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IoT Based Breath Monitoring System Using Foil Sensor

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ABSTRACT

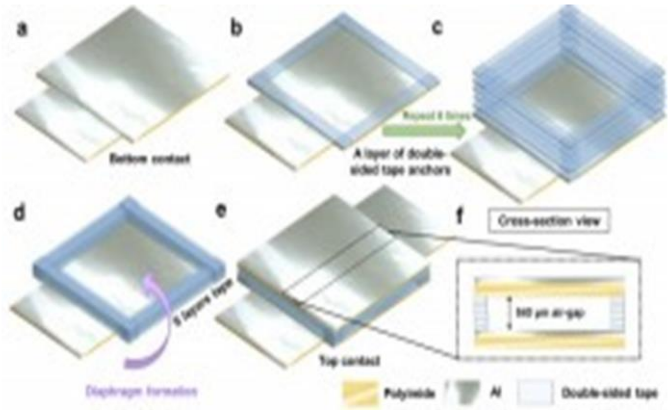
Health is the prime significance in our routine life. The Internet of Things has given a much simpler answer for remote continuous wellbeing check of patients from the clinic, just as at home. The other important thing in our project is the plan of sending the warning via Email and SMS alert, if any of the health parameters crosses the limit esteem. Traditional breath monitoring methods rely on wearable devices which are intrusive and uncomfortable. Here, We have used a flexible acoustic sensor that has been designed to detect breath level while attached to the chest of a human. The sensor has a parallel plate capacitive structure using air as the dielectric material. Secondly, the design itself acts as a low pass filter to reduce the effect of background noise which mostly lies in>1000Hz frequency range. The resulting analog interface is minimal and thus, consumes less power and occupies less space. The sensor is made up of low-cost sustainable materials (aluminum foil) which greatly reduces the cost and complexity of manufacturing processes. The sensor is connected to a smartphone via Wi-Fi, enabling signal processing and further integration into digital medical electronic systems based on the Internet of Things (IoT). This system is capable of sending current location to the doctor and delivering oxygen to the user in case of any emergency. The sensor which we used also measures and displays the temperature and humidity level.

Keywords- Breathing. Wireless. Foil. Low-Cost. Healthcare. Flexible.

I. INTRODUCTION

About 334 million people were affected by asthma as of 2014, and the number continues to climb. If a patient experiences three or more wheezing episodes in a year, they are diagnosed with active asthma. A study showed that asthma can be diagnosed at an early stage using non-invasive practices by monitoring the airway resistance in the trachea. The airway resistance produce wheezing characterized by musical, sinusoidal sounds superimposed on breathing with frequencies of 100-1000 Hz and duration of >250ms. Similar to the behavior of sound, wheezing -travels through a medium in the form of pressure fluctuations. Thus, an acoustic sensor can be used to detect wheezing or any other breathing problems.

The most familiar method used in health monitoring wearables for wheeze detection is electrocardiography (ECG).. The output voltage signal from the ECG electrodes is in the order of a few millivolts. Thus, they require amplification and signal conditioning circuitry before the data can be fed to a microprocessor. This increases the size and power consumption of the overall system. Soft materials have been used to detect human vocalization using muscle movements. For example, woven graphene fabric is used to monitor throat muscle movement in response to sounds originating from the neck. Some other flexible sensors used to collect reliable acoustic data include single-walled carbon nanotube (SWNCT) embedded in a hydrogel and nanowires grown on polytetrafluoroethylene (PTFE) films. However, additional sensors are required to interpret their data. Additionally, the graphene/CNT-based sensors require complex fabrication processes that increase the cost. Microphones proven to be the most practical solution to acquire sounds from the neck or chest. They are placed on the neck to monitor vital signs and ingestion habits. However, microphones based wearable devices are stiff, which makes them less comfortable to use for long intervals of time as a disease monitoring wearable. The sensors have small dimensions to reduce the high costs associated with silicon processing equipment and the silicon material itself. It results in a high resonance frequency (in the kHz range) diaphragm with small output signals. Thus, they require signal amplification circuits, which introduce additional noise in the system that must be reduced by added signal conditioning circuits. Thus the use of a higher resonance frequency diaphragm is made so that the sensor can respond to the large audible frequency range of an average human (20 Hz 20 kHz). This is desirable for microphones as they are intended to record human speech. However, in the case of wheezing, it is more beneficial to have a specialized acoustic sensor that is low-cost, minimalistic, consumes less power, and responds in the wheezing frequency range (100Hz-1000Hz). For that, a large diaphragm is needed to made with low-cost materials to get a low resonance frequency with a high signal to noise ratio.



