Title - Developing a Textile Bend Sensor

A Subtitle – Fabric bend detector

A Bend sensor or Flex sensor is a sensor that measures the amount of deflection or bending[1]. Here, an attempt is made to develop a bend sensor by using textile-like materials so that it can be easily fixed on clothes for sensing the bending without disturbing the clothes comfortability. When the sensor is bent, it exerts pressure on velostat which is placed in between Neoprene material. Velostat is used for making the sensor, because it allows more electricity to pass through as the harder it is pressed in between two conductive layers. Therefore, this sensor can also be used as a pressure sensor. The output of the sensor is represented by contacting the sensor in a simple dimmer circuit. When the sensor is bent, its resistance decreases so the LED glows brighter.

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Background

Basics

It is important to understand following things before we proceed further as this will be helpful for better understanding,

Textile Bend Sensor: Textile based sensor that provides an interface between the user and an electronic system by converting bending or deflection (physiological signal) into electrical signals.

Basic Principle:

In this project, a rectangular strip of Velostat material is placed in between two conductive layers, because Velostat allows more electricity to pass through as the harder it is pressed in between two conductive layers together[2]. This also explains why the resistance of the sensor is decreasing as the sensor is bent more and more.

Existing art or DIY projects

Based on the principle discussed above, the Bend sensor can be developed. Usually the price of the Bend sensor(flex sensor) is in the range of 8 to 15 Euros. So it is always in the interest of the researchers to provide some cheaper alternatives. One of the examples I would like to mention here is an existing DIY project on 'How to make a Flex Sensor for Robotic Hand and Arduino'[3]. In this Youtube video a simple project has been described to construct a flex sensor at home. They have not used the textile materials for making a sensor instead they have used aluminium foil and cardboard. Because they have used different materials their procedure cannot be the same but this procedure is relatable and helpful to understand the internal structure of the sensor.

Existing scientific literature

Specially within the last two decades researchers are showing their interest in research related to Flex sensor and its applications. I would mention few of them here,

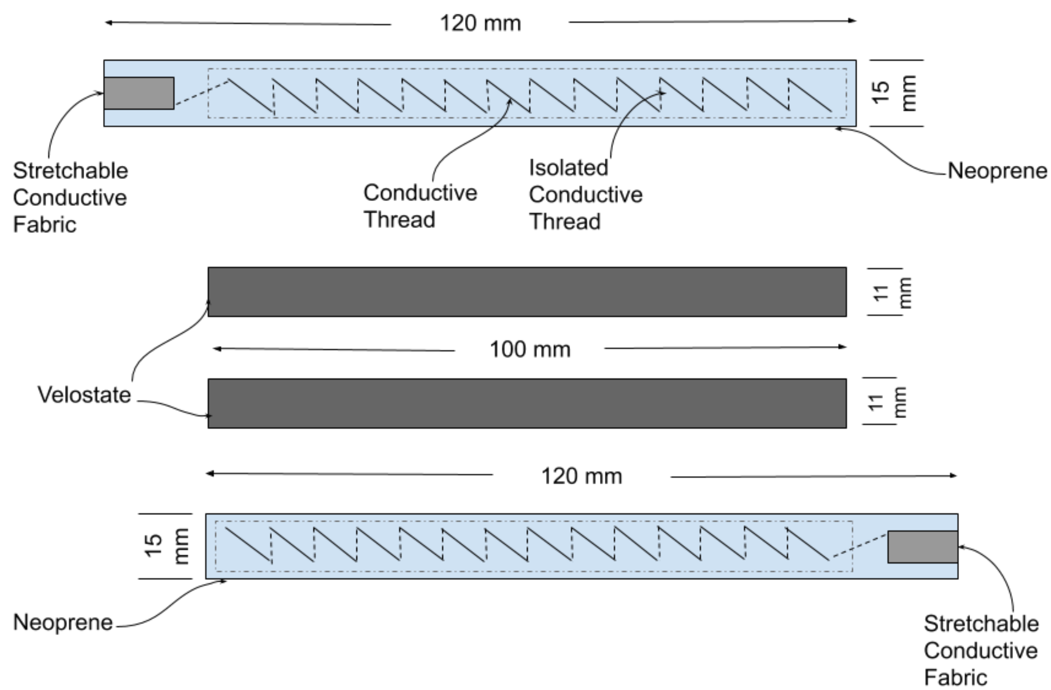
- The Development of Graphene-based Flex Sensors using Printed Electronics for physical Rehabilitation and Assistive Applications.[4]
  In this paper, they have presented the development of flex sensors based on the printed technology. They have shown the effect of various combinations of fabrication settings, i.e., different contact point materials during measurement, the use of graphene-modified vs. pure carbon pastes as the first layer material, different pattern parameters such as sensor width, sensor length, etc. This level of research work is advanced and requires more time and effort, but this is useful for me to understand the effect of different parameters.
- Flex sensor based wearable gloves for robotic gripper control[5]
  In this research work, they describe a method to develop a wearable glove by using bend sensors, its pros & cons and usefulness for robotic application. This is helpful for me to understand how we can use the flex sensor for real world application, what problems we might face during the implementation and how to tackle such problems.

