Smock Sensor

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99-360: E-Textiles, Fall 2022

Introduction

Ever since the medieval times, smocking has been used to bunch up fabric to make it more elastic. Because of its stretchiness, it could theoretically work as a sensor. But how would one incorporate conductive materials into smocking, and how would the techniques used affect the flexibility and resistance of the resulting sensor? To answer this question, I made two stretch sensors with smocking – one with a layer of conductive plastic, and the other with conductive thread– and tested their respective resistances in response to stretching.

Creating the Swatches

Materials:

- Any thin, non-conductive fabric
- Non-conductive thread
- Conductive embroidery floss
- Electrically conductive polyethylene (or any conductive fabric)
- Embroidering needle

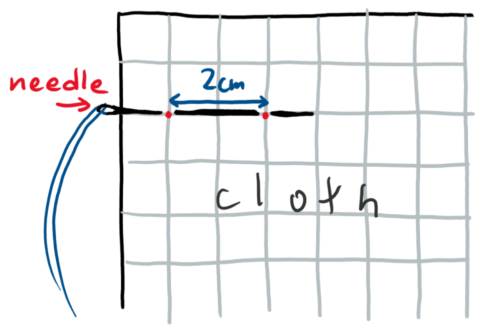
All materials were sourced from the E-Textiles homework bin.

- Using a pencil and a metric ruler, I drew a 1cm grid on a large piece of non-conductive fabric. If you already have experience in smocking, you can also mark out a grid of dots instead for a cleaner look.

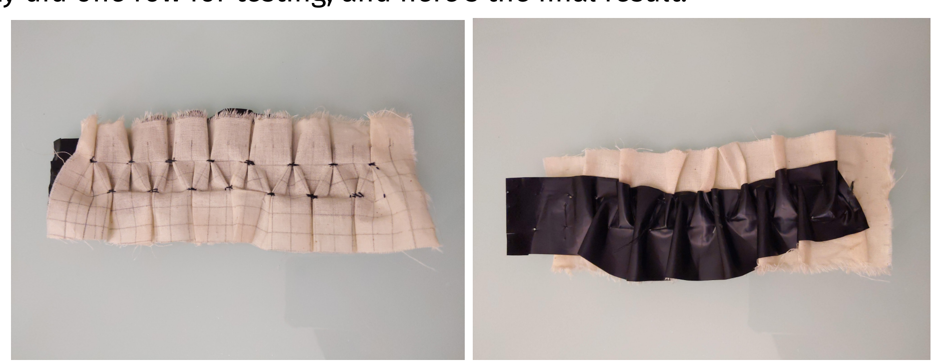
- To create the different swatches, I cut the fabric up into smaller strips.
- For both swatches, I used the honeycomb stitch for its apparently higher flexibility than other basic smocking stitches. Here's the tutorial I used: https://katafalk.wordpress.com/2010/02/05/honeycomb-smocking-tutorial/

With the conductive plastic:

- Lay a strip of conductive polyethylene or a conductive fabric on the *unmarked side* of the non-conductive fabric.
- Double-thread your needle using a non-conductive thread.
- Sew the conductive strip onto the non-conductive fabric using a honeycomb stitch and a double-threaded needle. Make sure you puncture through the conductive plastic/polyethylene layer to secure the conductive plastic to the cloth.



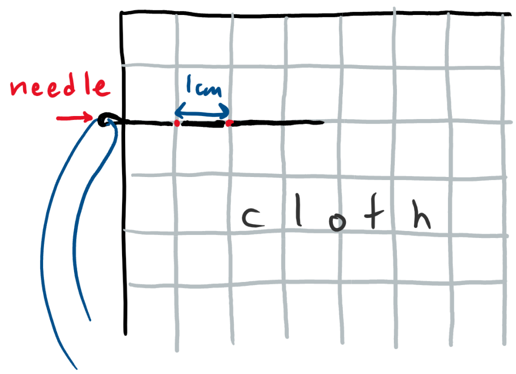
- Because of the difficulty of piercing through both layers, I made each stitch 2cm by 2cm, which means piercing through the cloth at every *other* crossing on the grid.
- I only did one row for testing, and here's the final result:



Left image: front, right image: back

With the conductive thread:

- Single-thread your needle with conductive embroidery floss.



