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Smart Portable Monitoring Device for Asthma Patients

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Abstract: Asthma is a life time chronic disease taking off to anomalous lung functions and difficulty in breathing. About 350 million people, which is equivalent to 1 in every 12 adults, suffer with asthma worldwide. Self-monitoring is the preliminary course of action to monitor, treat and control the chronic disease. Self-monitoring jointly helps physicians and patients to have control over real time monitoring and to provide on-time treatment. Classical spirometry test is currently the preeminent way to diagnose severity of lung functions and their response to treatment, but it requires supervision. Currently portable devices are available to monitor Peak Expiratory Flow, but it is expensive and inconvenient to use. The proposed system namely Smart Portable Monitoring Device for Asthma Patients helps to track real time symptoms of asthma and to make instant changes in medications. The developed system overcomes the shortcomings of existing system by home monitoring the lung functions and patient's environmental parameters over time without any supervision as in standard spirometry test. The proposed system includes portable hardware unit to monitor patient's activity, carbon dioxide content, exhaled air pressure and environment temperature of the asthma patient. The system also comprises of Android software application, through which physician can have real time track on parameters. Physician can send the results of medical evaluations through messages, which can be viewed by patients in display unit or mobile phones. The design and results shows that using sensors and a software application in mobile phones we can have a sufficient and real time monitoring on the symptoms of the asthma patients.

Key words: PEF · Wi-Fi · GSM · CO_2 · NTC · Pressure android · Activity

INTRODUCTION

Asthma is a lingering lung disease, which is pigeonholed by recurrent occurrence of shortness in breathing, wheezing, irritation in airways, etc. The severity and frequency of the lung disease varies from individual to individual and also depends on the age group. The persistent attack of disease causes swell in the lining of the air passages intending the airway to narrow down thus plummeting air flow in and out of the lungs. Hygiene Hypothesis, Atopy (a natural tendency to develop antipathies), childhood respiratory infections, aerial allergens or infant viral allergies are all the main causes of bronchial asthma. [1, 2] According to WHO (World Health Organization) around 230 million people suffer with the lung disease called asthma. Around 80% of death occurs in middle and low income countries. In developing countries such as India, it is estimated that about 15-20 million people are asthmatics. Roughly it is estimated that 10%-15% asthmatics are 5 to 11 year old children. Under the developing countries category about 20% people in Kenya are affected by this lung disease. In countries like Brazil, Peru and Panama, it estimates up to 20%-30% children. [3] While considering developed countries the situation greatly differs in the fact about 3 million asthma patients are in Japan of which 7% has severe and 30% has mild and moderate asthma. In Germany it is estimated to about 4 million asthma patients. In United States, 60% leapt in asthmatics every year since 1980's. [4]

The Global Asthma Network suggests diagnosing and monitoring bronchial asthma symptoms at earlier stages is the best way to control the lung disease. Earlier stage control is necessary because asthma is a life time disease and it cannot be cured. Now-a-days most health care professionals diagnose and monitor severity of

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symptoms and responsiveness to treatment through spirometry and measuring PEF (Peak Expiratory Flow) rate. Both these test measurements require supervision from experts. Expert supervision is absolutely important in this scenario, but daily visit to health care centers is extremely impossible. This inability can be greatly tackled by considering advance technology portable devices. Recent advancements in wireless sensor systems, software application developments and smartphones paved the gateway for real time monitoring of patient's health condition. The wireless data transmission to medical experts helps to diagnose and monitor disease symptoms at earlier stage. Physiological monitoring of asthmatics using various sensors and smart mobile devices is prominently increasing. These monitoring devices act as an opportune method to measure parameters thus improving healthcare.

The main aim of this paper is to design a portable, low cost and easily accessible device for asthmatics. A portable asthma monitoring device developed includes an accelerometer sensor to monitor the activity of asthma patient. The device also includes sensors to monitor temperature, air pressure and carbon dioxide (CO_2) content around the asthma patients. Other than the hardware unit, an application for smart phones is also been developed to view the examination results in smartphones, tables, etc. The developed software application displays the observed parameters and maintains a database, which helps to keep patient's history up-to-date. In future, the device can be further developed by incorporating various chemical biomarkers to virtualize the actual spirometry test.

