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E-Textiles for Screening Respiratory Disorders along with Temperature Monitoring

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ABSTRACT

This paper presents a branch of research where e-textiles is used for bio monitoring. This set-up is used for screening sleep apnea and to alert physicians when there is a case of Hyperthermia. This proposal is to monitor patients with respiratory disorders or diseases/disorders whose symptoms manifest as respiratory abnormalities and abnormal temperature, and make it available to the doctor by plotting the values in MATLAB. Conventional techniques used for screening and monitoring respiratory abnormalities include devices like cannula, nasal strips etc., which are grueling and strenuous, adding to the patients' suffering. The connection of this cutting edge electronics field with textiles will ultimately enable both the study of deviations in the breathing rate and temperature.

KEYWORDS: Lilypad, Velostat, E-textile, Ripstop conductive fabric, Lilypad temperature sensor, E-sewing

I. INTRODUCTION

Sleep apnea is a common disorder in which the person experiences one or more pauses in breathing, or has shallow breaths taken while sleeping. The pauses can last from a few seconds to a few minutes and may occur as frequently as thirty times or more in the space of an hour. Untreated sleep apnea increases the risk of high blood pressure, heart attack, obesity and diabetes.

The proposed method measures the breathing rate of the person and updates the data for the doctor's review. For diagnosis and monitoring, the doctor requires patient history.

Hyperthermia is the rise in body temperature due to the inability to maintain the body temperature when the body fails to dissipate more heat than what it absorbs. It is a medical emergency when the body can no longer regulate his/her internal temperature and this can lead to organ failures.

Traditional methods of respiration monitoring for sleep apnea use electrodes for this purpose, which need direct contact to the skin. Along with causing discomfort, the existence of numerous wires will restrict the freedom of movement of the patient. To accomplish the task of monitoring in a non-invasive way that doesn't cause distress to the patient, conductive fabrics are interfaced with electronics to make a breathing sensor.

Textiles are an excellent substitute to uncomfortable, bulky, restrictive methods of monitoring bio-signals as they are stretchable, flexible and light. Hence, they can be used for constant monitoring as wearable bio-monitors. Electronic textiles are an extension to the normal fabrics that we use every day. They can enable digital components and electronics to be embedded in them. They can be divided into two main categories:

i. E-textiles with electronics embedded in them
ii. E-textiles with electronics integrated directly to the textile substrate.

The first type has elements such as sensors and/or motherboard using which information can be transmitted or received. The second type includes thread, yarn and fabric that are passive circuits, meaning that they are either conductive or resistive elements.

The conductive fabric and velostat material are examples of the second type of e-textile.

II. BLOCK DIAGRAM AND PROCESS FLOW GRAPH

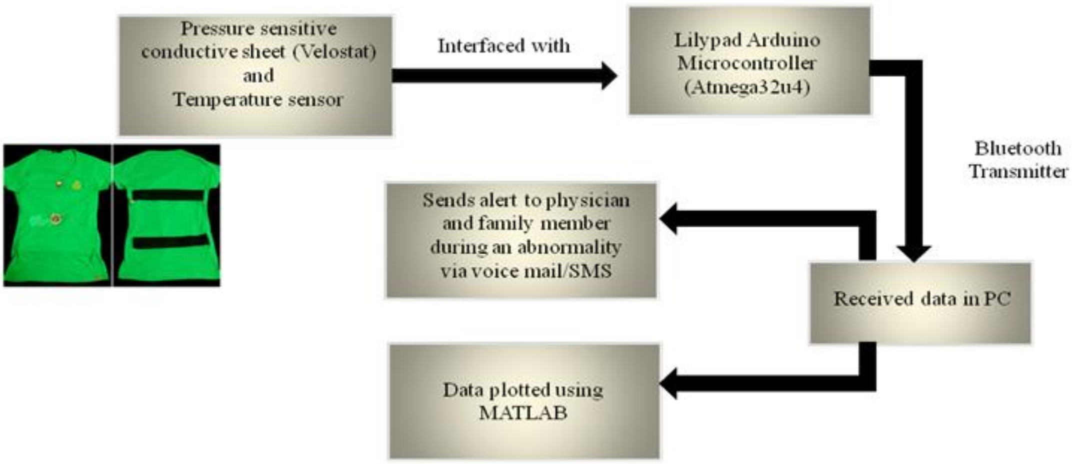

Figure 1: The overall block diagram of the system

A. SENSORS

Pressure sensitive conductive sheet, Velostat, along with Conductive fabric is used to fabricate a sensor to monitor the breathing rate of the person.