Existing commercial products

As a result of the researcher's interest in this domain, few products which are based on flex sensors are already available in the market. For example, Wearable Gaming Hand Glove[6] is available on amazon.com, which can be used instead of a gaming remote.

Project Concept

Based on the basic principle on which bend sensors work as explained in the Background section, we can develop a bend sensor.
There will be change in resistivity of a Velostat material depending upon the pressure exerted because of the bending[7]. A Low-fi prototype as shown in Image 1, represents the parts and its dimensions which will be used for making a bend sensor[8].



[Image 1: Low-fi Prototype of the bend sensor]

As shown in the image 1, the conductive thread will be stitched on the neoprene strip. Two identical neoprene pieces will be prepared. In the Image 1, Isolated Conductive Thread means conductive thread at that portion will be on the other side of the rectangular neoprene strip.
The reason why the stitching on both sides must be identical is so that when they lie on top of each other (facing each other) the stitches crisscross and overlap in one point.

Two identical neoprene pieces which are stitched by using conductive fabric individually as shown in Image 1, will be stitched together after putting a rectangular strip of Velostat in between. For enclosing the sensor, the periphery of the sensor is stitched by using non-conductive thread.
As shown in the DIY project video[3], I am not using the aluminium foil and cardboard because the goal here is to make a sensor which has a textile-like appearance. So that it can be easily fixed on clothes for sensing the bending without disturbing the clothes comfortability.

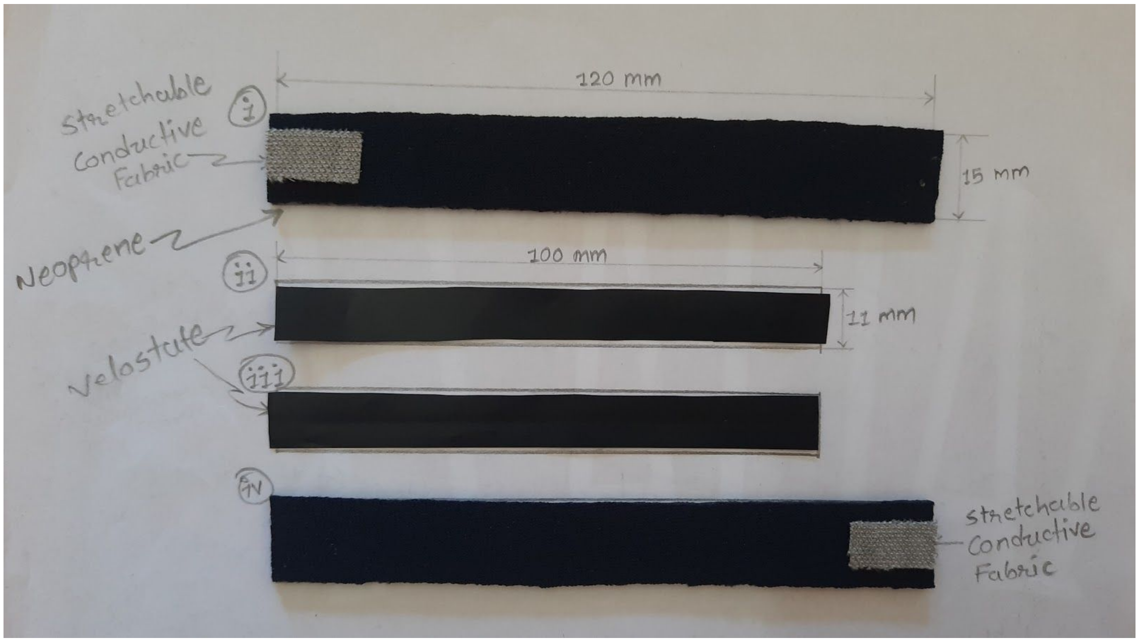
Project Implementation

List of Materials

1. Velostat
2. Conductive thread
3. Neoprene
4. Stretchable Conductive Fabric
5. Normal sewing thread and needle
6. 5 Volt Power supply (Battery)
7. LED