Background Works: Zhe Cao *et al* in the year in the year 2012 proposed a work on micro sensors based wireless portable device to monitor the respiratory diseases. [5] The proposed system consists of two integrated sensor nodes with Bluetooth transmission medium to wirelessly transmit the sensed data. The sensors used are micro-film sensors to monitor and diagnose the asthma symptoms. The system developed acts as a spirometer and as a sleep recorder to diagnose the pulmonary diseases. The main drawback of this system is that Bluetooth module is used to wirelessly transmit the data, which can only transmit to a shorter distance.

Daniel Tecihmann *et al* in the year 2014 proposed a study on wearable and bendable cardiorespiratory monitoring device by merging two noncontact sensor standards. [5] The study proposes a wearable device which can be held in the patient's shirt pocket. In order to get the optimum performance the device has to combine the standards of two sensors in noncontact way by invoking into several layers of textiles used by the patient. One sensor focuses on respiratory monitoring and the other sensor focuses on pulse detection. The main drawback of this study is that only two parameters are into consideration and real time monitoring is not taken into study.

Jun Luan *et al* in the year 2015 gives an overview of sternocleidomastoid muscle contraction for asthma assessment and control. [6] This study proposes the low power detection of muscle contraction near the neck area during inhalation of air. In this study a wearable monitoring device has been developed using LED and photo detector. The experimental result of this study explains the simplification of hardware design thus showing reduction in power consumption in monitoring parameters. This paper focuses on development of wearable device to monitor abnormal sternocleidomastoid muscle contraction during the lung disease asthma which is a sign of further respiratory problems.

Chinazunwa UWAOMA *et al* in the year 2015 proposed a work on monitoring and detection of asthma symptoms on resource constraint mobile device [7]. The work comprises of a resource oriented mobile device to monitor various physical and environmental factors of the asthma patients. The work concentrates on available sensors and modules in a mobile device to monitor asthmatics medical parameters, physical activities and environmental factors. The medical records are been stored in the same mobile device for patient's assistance. An algorithm is also developed to analyze the physical activity and breathe pressure. The study carried out in this paper can only be worked out in a smartphones readily available in the market. Eventhough it is a portable mobile device, the actual working scenario is been constrained within a single mobile device.

Alice M. Kwan *et al* in the year 2015 proposed a study on monitoring lung functions using a portable device. [8] The study was based on monitoring the lung functions using noninvasive chemical biomarkers to monitor various measurements from the exhaled breath. This study includes the pressure measurements in the graphical format, which on most cases is not understandable by the normal persons. The other factors which inflict on asthma patients are temperature and physical activity, which is not be taken into concentration in this study.

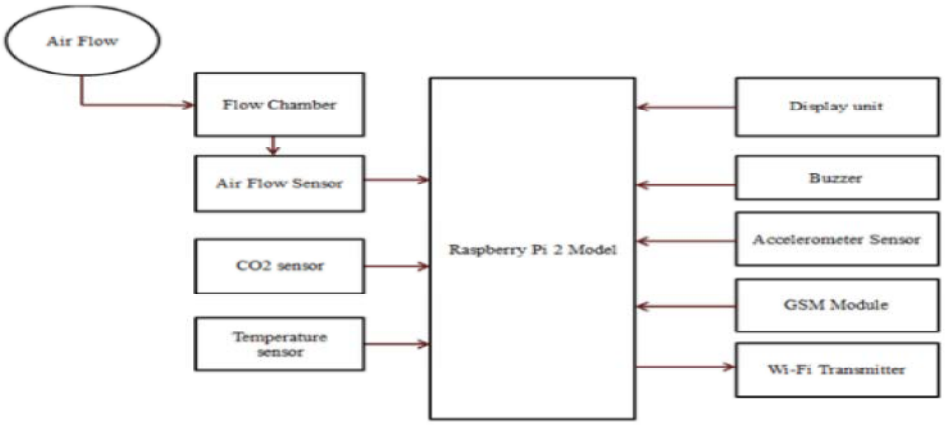

Fig. 1: Block Diagram of Patient Side Module

System Design: The proposed design, namely "Smart Portable Monitoring Device for Asthma Patients" uses Raspberry Pi, a digital computer to monitor and analyze the asthma symptoms in asthmatics. The downsides of the previous works are provided with a solution by considering all scenarios. The proposed system involves a hardware unit interfaced with various sensors in the patient side and an android software application in the physician side. The android application helps to monitor and diagnose the symptoms of asthma in the patients through real time monitoring. Modification in medicines can be achieved through real time monitoring and diagnosing symptoms at the earlier stage. As asthma is a non-curable disease but it can controlled by examining disease indications at the earlier stage.