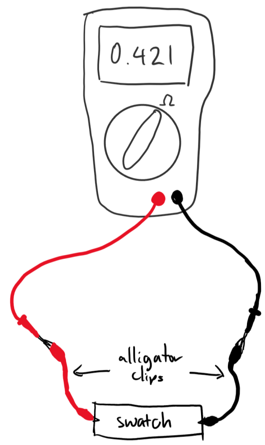
- I didn't attach anything extra to the non-conductive cloth this time– I just stitched through every 1 cm (every crossing on the grid), just like a regular I stitched two rows this time, creating a much more stretchable swatch than the conductive plastic swatch.
- Here's the final result:

Resistance Testing

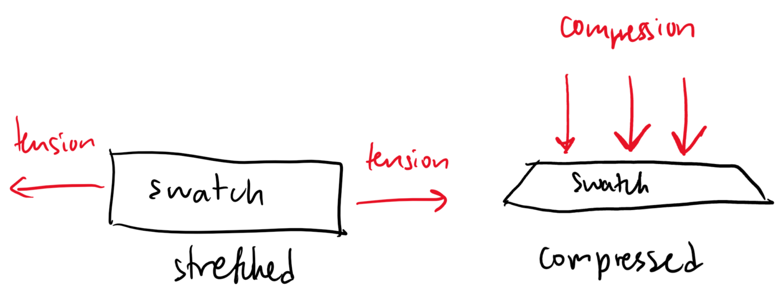
Additional materials:

- Resistors (can vary based on material used; based on my direct measurements of the sensors, I used 33Ω and 47kΩ)
- Multimeter
- Alligator clips
- Small male-male jumpers
- Small breadboard
- Power supply

Test 1: Direct measurement with just the multimeter

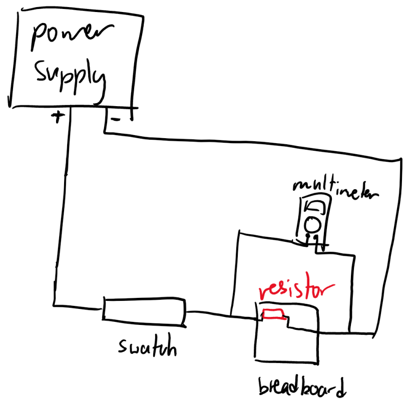


- For each swatch, attach it to a multimeter using alligator clips, set the multimeter to its resistance setting (Ω).
    - For the conductive plastic swatch, I attached the alligator clips to the conductive plastic and measured the resistance of the sensor in three states: at rest, stretched, and compressed.

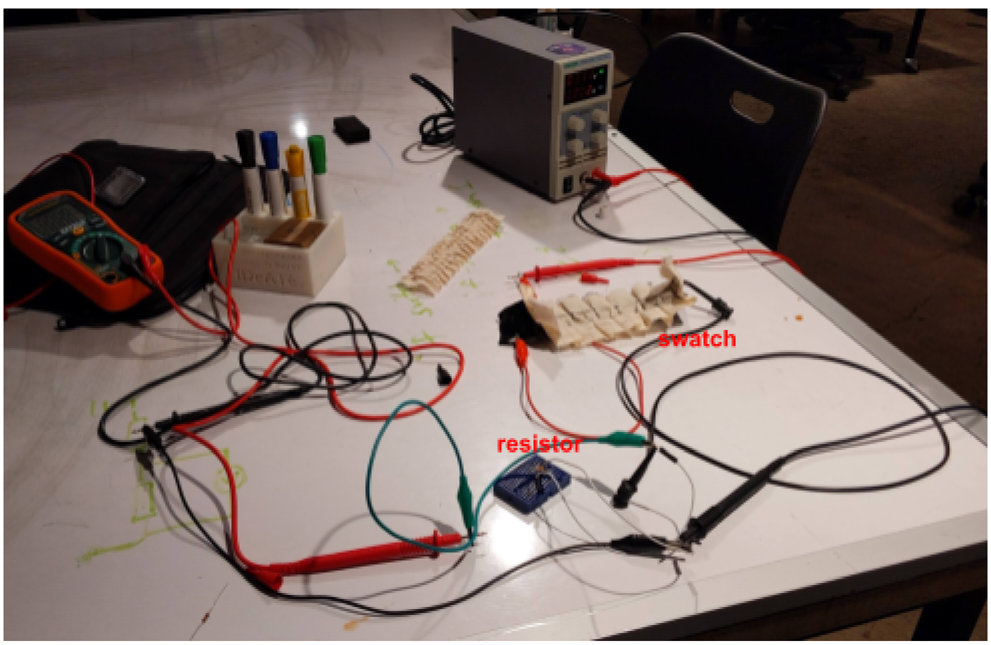


    - For the conductive thread swatch, I attached the alligator clips to the thread on both sides and measured the resistance of the sensor in two states: at rest and stretched.

