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Title – Force Sensitive Textile (FST)

An e-Textile for sensing the applied pressure on body to measure motor-neurological response based on Glasgow Coma Scale (GCS)

Emergency medical services, nurses, physicians use GCS for assessing consciousness of patients, mainly neck/head injured or trauma patients. The overall GCS score level is 3 to 15. It is the initial stage of assessing neurological injured also known as traumatic brain injury [10] patients. Three main elements for this scale: eye, verbal and motor response are measured. In this project I only consider the eye and the motor response relative to the external stimuli applied. Verbal response is out of scope of this project. Simple idea is applied in this project to measure the applied stimuli on the patient's limbs/specific parts of the body. To do so, I proposed a smart cloth that can measure the external stimuli (i. e. pressure, touch) applied on it. This smart cloth, FST, measures how much pressure applied by the physician and the doctor in the meantime observes the response of the patients. Based on the applied pressure level, and response, the neurological scale can be mapped and give the output result in GCS. Thus, studying the patients, we can make a universal scale in accordance with each level of pressure i.e. eye blink for level 3 pressure.

Background

Recently researchers have shown their interest much on electronic textile. Smart Wearable Textiles such as smart clothing [5] is one of the major parts of electronic textiles. Among the two measurement techniques resistive and capacitive, capacitive textile sensing [2] takes it to the one step ahead. Because capacitive structure is easy to implement in fabric level [11] and offer some advantages over resistive technology. On the other hand, for force sensing, resistive sensor works better as the resistive properties of an object fully depend on material properties of the object and less affected by the external environment i.e. proximity sensitivity in capacitive sensor. Textile sense is used in various applications such as monitoring physiological activities [3], i.e. blood pressure, heart bit rate, temperature measurement etc. and controlling devices [2], game controllers and so on. Multifunctional garments are considered one of the innovative ideas. zPatch [2] introduces such a kind of technology that can sense pressure, motion, touch and can be used in various applications. This product can easily be made and also can buy from the market. One important question can be asked why textile sense is important? It can be answered in this way- clothes are our daily parts of our body, it is one of the closest external objects to our body. So, if these clothes are smart enough that they can sense information from the body then why can't we use them to take care of our body? Again, we also don't feel annoyed carrying or wearing extra devices. M Sergio et al. introduced a textile-based sensor that can measure pressure in capacitive way [6]. This e-fabric can be stretched, bend and conductive [11]. Studies from [3, 5, 11] show that textile can be used to make sensor and can be integrated to the clothes for monitoring physiological purpose. And the paper [2] demonstrate it to the next level. Using the e-textile, they made touch/pressure sensitive e-Textile that can able to take input from user also. Even, they showed that how one can make this type of sensor at home using cheap material. So, my project is closely similiter to paper [2], because I also proposed an e-fabric that can measure pressure applied on it. As pressure is applied on clothes, so, obviously it can bend. So, in this sense, my project also takes idea of bending clothes from the paper [11]. Some of the existing commercial products are zPatch for capacitive touch sensing [2], smart fabric [7] for controlling device using touch patient by Apple.

Project Concept

GCS is used to asses a patient's consciousness level based on the neurological scale. Emergency medical services, nurses, physicians use GCS for assessing consciousness of patients mainly neck/head injured or trauma patients. The score level is 3 to 15. It is the initial stage of assessing neurological injured also known as traumatic brain injury [10] patients. Based on the score, farther treatment will be given to the patients. There are three main elements for this scale: eye, verbal and motor response. In this project I only consider the pressure input that is related to the eye and motor response.