Proposed System

Patient Side Module: Figure 1 shows the Block diagram of the Patient Side module. The hardware unit in the patient side senses the various parameters of asthmatics and environment of asthmatics through corresponding sensors interfaced with the processing unit. The processing unit is the Raspberry Pi 2 model integrated with BCM2836 by Broadcom, an ARM 7 architecture based microcontroller. [16] The activity of the patient is observed through a tri-axial accelerometer sensor, where depending upon the patient's physical activity, the sensor results will vary. If any abnormal activity is identified a buzzer will buzz to indicate the patient's supervisor about the abnormality.

Environmental temperature is an essential parameter to be scrutinized for self-monitoring. A thermistor, a temperature sensitive resistor is used to measure the environmental temperature. It is a negative temperature coefficient (NTC) thermistor; that is as temperature increases, resistance decreases. The temperature is an important aspect, whether it is a low temperature or a high temperature it may invoke breathing problem. The other parameter is the air pressure, which is monitored through air flow sensor. The pressure is measured through the exhaled air. The air pressure sensor results are taken in the form of pulses/minute. Depending upon the number of pulses, the severity of the asthma can be detected. The next parameter is the carbon dioxide content around the asthmatics. A sensor with corresponding amplifier unit is interfaced with the controller to detect the level of carbon dioxide.

Physician Side Module: Figure 2 shows the Block diagram of the Physician Side module. The other part of the system is the android application in the physician side. An android application is been developed to examine the medical parameters. The medical parameters are sensed by the hardware unit in the patient side through various sensors and sent to the physician side through Wi-Fi module. The transmitted parameters are viewed on the android application. A database associated with the application is managed to maintain the patient's medical record and history. After the examination and diagnosis of the medical parameters, the physician can manually send a message through GSM to the hardware unit about the actual status of the asthmatics which can be displayed in the display unit of the patient hardware unit.

Software of the Proposed System

Android Application Software: Real time analysis of the asthmatics is accomplished through android application software developed. The developed application software

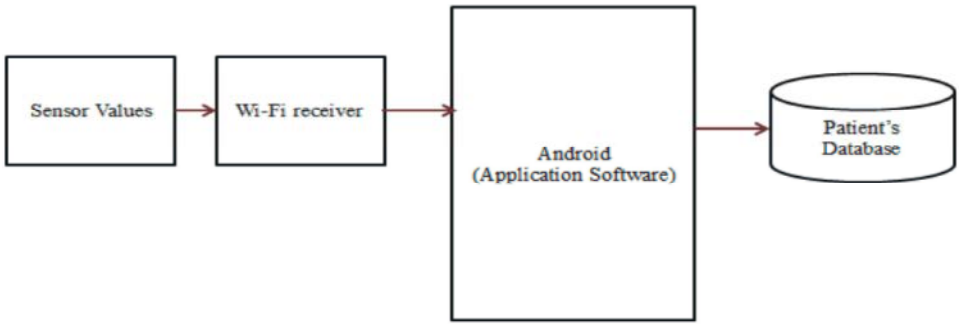

Fig. 2: Block Diagram of Physician Side Module

associates a patient's database to maintain medical record. The application software is developed through Android Studio and database through SQLite. The Android Studio has pick and drag functionality, so depending upon the need the application can be easily developed. The Android application developed is used by the asthmatics doctors or physicians to monitor the preliminary asthma symptoms present in the asthmatics. Quick, easy, efficient and effective data analysis is achieved through android application. Android Studio helps us to virtually view the android application developed, so actual working virtualization of android application is achieved. Wi-Fi acts as transmission medium, where sensed and collected sensor results are received through Wi-Fi in the mobile phone and displayed on the associated text boxes in the android application [9].

Software Algorithm: The software algorithm for detecting and analyzing the asthma symptoms is as follows:

