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Design and Development of affordable Cough Monitoring System

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***Abstract* – This paper proposes an effective portable cough monitoring system for early screening and treatment of pulmonary diseases at a very early stage. Cough acts as a protective and defensive act for the removal of mucus and infections from the bronchi. The effect of continuous cough may be harmful to the patient by interfering with breathing, social activities and sleep, muscle ache, insomnia and fatigue. According to the world statistics, more than 3 million people died of COPD in 2012, which is equal to 6% of all deaths globally a year. More than 90% of COPD deaths occur in low and middle income countries. On the basis of worldwide survey we find that majority of people are suffering from pulmonary diseases. In rural areas people find it difficult to monitor cough related diseases due to complexity of equipments and their cost of diagnosis. An affordable cough monitoring system is developed for recording the cough sounds and vibrational activities produced, by using sensors placed on the thoracic, tracheal and abdominal areas and a necessary amplification system for processing of cough signals in time and frequency domain is done for the analysis of various pulmonary diseases. By analyzing the signal pattern we are able to distinguish between normal and infectious cough and quick medical attention is given to people suffering from pulmonary disorders which seem to be a relief for the rural population in controlling the number of deaths due to COPD.**

***Index terms*:** mucus, tracheal, insomnia, bronchi, COPD

I. INTRODUCTION

Cough is the most important symptom experienced by every human in our day to day life. . It acts as an defensive and protective mechanism which clears the debris and other mucus particles from the lungs. Coughing is the most efficient and effective mechanism for clearing the lungs and act as an inbuilt natural mechanism. Its absence can be harmful if medical attention not taken. Thus the cough vibrations can be detected by a suitable hardware for analyzing the phases of cough and the event of cough occurrences[1].There are three phases of cough which include an initial inspiration, glottal closure and development of high thoracic pressure, followed by an expiration when the glottis opens [2]. The cough reflex is initiated by cough receptors which are located in the central airways in brain .Sound is generated during cough due to airflow, vibration of the tissue, and movement of fluid in the lungs. There are numerous causes for cough. Smoking is the most common cause of dry cough. Hay fever and other allergies can sometimes cause cough which causes a dry or tickly cough . Various sensors can be used to record the activity of cough such as sound vibrational and EMG activity [3]. EMG activity can be recorded by means of surface electrodes and an amplification and filtering device can be designed[4,5].A continous automated system for recording the cough activity can be done with this acquisition system by recording cough sounds can be done[6]. Controller based system proves to be more accurate in detecting the cough events for normal and abnormal cough sequence [7]. Instrument can be designed for measuring the frequency of cough [8] cough recording the EMG activity and vibrational activity produced in the abdominal wall by vibrational sensor attached to the chest wall [9]. These have not achieved clinical importance because of cost. Diagnostic approaches on chronic cough has been done so far to limit the occurrence of cough related diseases [10]. Although there are recording systems for cough there is no significant study on the basic signal pattern produced due to the variation in the frequency of cough between pulmonary diseases affecting the lungs. The pulmonary diseases have varying cough pattern in which all seem to share cough as the common symptom .

Hence a low cost cough monitoring system can be designed for the classification of various lung diseases using EMG and vibrational sensor and analyzing the signal pattern for early screening of pulmonary diseases.

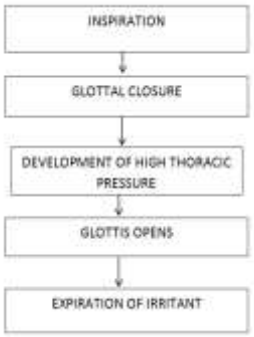

Figure 1.1: Mechanism of cough

II. ACCQUISITION SYSTEM

A low cost portable cough monitoring system is developed for recording EMG and vibrational activities produced, by placing sensors on the thoracic, tracheal and abdominal areas and a necessary amplification system using instrumentation amplifier and band pass filter as the filtering section is used for processing of cough signals in time and frequency domain .

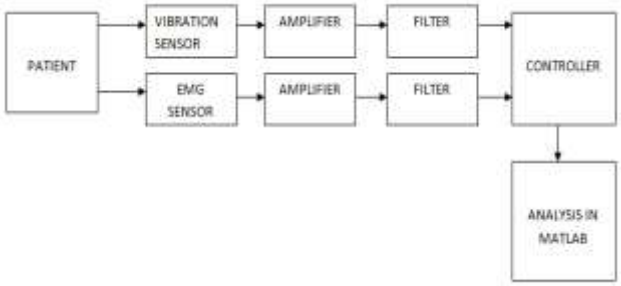

Figure 2.1: Block diagram of proposed system

SENSOR

In the proposed system two types of sensors are used, one is for recording the EMG activity and a piezo electric vibrational sensor is placed in the chest region for recording the vibrational activities produced during coughing.