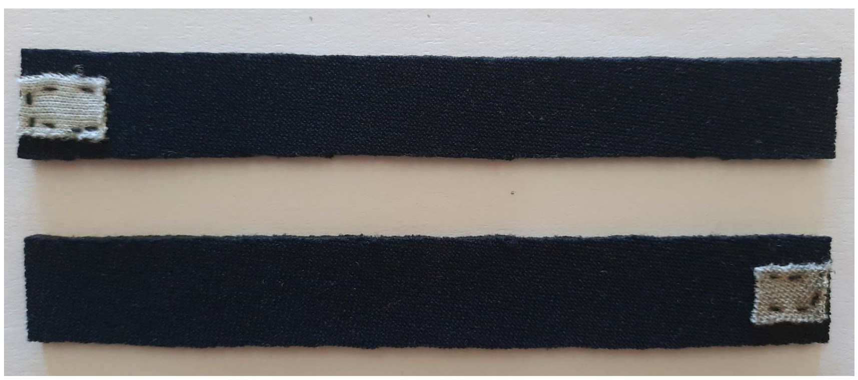
Development of the Sensor

Step 1: Cut Neoprene, Conductive Fabric and Velostate in a dimension as described in the Low-fi Prototype.



[image 3 : Cut material as shown in Low-fi prototype]

Step 2: Stitch conductive fabric on neoprene to make the terminals on the sensor.



[image 4 : stitched conductive fabric as terminals]

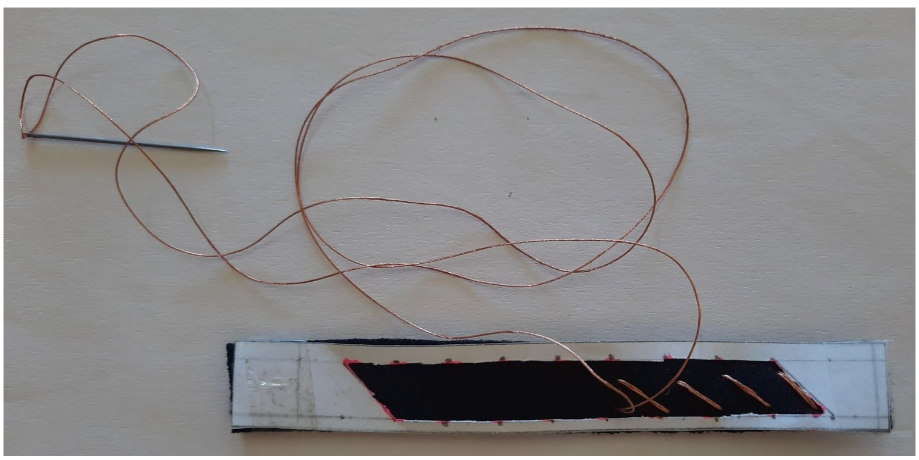
Step 3: Make a Stencil.

[image 5a : Stencil]

Create a stencil that shows the marking for stitches that should run diagonally as described earlier.

Step 4: Stitching the conductive fabric on neoprene.

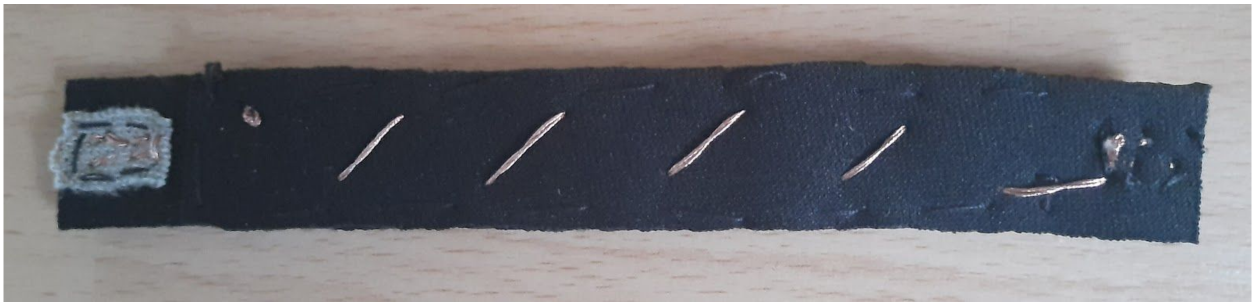
As shown in the image 6a, we can use the marking on the stencil for stitching the conductive fabric. Start from the end which is furthest away from the terminal(conductive fabric). at the end stitch the conductive thread on the terminal(conductive fabric). similarly stitch the other neoprene strip. make sure stitching on both the neoprene strips look identical as shown in the image 6b. I have stitched it in such a way that when these strips face each other, both the terminals will be visible. note that in image 6b, the terminal of one strip is faced down(not visible).