Relation between applied pressure and GCS scale:

Patient can give eye and/or motor response due to pressure applied on limbs. Physicians might give external stimuli on certain point on the body, for example eye corner, knee, neck, finger tips etc. and observed the response of the patient. Based on how the patient response, a score is given to the patient. But patient's response can be varied on the given level of pressure. Most of the time doctors gradually the pressure and observe the patients' response This increment of pressure can vary person to person. Let's assume a scenario: We have patient P1 having actual injured level 3 out of 5. Also assume that we have two doctors D1 and D2 having different health and body structure/strength, D1 is less strong then D2. Now if D1 asses the P1 and applied pressure 2 at his best and measure the patient's response and gives GCS scale 4. Again, our stronger doctor assesses the patient applying pressure 4 (it is normal to him/her) and make GCS scale 5. The higher GCS score means patient's condition is good. In this scenario, D1 consider that I gave high pressure but patient response is less, so condition is not good. But in case of D2, he considered for normal/little amount of pressure patient gave quick response. So, GCS score varied depending on the applied pressure on the limb and also depends on the strength of the doctor. This is obvious incorrect assessments because we see that this score is slightly depending on the physicians also. Thus, the idea comes, we can use CTS [2] or FST to measure the pressure level and then map them to the patient response and neurological scale. For example, Level 2 -> just feel the touch, Level 4 -> feel pain, eye blink and so on.

Figure: Pressure is applied to measure patient's response in GCS [12]

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Project Implementation

We need a sensor that can measure the pressure/force or pressure sensitive. I proposed smart e-Fabric, that can able to measure the pressure applied on it. To implement this type of intelligent, clothe sensor, we need conductive and piezo resistive textile fabric. This type of clothes already available on the market. We need the following components are needed to make our pressure sensor.

The Sensor

Non-conductive fabric for outer layer. For the top layer, glue must be bottom face and the Bottom layer, glue must be up face.
- Non-conductive thicker fabric for making the structure of the sensor and it must be non-elastic.
- Conductive Fabric. It should not be elastic.
- Piezo-resistive Fabric. It is highly conductive and pressure sensitive.
- Both side bonded tape or clothes that can attach all the clothes together.

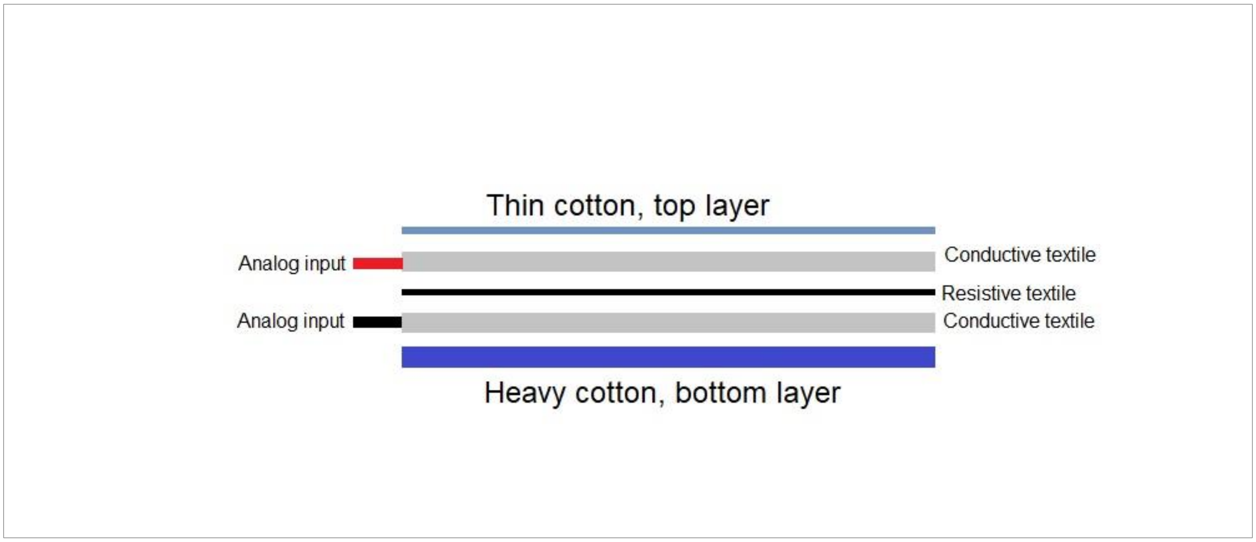

Figure: Sensor structure.