In addition to this, there will also be a temperature sensor placed at one of the armpits for the measurement of body temperature.

B. ARDUINO MICROCONTROLLER

A power supply of 3.7V is given from the coin cell battery to one end of the conductive fabric. The output from the two regions of conductive fabrics is given to input ports of the Lilypad simple board, and the microcontroller is programmed such that the average of the two outputs is computed. Similarly, the output from the temperature sensor is given to the input port.

During inhalation, as the chest and abdomen expand, the velostat gets squeezed. This reduces its resistance, rendering it conductive. The current that is applied at one end of the conductive fabric can be received at the other end of the second conductive fabric. The received current from the temperature sensor and respiratory sensors is translated as temperature and voltage reading and the same is displayed and plotted respectively.

C. BLUETOOTH

Bluetooth is a wireless technology for data transfer over short distances using short wavelength UHF radio waves. The communication is carried out at a frequency of 2.45GHz. This is in the ISM band which has been set aside for uses of Industrial, Scientific and Medical devices in an international agreement. Bluetooth works as a replacement for RS-232 cables.

Here, Bluetooth is used to transfer data from the Lilypad arduino kit to mobile phone or a personal computer.

D. GSM

In case of any abnormality, the microcontroller triggers the GSM module which consists of a SIM card and a transmitter system to send alerts to the pre-programmed numbers via SMS.

III. SENSOR CONSTRUCTION

Both of the two types of textiles, woven and non-woven can be employed to make the sensing element. Here, the conductive fabric is woven and the velostat is non-woven.

The Velostat sheet is sandwiched between two layers of conductive fabric. Squeezing it will reduce the resistance and thus, this set up works as a pressure sensor. The ends of the conductive fabric are attached to each of the two parts of the Velcro fasteners to provide adjustability. One of these is placed at the thoracic region and the other at the abdominal region due to varied breathing pattern of different people. The type of breathing is significant in different regions for different people.

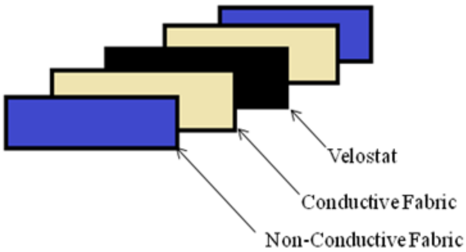

Fig 2: Illustration of the arrangement of conductive fabric and velostat in the respiratory sensor.

A. VELOSTAT

Velostat is an anti- static black, opaque, volume-conductive, carbon-impregnated polyolefin. The carbon black gives it the property of electrical conductivity. It is also called Linqstat.

Velostat is a piezo-resistive material. The piezo-resistive effect is the change of electrical resistance of a material under mechanical pressure. The decrease in resistance is stable but not linear. The sensitivity of a sensor using a velostat can be adjusted by adding layers of velostat.

The velostat can be used as a pressure sensor the way it is used in this project. Otherwise, it can also be used as a pressure sensor to measure the pressure that is caused by bending.

B. CONDUCTIVE TEXTILES

Conductive textiles are fabrics that can conduct electricity. These textiles are generally soft, like every other fabric. They can be used where soft, flexible and sometimes washable circuit is needed. Washing ability is not a feature of every type of conductive material, but it is an appealing quality for the purpose of everyday use.