[image 6a : stitching conductive fabric on neoprene]

[image 6b : stitched neoprene strips]

Step 5: Enclosure of the sensor.
Now, place the strip of neoprene in between the two stitched neoprene strips. after that stitch the outer periphery with the normal cotton thread.

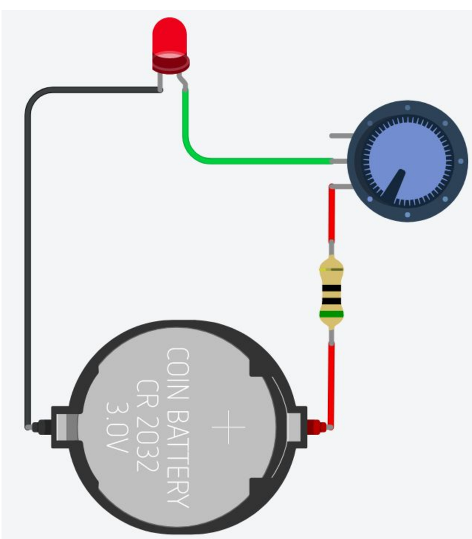


[image 7 : textile bend sensor]

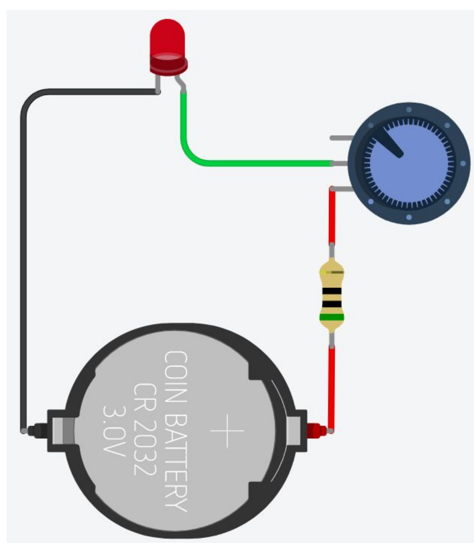
Representation of the Output

I planned to represent the output of the sensor by using the LED. In the circuit diagram shown in Image 8a & Image 8b, the simple idea is that the brightness of the LED will increase as the resistance of the sensor will decrease. So at the end, more bending of the sensor will result in the increment in the brightness of the LED. If you want to use the sensor for different purposes, you might not need LED and Battery.

Circuit diagram:

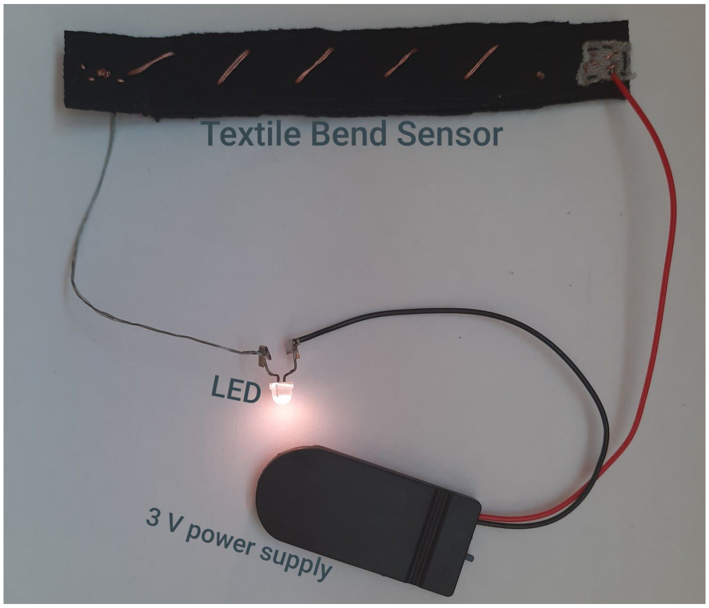


[Image 8a: Brighter LED-low resistance]