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List of materials

1. Arduino Uno
- Connect the sensor to the monitor
- Take the input
- Display the output
2. Non-conductive, thin fabric
- It will use for outer layer of the sensor
3. Non-conductive, thicker fabric
- It will give the strength to the sensor
- Make the structure of the sensor
4. Conductive fabric
- For making the Anode and Cathode of the sensor.
-Passing the electric signal
5. Piezo-resistive fabric
- Give the resistance of the sensor
6. Dual sided bonding material
- Attaching the 1-5 materials together
7. Alligator clips
- Helps to connect the sensor end to the Arduino
8. Scissors
- For cutting the materials
9. Iron
- It will be using the iron the cloth after applying the wax paper and glue.
- Attach the glued cloth layer strongly
10. Wax-paper
- For separating the conductive layer from cloths
- Help to reassemble later.

11. Wire/Jumper/Cable
- Connect the Micro-controller to the monitor/computer
12. Monitor
- Display the output result
13. RGB LED (optional)
- Indicating the pressure level according to color gradient: green (Low) to red (High)

Building e-Textile pressure sensor

Make an e-Textile sensor is the most important and primary goal of my project that can lead me to the farther step and to the final goal. It is known that wearable garments can be used to monitor body temperature, humidity, strain, pressure and so on. The main electronic working principle behind the e-Textile pressure sensor based on resistive and capacitive sensing properties of specially made fabrics. The resistive and capacitive layer of the clothes sense and discriminate the external pressure and then convert it to electric signal. The signals then pass through the micro-controller and use for farther process.

Steps of making sensor (prototype):

1. Cut out a piece of bonding material (Iron on glue) about the same size of the material intended to use
2. Take one piece of fabric(nonconductive) and on top of that place bonding material
3. Start ironing them so that they bond together, then take of the paper from the top of bonding material

4. Place the conductive material on top of it and start iron for 6-8 seconds. (So, we have conductive material bonding with the non-conductive material)
5. Now place a resistive material on it. Remember no glue will be attached to resistive to conductive material
6. On top of it, place second conductive material and then followed by a bonding material.
7. Then, on top of it place nonconductive material and iron on it.