- Configure a static IP to the raspberry pi board.
- Include header files and macros for interfacing sensors, LCD and to initiate serial communication.
- Initialize the GPIO header to interface the GSM module.
- Initialize the ADC to get the analog output values from the sensors.
- Allocate the digital port to collect data from sensors and transmit it to the physician side.
- Check the temperature value.
    - If the temperature value < 16ºC, "Temperature is low" is displayed in the display unit
    - If the temperature value > 35ºC, "Temperature is high" is displayed in the display unit.
    - If the temperature value is >16ºC and <35ºC, "Temperature is normal" is displayed on the display unit.
- Check the carbon dioxide value.
- If the carbon dioxide value > 600ppm (80cfm), "Carbon dioxide content is high" is displayed on the display unit.
    - Check the pressure value.
- If the pressure value is <100 pulses/min, "Asthma is mild" is displayed in the display unit.
- If pressure value is within 100-120, "Asthma is moderate" is displayed in the display unit.
- If pressure value >120 "Asthma is Severe" is displayed on the display unit.
    - Check the accelerometer values. If any sudden variations are sensed by the sensor, buzzer is set high.
    - Use Android Studio to develop the android application in the physician side.
    - The sensed data on the patient side are sent to the android application through Wi-Fi and viewed.
    - The message sent by the physician is received through GSM and viewed in the LCD display unit on the patient side.

RESULTS

Experimental Results: The proposed system "Smart Portable Monitoring Device for Asthma Patients" is been developed and some preliminary results are been obtained. In the developed system, two modules are developed. One module is the asthmatics hardware unit and the second module is physician side android application software.

Patient Side Hardware Unit: The asthmatics hardware unit associates interfaced sensors and communication modules for sensing medicinal parameters and data communication. The developed system of asthma portable monitoring system is shown in Figure 3.

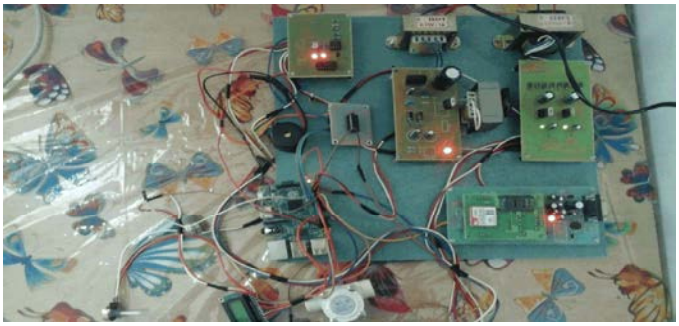

Fig. 3: Overall System of the Patient module

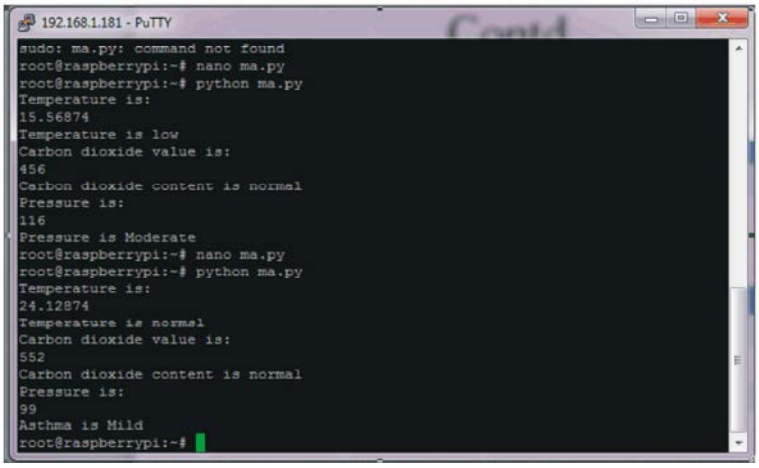

Fig. 4: Python Results

Fig. 5: Titration Result of Accelerometer sensor

Depending upon the environmental, physical and medical condition of the asthmatics, results obtained from the sensors will vary. An algorithm is been developed to monitor and diagnose various parameters of asthmatics and desired results are displayed in the display unit as shown in the Figure 4.

The physical activity of the asthma patient is monitored through I2C interfaced tri-axial accelerometer sensor. The result of change in titration is shown in the Figure 5.

Physician Side Software Application: An android application on the physician side is developed using Android Studio. This application mainly helps to view the

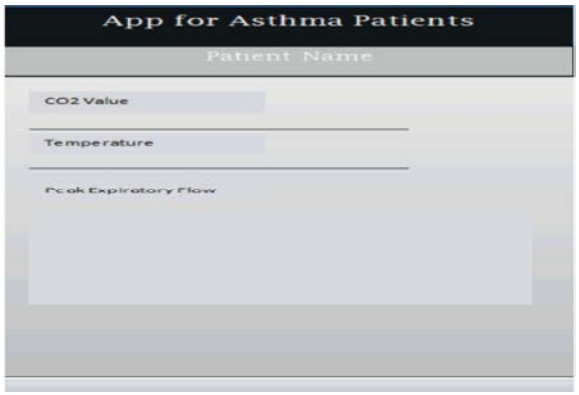

Fig. 6: Front End of Android Application

Table 1: Temperature Analysis

Temperature	Result
<16°C	Temperature is Low
>16 °C and <35 °C	Temperature is Normal
>35 °C	Temperature is High

sensed results from the patient hardware unit. Front end view of the application developed is shown in the Figure 6.