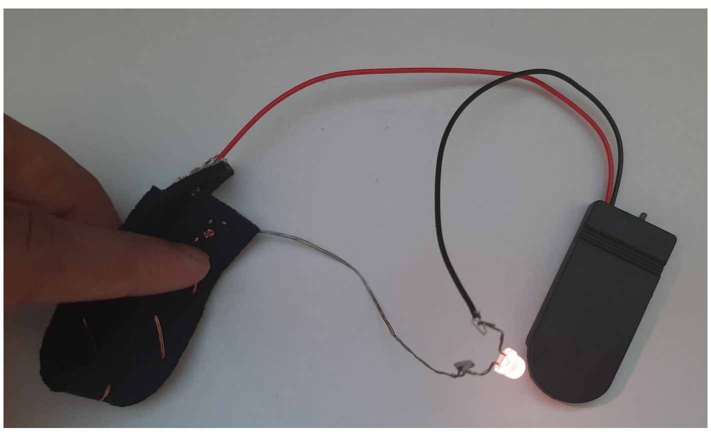


[Image 8b: Dim LED-High resistance]

To represent the output of the bend sensor, I have made the LED dimmer circuit. The sensor is working well as you can see the result below in Image 9a and 9b, when the sensor is bent its resistance is decreased so the LED is glowing brighter.



[Image 9a: Dim LED when Sensor is straight]



[image 9b: Brighter LED when sensor is bent]

Lessons Learned

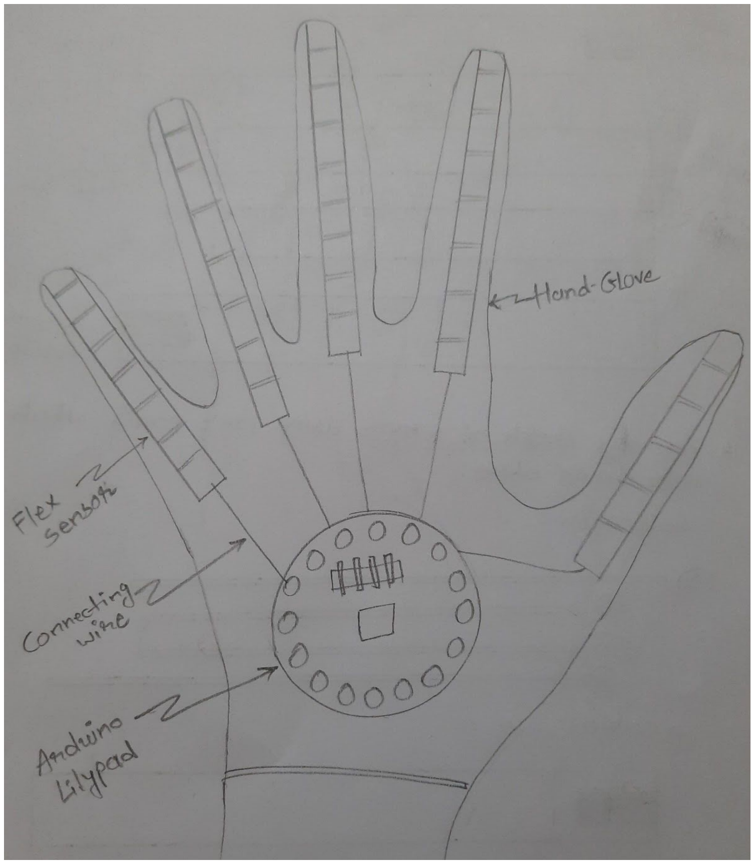
- After understanding how this bend sensor works, I have found out that the same sensor can also be used to measure pressure.