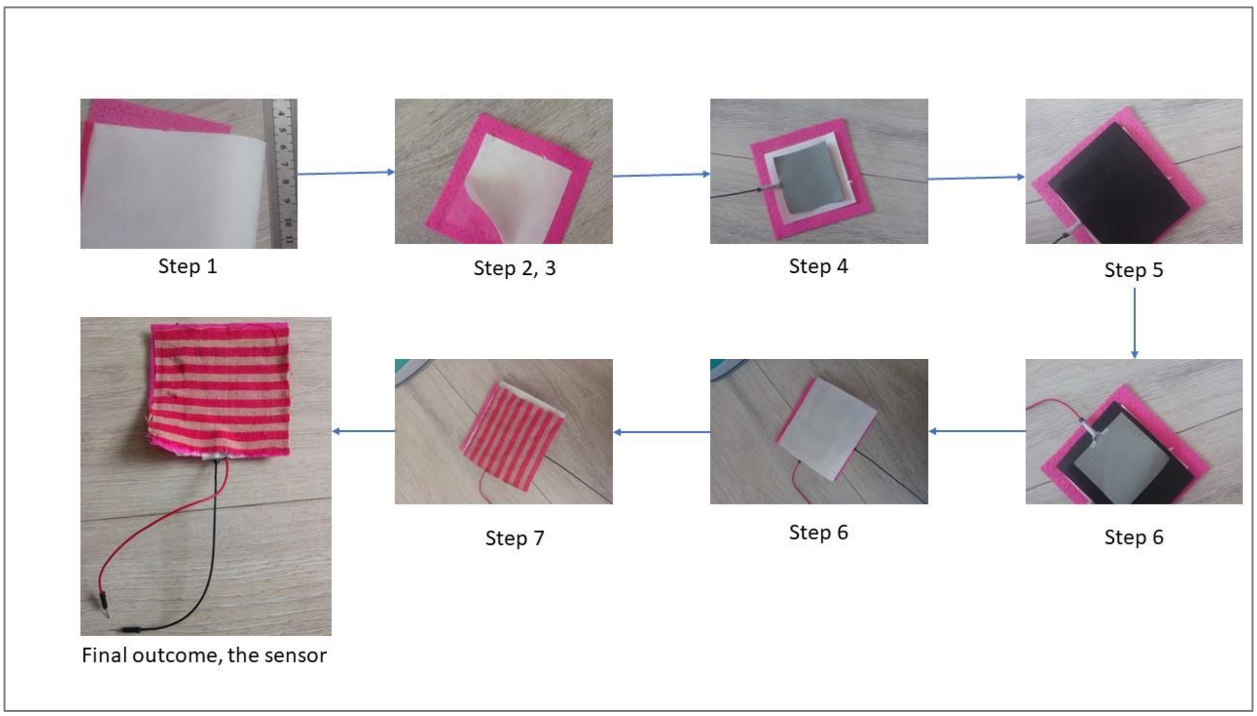

Figure: Steps of making the sensor.

Arduino integration to the sensor

Arduino or other micro-controller is must needed for this project because the sensor senses the pressure, generate analog electric signals, micro-controller reads these signals and then visualize it to the human readable and easily understandable representation. Initially serial monitor from Arduino will be used to visualize the data.

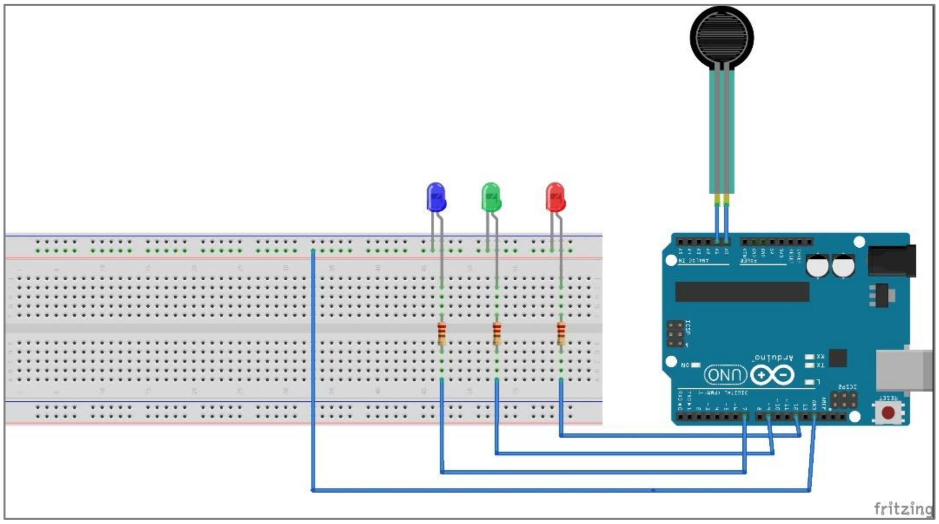

Figure: Circuit layout

Testing and Bug fixing

I use trial and error method for my project to make it correct and full functional. It is obvious there will be bug and/or error in code and also in making the sensor. So, I will give trial find the flaws and make correction, then continue the process until the it runs correctly.

Phase 1:

- Bug: Noise reduction
    - Bug Description: I've found lots of noise in my data. After some inspection I've found that these noises mostly generated because of the faulty construction of the sensor. There is a friction in conductive and resistive layer. And this generate the additional signal called noise
    - How to resolve:

- Try 1: add thin layer between resistive and conductive layer. It reduces noise but also increase the rigidity of the pressure sensor and output is not up to the expectation level.
- Try 2: Use strong outer layer and glued the material stronger and attach them more tightly. I've found that this works fine.

Phase 2:

- Bug: Proximity sensitivity problem
- How to solve:
  - in capacitive sensor, try to use nonconductive thin clothes. It works fine but not up to the mark
  - Then I use the resistive sensor. It works best. (See design decision)

Design Decision

Capacitive pressure sensing vs Resistive pressure sensing:

I tried both of the sensor type. I encounter some problems in capacitive pressure sensor. It is too sensitive and at certain point, it cannot measure the applied pressure. Moreover, it is too sensitive to any conductive material and gives redundant output. It shows proximity sensitive as the mutual capacitance changes if any conductive material comes nearby. Comparing to capacitive pressure sensor, resistive pressure sensor can overcome these issues. Resistance is an internal property of a material and cannot be altered by external elements in normal environment. It is also stable, in force sensitive register, resistance only decreases if external pressure is applied. So, considering all of these facts, I decided to use pressure sensitive resistor to build Force/Pressure sensitive textile sensor and challenges of capacitive sensor are discuss in Challenges section.