Crumpling of Al foil–based sensor after normal handling.

Fig. 1. Fabrication of the sensor. (a) Cutting the sheet to make bottom contact. (b) Placing a thin layer of 90 μm double-sided tape at the edges. (c) Repeating step six times to get a 540 μm height. (d) Placing the top contact in line with the edges of the bottom plate and the double-sided tape. (e) Illustration of the fabricated sensor. (f) Cross-section view of the sensor showing how the tape creates an air space between the two sheets.

We present a flexible acoustic sensor that has been designed to detect breath rate while attached to the chest of a human. The sensor has a parallel plate capacitive structure using air as the dielectric material. The acoustic waves from breathing vibrate the top diaphragm of the structure, thereby, changing the output capacitance. The sensor is designed such that it resonates in the frequency range of 100-1000Hz (Breath Rate) which presents two fold benefits.

(i) The resonance results in large deflection of the diaphragm that eradicates the need for using signal amplifiers (used in microphones).
(ii) Secondly, the design itself acts as a low pass filter to reduce the effect of background noise which mostly lies in >1000Hz frequency range. The

resulting analog interface is minimal and thus, consumes less power and occupies less space.

The sensor includes low-cost sustainable materials (aluminum foil) which greatly reduces the cost and complexity of manufacturing processes. The (Matched filter) algorithm is used to identify different types of wheezing sounds among the noisy signals originating from the chest that lie in the same frequency range as wheezing. The sensor is connected to a smartphone via IoT.This model also facilitates remote monitoring of the patient . This system consists of a camera and a GPS tracking system to help in times of emergency . This allows us to monitor the patient irrespective of their location. During emergencies the system allows us to track the patient's location and to monitor them without being physically present.The system also consists of a solenoid valve which works during emergency by providing oxygen supply when the breath rate becomes abnormal. We also added a DHT11 sensor to measure and display the temperature and humidity level of the surrounding.

II. DESIGN AND FABRICATION

A. Fabrication of Wheezing Sensor

Sound traverses in the air in the form of pressure fluctuations produced by acoustic waves. We have thus created an acoustic sensor in the form of a parallel plate capacitor where an air gap between the two parallel plates acts as the pressure-sensitive dielectric material. Acoustic waves put pressure on the top movable diaphragm, thereby, reducing the thickness 'd' of the air gap which in turn increases the output capacitance 'C',as expressed by Equation 1.

$C = \varepsilon 0 \varepsilon r A/d$ eqn 1

Where $\varepsilon r = 1.0006$ and $\varepsilon 0 = 8.854x10-12$ F·m−1

Due to the high compressibility of air, commercial parallel plate based accelerometers also use air gap as the pressure sensitive dielectric material [24, 25]. The high compressibility factor of air allows the air gap based capacitive structure to respond to the extremely low pressures of acoustic waves. We have adopted a low-cost method, compatible with large-scale manufacturability, to make the sensor structure.