Result Analysis

Analysis of Temperature: Body temperature or environmental temperature, whatever it is so; it is a very important concern in today's medical field. Especially for asthmatics, very low temperature or very high temperature leads to effect of respiratory problems, in specific shortness in breath. Asthmatics should always stay in a normal temperature field. The following Table 1 shows analysis in temperature variations for asthma patients.

In this experimental setup, a Negative Temperature Coefficient (NTC) thermistor is interfaced with the processing unit to measure the temperature. As name implies the resistance value of the thermistor decreases as temperature increases, along with it the analog output voltage will increase in association with temperature. The sensitivity of thermistor varies from -55 °C to 120 °C. The voltage in variation will be from 0V to 5V. The analog voltage variation mainly depends upon the input supply voltage and the variance resistance of the thermistor used. The Figure 7 shows the graphical analysis of temperature vs. corresponding output voltage from thermistor.

The next graph, Figure 8 shows variations in resistance as temperature varies. The result shows decrease in resistance as the temperature increases as the effect of negative temperature coefficient of thermistor.

Fig. 7: Temperature vs. Output Voltage

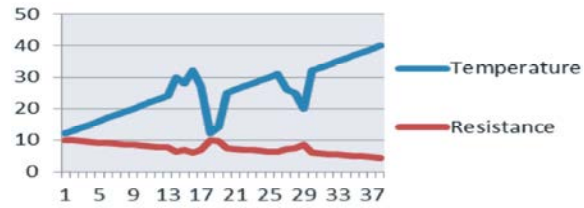

Fig. 8: Temperature vs. Resistance

Table 2: Carbon dioxide Analysis

Carbon dioxide Level	Result
> 600ppm	Carbon dioxide level is high.
< 600ppm	Carbon dioxide level is normal

Table 3: Air Pressure Analysis

Pressure	Result
<100 pulses/min	Asthma is Mild
Between 100 and 120 pulses/min	Asthma is Moderate
>120 pulses/min	Asthma is Severe

Analysis of Carbon Dioxide: The level of carbon dioxide from the exhaled air and environmental space leads to serious issues in asthmatics. People suffering with asthma should inhale good oxygen and reside in air free space in order to stay away from respiratory problems. Table 2 shows the analysis results of carbon dioxide level.

A CO_2 sensitive sensor is integrated on the patient side to detect the carbon dioxide level. Depending upon the results obtained it is analyzed that when the CO_2 level is more than 600ppm, the asthmatics will feel discomfort in breathing.

Analysis of Air Pressure: Breathe air pressure is analyzed by finding out the pressure of the exhaled air through an air flow sensor. Depending upon the volume if the air, pressure values are examined through the number of pulses/minute. Table 3 shows the pressure values, which determines the severity of the asthma disease in asthma patients.

CONCLUSION

The proposed system namely Smart Portable Monitoring Device for Asthma Patients monitors and

diagnoses the lung disease specifically asthma in asthmatics. The portable device, with the assistance of its hardware module detects various medicinal parameters and determines the severity of respiratory disease. Real time monitoring is achieved through an Android App on the physician side. The sensed data are sent to the android app through Wi-Fi interfaced on the patient module. The physician after examining the results can communicate the change in medications and severity of disease through manual messages. The messages are received through GSM module and displayed to the patients. Quick and effective way of asthma examination is achieved by the developed device. The developed system is very cost efficient, reduces time consumption and easy to handle.

Future Work: The developed system achieves the real time monitoring through a portable hardware module and an android application. The module developed monitors the basic respiratory and environmental factors. Along with it there is a small unit to monitor the physical activity. In future, advanced respiratory monitoring will be taken into consideration. Advanced respiratory monitoring for early asthma diagnosis will be achieved by using gas biomarkers through which breathe analysis will be carried out. Efficient breathe analysis algorithms will be developed to determine wheeze detection, chest tightness and other lung problems. The work will be carried out to exactly resemble the spirometry test carried out in the medical centers.

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