Pressure sensing (measurement)

Applied pressure on the sensor can be converted into pressure unit in several way. For my project I measure pressure using the change of resistance. As we know that, resistance decries when force/pressure is applied on it. So, following this rule, pressure can be measure in the following way:
Force (denoted as F) per unit area (denoted as A) is defined as Pressure, P. P = F/A. For our project, A is constant (i.e. 2 sq. cm). So, pressure is directly proportional to F. Changing of F on the sensor eventually change the resistance. For example, if we increase F, then resistance decreases. Now we know that F = mg, where m = mass of the object, g = gravitational acceleration. Here, for us, g is constant. To map the pressure to GCS, I use different weight for m (mass) (i.e. 2g, 4g, 10g etc.). Example: 6g object put on the pressure sensor (get the F = 0.006 x 9.81). Then take the output value given by the sensor. This output is the applied pressure measured by the sensor. So, varying the weights, we will get the pressure variation.

Final Result

The sensor is responsive to pressure and successfully can map the applied pressure to the change of resistance. Though my main goal is to measure the response of the patient according to the external stimuli (i.e. eye response for level 3 pressure). Thus, user (patients) study is needed to get the actual mapping between response to the applied pressure and then mapped it to the Glasgo Coma Scale. But during this COVID-19 pandemic it could not possible for me. So, I use demo for mapping the pressure to the GCS. (see Video)

Challenges

- Noisy data (in capacitive sensor): Noises are noticed in the data/graph. Even if there is no external pressure is applied on the sensor, still there is a fluctuation in reading
- Proximity sensitivity (in capacitive sensor): I also noticed that this sensor is also proximity sensitive. It can identify body (finger) and distinguish between body and other plastic material (I tried pen, but not deviation on output).
- Measuring pressure: It is also changeling and time-consuming task how to measure right amount of pressure with the textile sensor. To overcome these challenges, I use force sensitive resistor sensor (please see Design Decision)
- Real-time data visualization: I want to use python for real time data/output visualization. But I've found it is difficult. There is a 3/4 seconds delay between external stimuli and output on the screen. I need to find more efficient technique to plot real time data.

Lessons Learned

- I've learnt how to make a textile sensor and read the values using both Arduino and Python.
- Proximity sensitivity: The way I make this pressure sensor, it also behaves like a proximity sensor. It can distinguish human and other object's proximity. Possible reason: The outer layer of my sensor is not fully non-conductive clothes. Steps to resolve issue: I use thick paper, cardboard. Find that reduction of proximity sensitivity.

- Delayed output: For real time data output using python, it delayed 3/4 seconds to display the output. Still I am working on it why it happens and how to solve this issue.
- Denoise the data: I have found a tricky way to reduce the noise of the sensor that actually occurs because of the construction of the sensor. *This denoise technique is described under section: Testing and Bug Fixing (Phase 1)*
- Measure pressure using capacitance and resistance.
- Using carbon sheet instead of resistive material (Velostat) does not work well
- For force sensing, Resistive sensor is better than Capacitive sensor

Vision and Outlook

My future vision is FST can also be used for lock/unlock device combining with vibration. Varying the pressure and indicating by the vibration. So, only by seeing externally, no one can guess how much pressure is applied, thus cannot guess the pressure lock. This Force Sensitive Textile can also be used to map GCS for assessing the traumatized patients initially within few times. To do so, we need to run user study for better response mapping. Clinical trial is needed as this result is too sensitive for the pressure. So, this sensor needs to be more precise and accurate. This FST can also use in various sports and game for user study, how much pressure is generated by the players. For example, while running, how much pressure/force is applied on the ground, this data can use in farther sports research.

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Resources

https://github.com/MoonRiyadh/eTextilePressureSensor.git

Video

https://oc.cs.uni-saarland.de/owncloud/index.php/s/FZRQAWkcN38KCjF

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