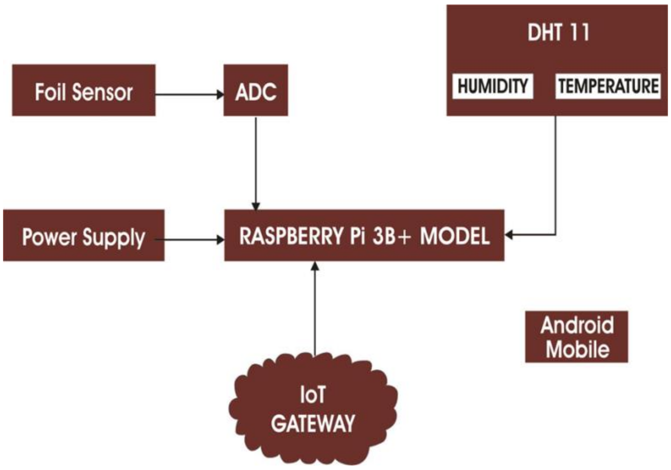
B. Selection of Sensor Material

Aluminum foil is cheap, readily available, and responds reliably to pressure. Although it is made up of metal, aluminum foil tends to crumble and deform very easily after undergoing normal wear and tear due to its small thickness. A thin metal film has less elastic strength and bends easily, as the elastic modulus is inversely proportional to the cross-sectional surface area. The crumpling (plastic deformation) of the aluminum metal film after prolonged usage can be observed in Fig. 1j. Thus, we tested different diaphragm materials: copper (Cu) foil, aluminum (Al) foil, Al on PET (Polyethylene terephthalate), and Al on polyimide (PI) to find a more versatile metal foil. The Al and Cu metal foils showed buckling and dents after prolonged usage. Al on PET and PI showed higher mechanical strength due to the mechanical rigidity provided by polymers. Al on PI exhibited maximum displacement with the application of pressure. Therefore, we decided to use the commercially available Al metalized PI film, Liren's LR-PI 100AM, in order to improve the strength of the diaphragm while maintaining the useful characteristics of aluminum foil. PI is a flexible substrate with high thermal and mechanical stability that acts as supporting and carrier film for the Al, while Al provides the relevant conductivity necessary for the formation of a capacitor. Also, Liren's LR-PI 100AM is thin, consisting of a 200 nm thick Al on top of a 25 µm thick PI.

III. BLOCK DIAGRAM

DESCRIPTION:

This is the general layout of our project. Here we used two types of sensors. One of the sensors is a flexible acoustic sensor (Foil Sensor) which senses the change in breath rate. The sensed signal is then passed through an ADC and given to the Raspberry Pi. The other sensor (DHT11) senses humidity and temperature. This information is then sent to Raspberry Pi. The Raspberry Pi processes the signal and sends it to an Android mobile via IoT Gateway.



IV. MODULE DESCRIPTION

A. Raspberry Pi 3B+

Raspberry Pi 3 B+ is a tiny computer which is connected to external monitor, keyboard and a mouse.The Raspberry Pi 3 Model B+ is the latest product in the Raspberry Pi 3 range, boasting a 64-bit quad core processor running at 1.4GHz, dual-band 2.4GHz and 5GHz wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and PoE capability via a separate PoE HAT.

The dual-band wireless LAN comes with modular compliance certification, allowing the board to be designed into end products with significantly reduced wireless LAN compliance testing, improving both cost and time to market. The Raspberry Pi 3 Model B+ maintains the same mechanical footprint as both the Raspberry Pi 2 Model B and the Raspberry Pi 3 Model B.

B. Raspberry PI 3B+ Camera

The Raspberry Pi Camera Module v2 replaced the original Camera Module in April 2016.The v2 Camera Module has a Sony IMX219 8-megapixel sensor(compared to the 5-megapixel OmniVision OV5647 sensor of the original camera). The Camera Module can be used to take high-definition video, as well as stills photographs. It's easy to use for beginners, but has plenty to offer advanced users if you're looking to expand your knowledge. There are lots of examples online of people using it for time-lapse, slow-motion, and other video cleverness. You can also use the libraries we bundle with the camera to create effects.

The camera works with all models of Raspberry Pi 1, 2, 3 and 4. It can be accessed through the MMAL and V4L APIs, and there are numerous third-party libraries built for it, including the Picamera Python library. See the Getting Started with Picamera resource to learn how to use it. The camera module is very popular in home security applications, and in wildlife camera traps

C. Wifi Module NodeMCU

NodeMCU is an open source firmware for which open source prototyping board designs are available. The name "NodeMCU" combines "node" and "MCU" (microc unit). The term "NodeMCU" refers to the firmware rather than the associated development kits. ESP8266EX offers a complete and self-contained WiFi networking solution; it can be used to host the application or to offload WiFi networking functions from another application processor. When ESP8266EX hosts the application, it boots up directly from an external flash. It has integrated cache to improve the performance of the system in such applications.

D. Foil Sensor (Metal Foil)

Metal foils are mostly preferred, because of several characteristics, including lower chemical sensitivity, lower air and moisture permeability, and the ability to withstand higher process temperatures. When selecting a metal foil substrate, the following primary properties should be considered: the coefficient of thermal expansion (CTE), surface roughness, chemical sensitivity, and maximum process temperature. These properties should be compatible with the materials that comprise the devices built on the substrate.

E. DHT11 Sensor

DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It's fairly simple to use, but requires careful timing to grab data. You can get new data from it once every 2 seconds.

