to measure the acceleration and the position (inclination/orientation) of the patient in three orthogonal axes (dimensions) during the sleep, it depends on the change of pressure, acceleration and strain of the patient body.
- The direction of the patient during his sleep may cause breathing disorder. When the patient moves from his side to his back it may cause obstruction in breathing because of gravity and this information can be stored and sent to the doctor.
- And it is important for detecting false readings from the strain gage for when the patient lay on his belly and this will cause the pressure to increases exponentially and by detecting the patient's position we will know whether if our force sensor is working without any problem or if there is false readings in the sensor.
- That means the accelerometer important to monitor the position of the patient.

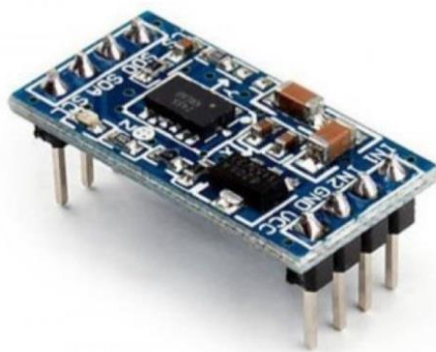


Figure 13: Accelerometer

3.2.7 LEDs:

- Light emitting diodes which are the light source which convert an electrical energy into light; we use it in issuing an alert when the patient's condition changes from moderate to severe.
- It's easy to be programmed, cost effective and it comes with different types of light colors.

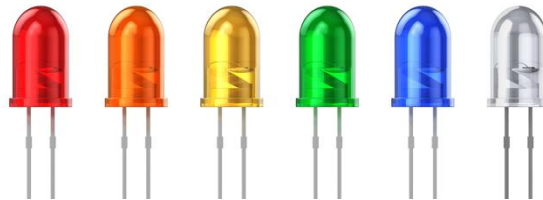


Figure 14: LED's

3.2.8 Buzzer:

It's a device which beeps noise whenever the parameters being measured exceed the normal rates we set. We are using buzzer in our project to alarm the patient's family if there is any problem occurred with the patient while he is sleeping.



Figure 15: Buzzer

3.2.9 Nextion touch screen:

Our screen is used it to display the parameters from our sensors.

By using nextion editor program, we can program the screen adding wallpapers and creating buttons and customize the buttons to show us the values of the sensors. After finishing from designing our screen shape and buttons we must transfer them to micro memory card which is compatible with our screen by using computer then insert the memory card to the screen to

upload our design and display it on it. The screen has four ports that will be connected to the Arduino, one port is connected to the five Volt and one to the ground and RX and TX ports that's going to connects to the RX and TX in the Arduino.

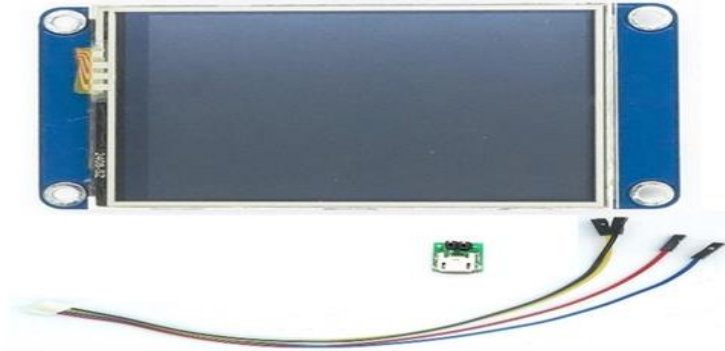


Figure 16 Nextion touch screen

3.2.10 nRF24L01:

We used this kind of module to make a connection between the two Arduinos. By using two NRF module (first one is sender and another one is the receiver), each NRF should be connected to each Arduino to make communication between both of Arduinos.

The propose from connecting this module in our device is to obtain easy way to let both of Arduinos communicate wirelessly.



Figure 17 NRF24L04

3.3 Methods:

Our device will function by combining the parameters taken from the sensors that are connected to the UNO Arduino, and it will monitor these parameters, and it will look for any abnormality's and silence period in breathing.

The parts that we added in our device are:

Two board of Arduino UNO: Which is the microcontroller of our device, we will connect the sensors and the touch screen to the first Arduino, where we can write the codes for them. And the second Arduino we will be connected to the buzzer and LEDs.

Touch screen: to show us the parameters and monitor the situation of the patient.

we will design a belt compatible with the size of the patient, where we can put the Arduino that connects the sensors and the sender NRF. The dimensions of the pocket on the belt must have the same size of the Arduino so we will prevent the Arduino from making any movement and preventing any changes to the measurable parameters. And the screen will be used to display the parameters of the sensors.

The sensors in the device are connected in a specific area in the belt, force sensor connected between the belt and the chest of the patient, so we can measure the applied pressure of the chest,

Temperature sensor also is connected on the belt to directly measure the temperature of the patient.

A long wire connected with pulse oximeter sensor exiting from the Arduino to reach the finger to measure the heart rate of the patient, the sensor should be sealed correctly to the finger of the patient to prevent any false reading from the sensor.

An accelerometer which is an electromechanical device fixed on the breadboard that present on the belt. This small device will monitor the position of the patient.

The values of those sensors will be displayed on our screen.

Second Arduino should be placed in room where the patient family are sitting there, and it will have an alarm and a buzzer that will turn on when there is any abnormal reading sensed from the patient.