- Sensitivity: I have learnt that sensitivity is dependent on the gap between stitches of the conductive thread on Neoprene strips. So by changing it I can control the sensitivity upto certain extent.
- Output range: I learnt that Initial pressure in the sensor(because of the stitches at outer periphery) affects the output when the sensor is straight. so by changing the initial pressure (while stitching the outer periphery with normal thread) i can control the output range upto certain level.
- Solution can be found anywhere: As i don't have arduino i was wondering how i can show the output of the sensor. When I was using Tinkercad software, while looking at the example circuit(LED dimmer) it struck me that I can use a similar concept to show the output without using a microcontroller.
- Even though our design and plan is ready, we should have some extra material. I know how I am going to stitch the conductive thread on neoprene but still i made a mistake and i have to do it again by using another neoprene strip.
- You should be ready to make more than one prototype. so plan in such a way that you have enough time for that. As I had enough time, I could make another sensor that can show results nicely when attached in a dimmer circuit.

Vision and Outlook

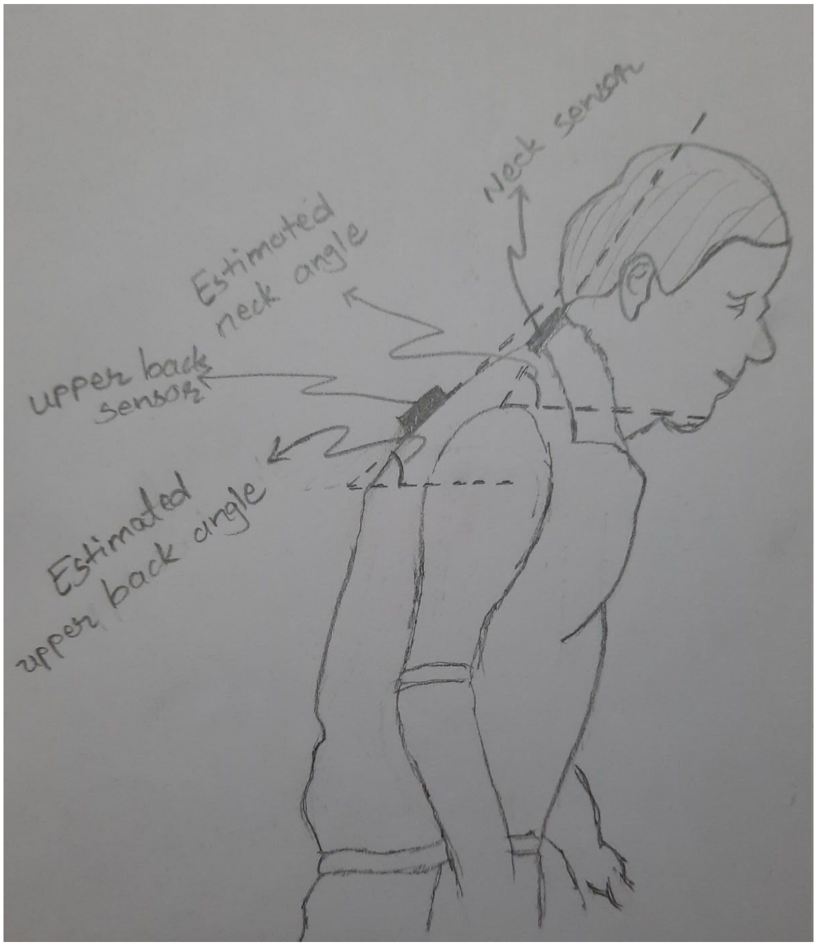
This sensor can be used for different real world applications. I would like to mention couple of them here,

1. Making a glove which can detect the hand gesture by using the Bend Sensor.
   By using the bend sensors we can detect a specific gesture of a hand. For doing this we can fit five bend sensors, one at the upper side of each finger of the glove to measure the amount of bending in each one of the fingers.[5] Moreover, Gyro Sensor can be used optionally to detect angular movement as shown in the sketch.



[Image 8: Design of glove to detect hand gesture by bend sensor][9]

2. Detecting a person's energy level by his/her neck & spine position while interacting in general by using a bend sensor.



[Image 9: Bend sensor for detecting posture][10]

We can fix a bend sensor which is placed vertically(as shown in the sketch) on some fashion wear(e.g. turtle neck t-shirt, neck band) which is bent with the movement in the neck. This bend sensor can detect whether the person is looking straight with a firm posture or looking down. Moreover, another bend sensor can be used to detect spine position by fixing it vertically in a T-shirt on the upper back as shown in the sketch. Different posture can be identified by calculating the neck & upper back angles.

Resources

In case you need more details on the project, you can visit my git repository[11].

Video

You can see the demo video via this link which shows the making of the sensor and representation of the output.

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