F. GPS (UART GPS NEO-6M)

The NEO-6 module series is a family of stand-alone GPS receivers featuring the high performance u-blox 6 positioning engine. These flexible and cost effective receivers offer numerous connectivity options in a miniature 16 x 12.2 x 2.4 mm package. Their compact architecture and power and memory options make NEO-6 modules ideal for battery operated mobile devices with very strict cost and space constraints. The 50-channel u-blox 6 positioning engine boasts a Time-To-First-Fix (TTFF) of under 1 second. The dedicated acquisition engine, with 2 million correlators, is capable of massive parallel time/frequency space searches, enabling it to find satellites instantly. Innovative design and technology suppresses jamming sources and mitigates multipath effects, giving NEO-6 GPS receivers excellent navigation performance even in the most challenging environments.

G. Electric Solenoid Actuator

Solenoid Equipment used to convert electrical signals or electric currents into mechanical linear motion. Made of the movable coil and iron core. The pulling and pushing strength is determined by the number of turns on the coil. An important aspect of the solenoid is a jolt. A small jolt will produce a high level of operation, and the power needed is also small. The solenoid Valve is a combination of two basic functional units, namely,

1. Solenoid with core and component
2. The valve body where there are plates/plugs positioned to stop/flow the flow.

The flow can flow depending on the core movement and depends on whether the solenoid has flowed or not. If the current flows, the coil will push the core to open the channel/valve, and when it is not flowing, the channel will be closed.

H. Relay

Relay is an electromechanical device that uses an electric current to open or close the contacts of a switch. The single-channel relay module is much more than just a plain relay, it comprises components that make switching and connection easier and act as indicators to show if the module is powered and if the relay is active or not.

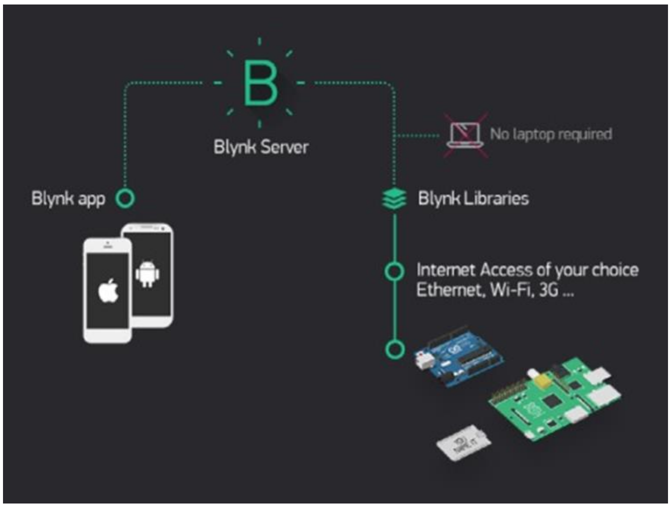
There are two advantages of this system – First, the current required to activate the relay is much smaller than the current that relay contacts are capable of switching, and second, the coil and the contacts are galvanically isolated, meaning there is no electrical connection between them. This means that the relay can be used to switch mains current through an isolated low voltage digital system like a microcontroller.

I. BLYNK

Blynk is a Platform with iOS and Android apps to control Arduino, Raspberry Pi and the likes over the Internet. It’s a digital dashboard where we can build a graphic interface for our project by simply dragging and dropping widgets. It’s really simple to set everything up and we'll start tinkering in less than 5 minutes. Blynk is not tied to some specific board or shield. Instead, it's supporting hardware of our choice.