CONTROLLER BOARD

The controller board is used for transferring the data or signal which we receive and convert into digital form.

ARDUINO UNO

The Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz crystal, a USB port, ICSP header.

FILTER

Band pass filter allows the signal to pass around specific bandwidth, but blocks the signals at other frequencies. Here the BPF is designed with frequency range between 50 Hz to 16 kHz since the cough frequency range lies in this range and the respective capacitor and resistors values were calculated.

AMPLIFIER

INA 2128

The INA2128 is a dual, low power, instrumentation amplifier having excellent accuracy. Due to its dual input it makes the device more compact and hence two types of input can be given one from EMG sensor and another from vibrational sensor to record the EMG and vibrational activities of cough sequence. It has a wide range of application due to its three op-amp design. It has high gain and wide bandwidth. A single external resistor sets any gain from 1 to 10,000.

AMPLIFIER AND FILTER DESIGN

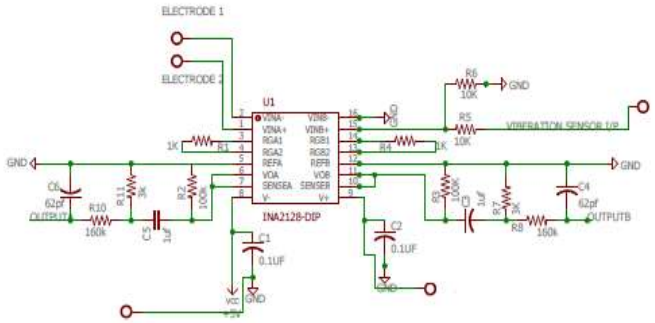

Figure 2.2: Amplifier and filter section

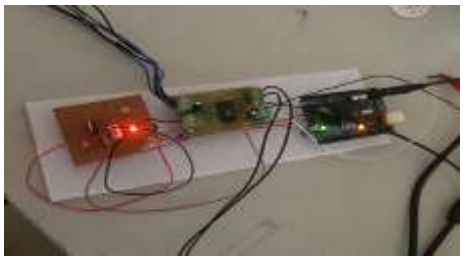

Figure 2.3: Proposed hardware

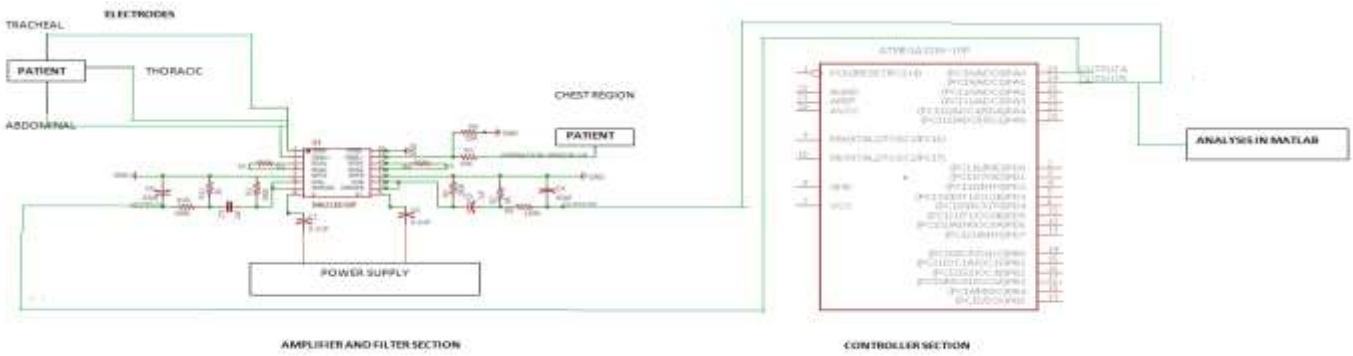

Figure 2.4: Overall circuit diagram

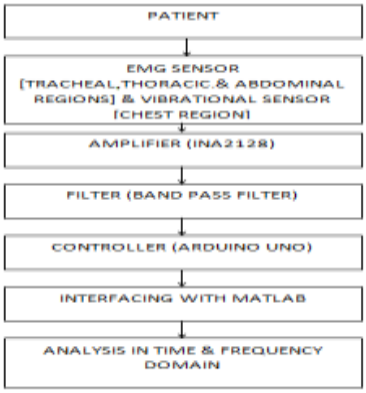

Figure 2.5: Flow diagram

The overall process consists of connecting the EMG electrodes at various positions of the patients at the tracheal, thoracic and abdominal regions. A vibrational sensor is placed in the chest region to capture the vibrations pronounced during the cough sequence. Power supply is given by 12 V adaptor and power supplied by means of the 5 V regulator. The Amplifier and filtering circuit is supplied dual power supply of 5 volts. The instrumentation amplifier has dual inputs and hence it produces two outputs one from EMG sensors and other from vibrational sensor. Both the outputs are given to the analog inputs of the controller. By interfacing coding the digital data is being transferred and analysed using MATLAB. The proposed hardware is shown below. The circuit was successfully tested using breadboard and the results were checked using oscilloscope, waveforms during normal and cough activity were differentiated and checked. The proposed hardware is shown in the figure below which consists of three units power supply unit, amplifier and filter unit and finally the controller unit from which the data is transferred and analyzed using MATLAB by interfacing using GUI and the waveform is plotted in real time in MATLAB software.