Conductive textiles can be made with metal strands woven into the construction of the textile and thus providing a high degree of malleability. Fabrication of conductive fabrics can also be done using less conductive or non-conductive substrates that are coated with electrically conductive materials. The substrate can be cotton, nylon, polyester, etc. The procedure of coating these substrates can be done using methods like vapour deposition, sputtering, electrodeless plating using noble metal salts and reduction of complex salts with conductive materials like copper, gold, silver, titanium, nickel and carbon. A few inherently conducting polymers (for example, Polypyrrole) can also be used. They have an advantage over the metals used because of their adhesiveness and non-corrosive character. This coating can be applied to any fabric, and has no effect on the fabric's strength, feel or flexibility. Certain formulations of this kind do not have effect on the colour of the fabric.

Depending on the substrates used, the prepared conductive fabrics can be non-stretchable, stretchable in one direction, or stretchable in both directions.

IV. LILYPAD ARDUINO

Lilypad was designed by Leah Buechley. It is a set of sewable electronic pieces designed to build interactive textiles. A set of sewable electronic modules- including a small programmable computer called a Lilypad Arduino, can be stitched together with conductive thread to create interactive garments and accessories. Lilypad can sense information using inputs like light, temperature sensors and act on the environment

with outputs like LED lights, vibrator motors, and speakers.

Unlike other Arduino boards, Lilypad Arduino is more flexible because Lilypad Arduino USB uses a single ATmega32u4 processor to run the process and also communicate over USB with the computer.Atmega32u4 has built in USB communication and thus eliminates the need for a separate USB-to-serial adaptor. It has 9 digital I/O pins comprising of 5 PWM outputs and 4 as analog inputs. It also has an 8 MHz resonator, a micro USB connector, a JST connector for LiPo battery and a reset button.

The on-Board switch can be used to turn the Lilypad ON and OFF. The ON position indicates that the board is receiving supply and the CNG position indicates that no supply is provided to the board.

The ATmega32u4 has 32KB (with 4 KB used for the bootloader) memory space. It also has 2.5 KB of SRAM and 1KB of EEPROM.

INPUT AND OUTPUT

The 9 digital I/O pins on the Lilypad Arduino USB are used as an input or an output. Each pin can provide or receive a maximum of 40mA. It has an internal pull-up resistor (disconnected by default) of 20-50 KOhms

In addition, there are a few more specialized pins with functions:

- TWI: 2(SDA) and 3(SCL). Supports a simple TWI communication.
- External interrupts: 2 and 3. These pins can be configured to trigger an interrupt.
- PWM: 3, 9, 10, 11 and 13. Provide 8-bit PWM output with the analogWire() function.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH, the LED is on, when the pin is LOW, it's off.
- Analog inputs: A2-A5. The Lilypad Arduino USB has 4 analog inputs, labeled AO through A11, all of which can also be used as digital i/o. Each analog input provides 10 bits of resolution (i.e., 1024 different values).

A. COMMUNICATION

The Lilypad Arduino has many facilities to communicate with a computer, another microcontroller and another Arduino. The microcontroller allows serial (CDC) communication over USB and appears as a virtual COM port to the software on the computer. The chip also acts as a full speed USB 2.0 device, using standard USB COM drivers. The Arduino software includes a serial monitor which allows simple

textual data to be sent to and from the Arduino board. The TX and RX LEDs on the board flash when data is being transmitted via the USB connection to the computer.
The Lilypad Arduino USB also supports 12C (TWI-Two wire interface).

V. LILYPAD COMPONENTS USED

1. *Lilypad Arduino Simple Board*

It is controlled by an ATmega328 with the Arduino bootloader. It has a built in power supply socket, and an on/off switch. The LiPo batteries can be plugged right into the socket. The simple board is designed to eliminate the need to sew a power supply. Each Lilypad was designed to have large connecting pads which allow them to be sewn into clothing. They are also washable.

2. *Lilypad Temperature Sensor*

The MCP9700 is a thermistor type temperature sensor. This sensor will output 0.5V at 0˚C, 0.75V at 25˚C, and 10mV per degree Celsius. ADC allows us to establish the local ambient temperature. It has a 20mm diameter and the PCB is 0.8mm thin.