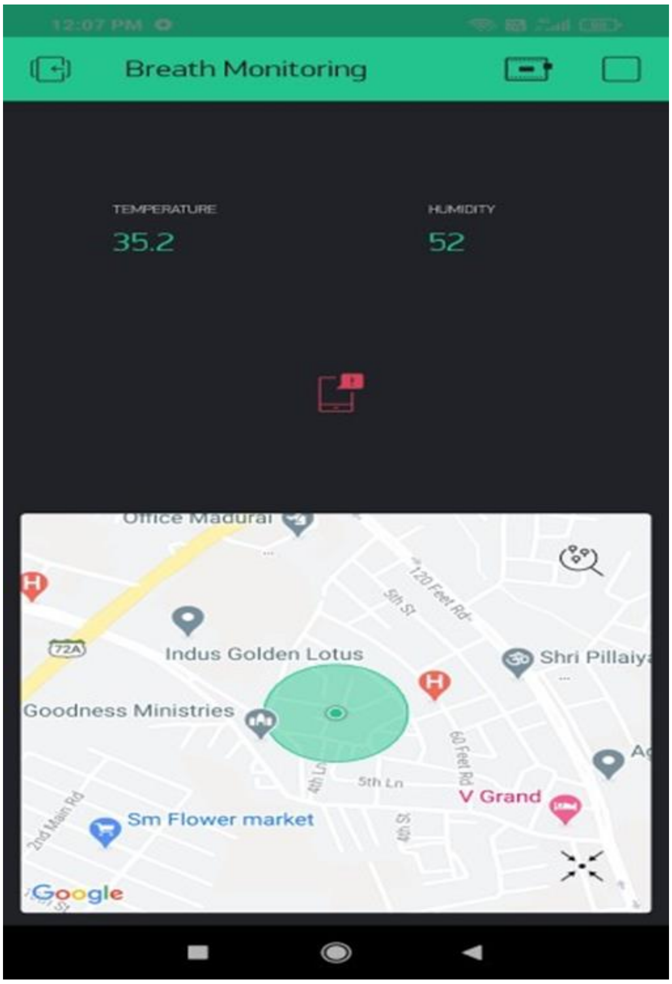
Blynk Server

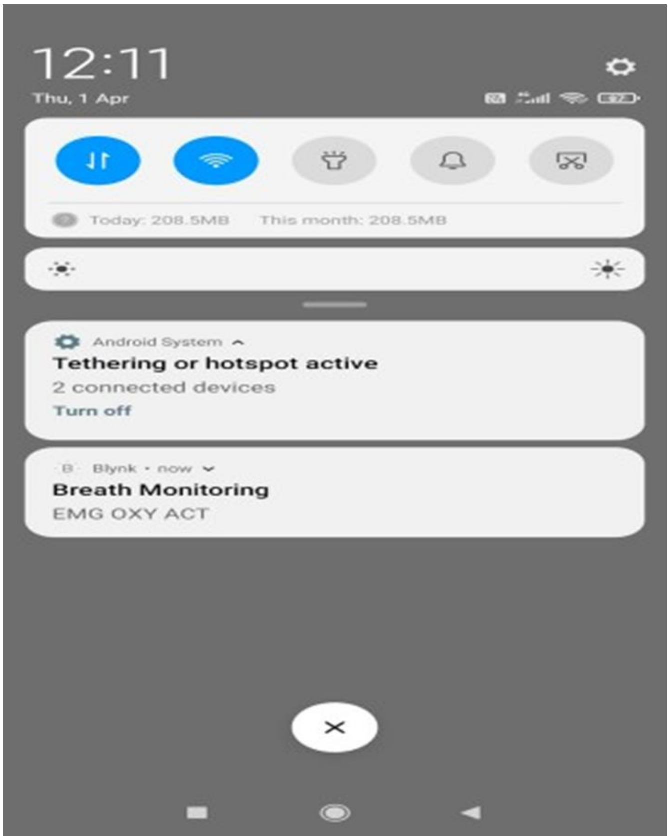
Responsible for all the communications between the smartphone and hardware. It's open-source, could easily handle thousands of devices and responsible for forwarding messages between Blynk mobile application and various microcontroller boards (i.e. Arduino, Raspberry Pi. Etc.,). Blynk Cloud is software written on Java using plain TCP/IP sockets and running on our server. Blynk iOS and Android apps connect to Blynk Cloud by default. Access is free for every Blynk user.



V. RESULTS AND DISCUSSIONS

The below sample gives a clear view of our IoT based Breath monitoring system using Foil sensor. As described earlier, the dht11 sensor provides the reliable temperature and humidity level. The current location can be accessed anytime by using Neo 6m Gps module.This system also delivers oxygen to the user in case of any emergency. whenever the foil sensor experiences an abnormal breathing rate, it gets triggered and provides notification to the health care units.





VI. CONCLUSION

We have proven the utility and versatility of our low-cost sensor for the potential application of breathing episode detection in point-of-care diagnostics. We demonstrate a proof-of-concept device with a specialized design to detect wheezing while being attached to the chest of a human. The cost and complexity of the manufacturing process are low because of the use of sustainable materials and a scalable manufacturing process. The circuit is less complicated compared to the alternatives, resulting in a reduced size and lower power consumption of the overall system. The smart design combined with the matched filter implementation forms a robust wheezing detection system that can detect wheezing among several real- life noise case scenarios. The flexibility of the sensor allows it to conform to irregular shapes so that it can be attached non-intrusively to the human chest. The low-cost sensor allows for integration at a large scale in the healthcare industry for real- time monitoring of patients that are at a risk for becoming asthmatic. The sensors are interfaced with Bluetooth enabled chip, which further allows integration in the Internet of Things (IoT) enabled systems for early intervention when a patient is having an asthma attack.

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