III. RESULTS AND DISCUSSION

The EMG electrodes were placed in the tracheal, thoracic and abdominal regions. Difference in peak was observed during cough sequence than normal EMG activity. The controller was successfully programmed using ardunio software and GUI was created for interfacing arduino with MATLAB software. The results were plotted in MATLAB for both the sensors during cough sequence against amplitude and time. The normal amplitude range for cough signal is 0.5 mV to 1 V. The normal cough and cold cough waveform were plotted separately using electrodes lace at the thoracic , tracheal and abdominal regions and their amplitude peaks were compared.

Figure 3.1 Normal cough sequence in tracheal region

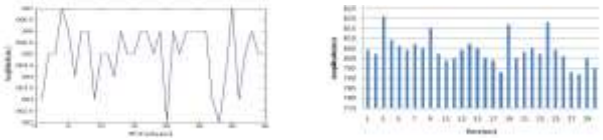

Figure 3.2 Normal cough sequence in thoracic region

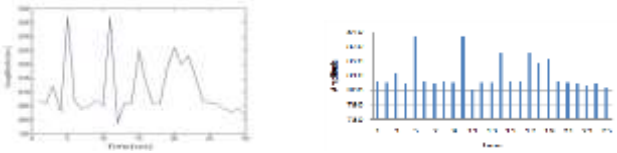

Figure 3.3 Normal Cough sequence in abdominal region

Figure 3.4 Normal Cough sequence for vibrational sensor

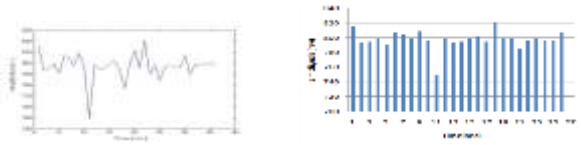

Figure 3.5 Cold Cough sequence in tracheal region

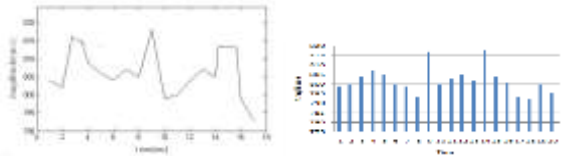

Figure 3.6 Cold Cough sequence in thoracic region

Figure 3.7 Cold Cough sequence in abdominal region

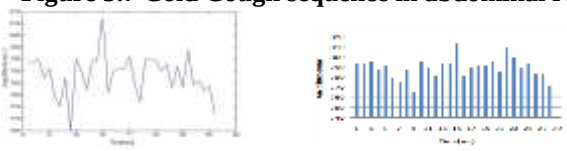

Figure 3.8 Cold Cough sequence for vibrational sensor

IV CONCLUSION

The amplitude range of the cough sequence for normal and cold were recorded and the results were tabulated below.

Regions	Tracheal	Thoracic	Abdominal	vibration
Amplitude (mv)	812	807	834	803

Table 4.1 Cough amplitude during normal cough sequence

Regions	Tracheal	Thoracic	Abdominal	vibration
Amplitude (mv)	820	817	852	812

Table 4.2 Cough amplitude during cold cough sequence

Regions	Tracheal	Thoracic	Abdominal	vibration
Amplitude (mv)	99.024%	98.776%	97.88%	98.89%

Table 4.3 Percentage deviation between normal and abnormal cough events

From the three graphs we note that the vibrational sensor activity placed in the chest region is almost the same with an amplitude of 800mv. But the EMG sensor activity in three regions is different with the highest amplitude peak of 835mv in the abdominal region (lower lung). The same can be done for abnormal activity of cold sequence. We note in cold sequence also the highest amplitude is near lower lung region(abdominal region) of 853 mv. On comparison we find that there is an increase in the amplitude range between normal and abnormal and the percentage deviation is about 97.88%. The same can be applied for other pulmonary diseases and a comparative study can be done through signal processing techniques.

V FUTURE SCOPE

In this proposed system cough monitor to record the vibrational and EMG activity for normal case has been done using MATLAB software. This work can be extended by analyzing the waveform pattern for various pulmonary diseases using signal processing techniques and classify them using neural network and artificial intelligence.

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