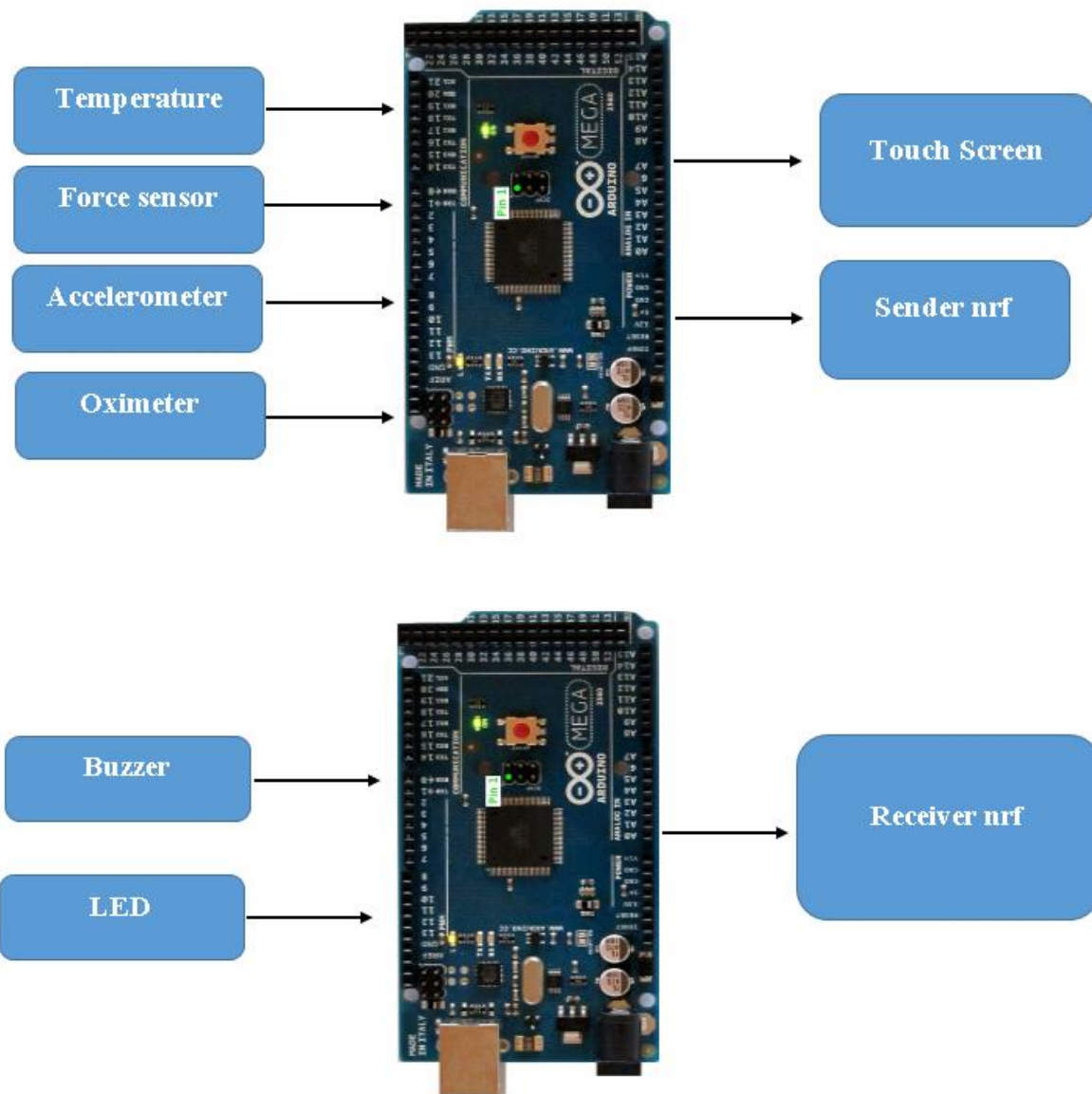


Figure 18: Block diagram

CHAPTER 4

DISCUSSION

4.1 Advantages:

- 1- Cheap and affordable when compared with other devices.
- 2- Monitors more than one parameter.
- 3- Non-invasive.
- 4- Doesn't need a high voltage.
- 5- Alarms in severe conditions of the patient.
- 6- Detects severe cases of the disorder.

4.2 Disadvantages:

- 1- Might cause discomfort to the patient, which will wake him up.
- 2- The simplicity of it may affect its accuracy.
- 3- Measured parameters might sometimes be inaccurate.

4.3 what we can improve:

- 1-We can always use a more accurate sensors.
- 2-We can add a second touch screen to the second Arduino
- 3-An air flow sensors can be add to measure the exhaled and inhaled air.

CHAPTER 5

CONCLUSION

Sleep apnea is a chronic disease that happens when the muscles in the throat become relaxed and block the air ways passage to the lungs due to gravity. Sleep apnea will affect the patient sleeping quality and it will make him wake several times in the night which will make him tired, sleepy and inactive during the day. Sleep apnea can happen due to relaxing in throat muscles, or it can happen due to neural problems in the brain, or it can be mix between the tow.

Sleep apnea is impossible to be diagnosed in the laboratory and the patient himself may not know that he has sleep apnea, so it is important to make a device that monitor the patient sleeping continuously. While making such device its essential to take some points in consideration like temperature, humidity, acceleration, heart rate and chest movements of the patient.

Combination these parameters measurements will make us capable to continuously monitor and observe the patient's level of severity related to apnea disease. By the usage of these measurements and observations we can be sure that the patient's condition is under our control so we can deal with any changes occurs to the patients once they're detected.

The ability to diagnose such disease will provide a whole new degree of comfort and health assistance for those who are suffering especially from snoring in their sleeping periods. To sum up, appreciating the value of human life will lead us to unlimited range of creativity! and upon that we worked on our idea in order to add something that can affect positively and support the health of our society.

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