VI. IMAGE OF RESPIRATORY SENSOR, SHIRT DESIGN AND GSM MODULE

Figure 3: Respiratory sensors

Figure 4: Shirt Design

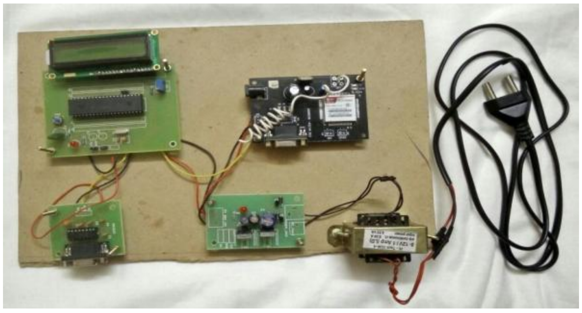

Figure 5: GSM Module

VII. RESULTS AND DISCUSSIONS

The breathing rate of four different people, namely: Janani, Arya, Veeralakshmi and Nandhini were observed and the resistances were measured using a multimeter. The result of observation produced two sets of readings from the two sensors placed in the abdominal and the thoracic regions. The observed values are plotted into 2 graphs.

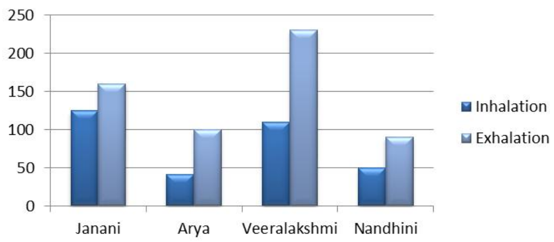

Figure 6: Resistances measured from the sensor placed in the abdominal region

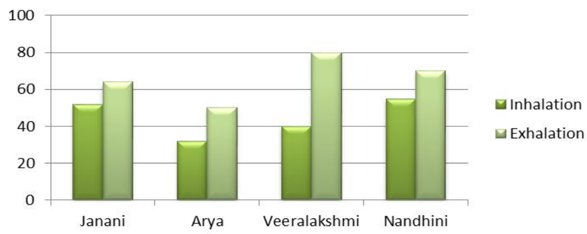

Figure 7: Resistance measured from the sensor placed in the thoracic region

Figure 6 and 7 are graphs that plot the resistance values measured from the sensors placed in the abdominal and thoracic regions respectively. The readings were taken with the subjects lying down. Comparing the above graphs, it can be seen that the abdominal breathing pattern is different from the thoracic breathing pattern. Extensive discussions with various pulmonologists about the breathing pattern have brought us to the conclusion that the monitoring of the breathing pattern of any person requires observations to be made both in the abdominal and the thoracic regions. This is because the breathing pattern is more pronounced in different regions for different people.

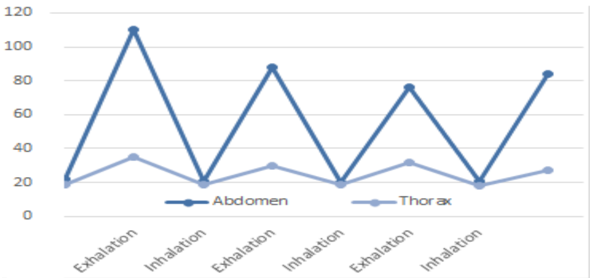

Figure 8: Series of resistance values Observed for a single person

Figure 8 shows the resistance value observed for a single person. The minimum and maximum readings for abdominal and thoracic regions were noted down.

MatLab software is used to continuously plot the graph of the data that is being transmitted by the Bluetooth. This plot is shown in Figure 9. The plot gives the breathing pattern of the person wearing the shirt for the complete night. The results of the breathing pattern throughout the night, enables the physician to identify the pauses in the breathing and the lengths of the pauses. The time at which the device is turned ON is also displayed. This makes it possible for the doctor to identify the stage of the sleep when the Apnea has occurred. Thus, with the results obtained, a pulmonologist can decide if a sleep study should be recommended for the patient as a diagnostic method for Sleep Apnea.