Test 2: Voltage divider



- Create a voltage divider circuit based on the diagram above.
- Set the multimeter to its voltage setting.
- I turned the power supply to 3.1V.
- Here's a very disorganized picture, for a reference to the different materials:



- For the conductive plastic swatch, I used a 47kΩ resistor and measured the voltage of the sensor in three states: at rest, stretched, and compressed.
- For the conductive thread swatch, I used a 33Ω resistor and measured the voltage of the sensor in two states: at rest and stretched.
- Using the voltage measurements from the multimeter, I estimated the resistance:

$$R_{swatch} = R_{resistor}\left(\frac{V_{supply}}{V_{multimeter}} - 1\right)$$

Results

Based on both tests, the conductive plastic swatch seems to have a resistance ranging from 50k to 79k ohms. The conductive thread swatch, on the other hand, has a much lower resistance of 15 to 21 ohms.

For both swatches, I directly measured the resistance once, did the voltage divider test, then directly measured the resistance again when I realized that the resistance was lower. The second time I did a direct measurement, the resistance of the conductive plastic swatch dropped from ~70kΩ to ~50kΩ, but stayed at 15 to 18 Ω for the conductive thread. Based on that behavior, I'm guessing that the thread swatch maintains its resistance better than the conductive plastic swatch, but that could've been influenced by the fact that I accidentally ripped out a stitch while stretching it.

The interesting part was the swatches' behavior when they were deformed. When stretched, the plastic swatch's resistance went up by 5-7 kΩ, and when compressed, it went up by 3-5 kΩ. On the other hand, the conductive thread swatch's resistance *decreased* by 3-4 Ω when stretched, opposite of what I'd expected to happen.

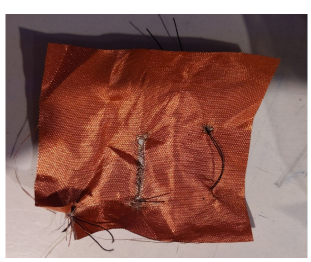
I hypothesized that compressing the plastic swatch would decrease the resistance, since the plastic would overlap itself. But to my surprise, the resistance also increased when I pressed down on it, though the resistance didn't reach as high as it did when stretched.

Reflection

It was amazing to see that smocking could create a functional stretch sensor, and that a stretch sensor would behave differently based on which parts of the sensor were conductive.

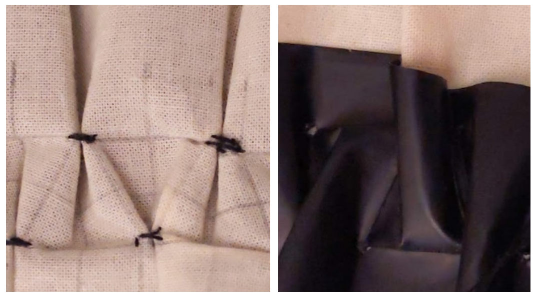
Due to my lack of experience in sewing, the conductive plastic was stitched awkwardly onto the sensor, and it was oftentimes difficult to force the needle through both layers. The resulting sensor was stiffer, possibly because I only completed one row of smocking.

I'd first used copper conductive fabric, but it was even more difficult to pierce the needle through. I attempted to use heat-n-bond, but it just made the layers stiffer. Conductive polyethylene works a lot better because it gives way to the needle more easily.



As you can see, I gave up.

Next time, I would try softer, stretchier conductive fabric, actually pinning the conductive fabric so it would lay straight and wouldn't shift out of place. I'm also curious how the sensor would behave if I placed the conductive fabric on the marked top side, so that the fabric folds *inwards* and overlaps itself, creating shortcuts for the current to pass through.



The marked side of the smocking folds inwards, while the underside (where I sewed the conductive plastic) bends outwards.

The conductive thread sensor is a lot lighter and more flexible, so it would be better out of the two for wearables and smaller stretch sensors (since it would be easier to do more tightly packed stitches). However, although the conductive plastic sensor is stiff, it can be compressed as well as stretched, so it can work as a pressure sensor.

I'm thinking that most smocking sensors would be used as wearables. It could be an interactive part of a dancer/actor's outfit, or used for fitness gear. For example, its stretching and bending properties could be used to control the brightness of lights or speakers attached to a sleeve or measure a person's breathing as their chest expands. Since the conductive plastic could be used as a pressure sensor, it could sense if someone sat down, laid on the floor, or placed their foot on the ground.