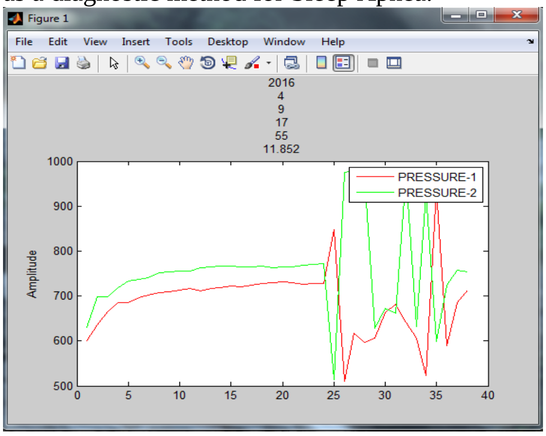

Figure 9: Plot of the breathing pattern

Additionally, to monitor the patient for Hyperthermia, the values from the temperature sensor placed in the armpit is continuously transmitted to the microcontroller and is displayed on the screen. When the temperature of the person wearing the shirt becomes equal to or above 40˚C, an alert is sent as an SMS to the preprogrammed numbers. Figure 10 shows the values of the temperature that is transmitted and the Figure 11 shows the alert sent to the mobile phone via a GSM Module.

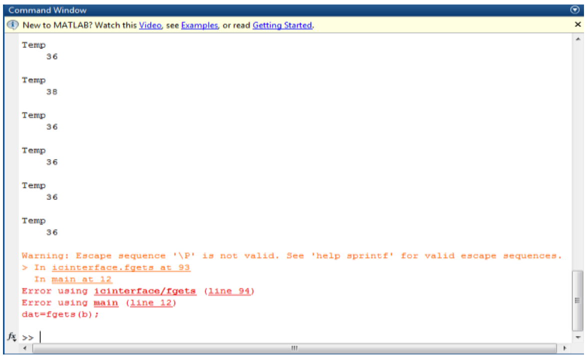

Figure 10: Body temperature displayed on the computer screen

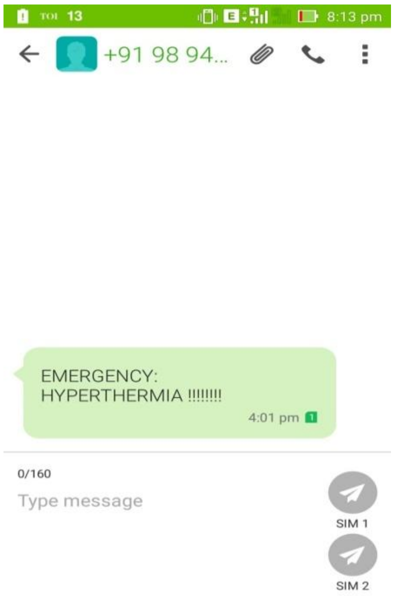

Figure 11: SMS Alert

VIII. CONCLUSION

The developed microcontroller based respiratory and temperature monitoring system can work for an infinite time without having the need of any human intervention. It effectively saves human energy, time and cost. Thus the microcontroller is programmed efficiently such that the device plots the respiratory pattern for the entire night. Unlike other systems that make use of large number of wires and other structures that make the patient uncomfortable, this screening device is designed to provide comfort and does not hinder the patient's body movement. It also monitors the patient for Hyperthermia. It effectively sends an EMERGENCY ALERT whenever there is an abnormality.

IX. ACKNOWLEDGMENT

We have put in a lot of effort in completing this project. However, this would not have been possible without the kind support and help of many

individuals of our University. We would like to extend our gratitude to all of them.
We are highly indebted to Dr.R.Brindha, B.E., M.E., Ph.D., Professor and Head, Department of Electronics and Communication Engineering, Avinashilingam University for her guidance and constant supervision towards the success of this project. We thank our parents for all the support that they constantly provided. We also extend our sincere gratitude towards our Laboratory Assistant for her kind cooperation and encouragement.
The aim of monitoring vital signs is achieved partly or completely by many means. Methods for heart rate measurement using electrodes [3], [4] are proposed. For temperature monitoring sensors (like LM35) [8] have been used. The blood pressure of the patient has been measured employing digital sensors [7] and the technique of PPG [8]. LC based smart sensors [2], fabric based sensors [4], etc. are used. Many works describe e-textiles [5], their modelling, [11] and their usage as sensing materials of vital signs [1].

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