Salmon

Smart Thread Data Glove

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Introduction

The Nano Laboratory at Tufts University headed by Professor Sameer Sonkusale has been developing what they refer to as "smart threads" since 2017. These smart threads function as sensors which can detect the strain put on them as they are stretched. A common application of these threads is to measure human movement by attaching them to different articles of clothing. For our senior design project we attached the threads to a glove and created a "Data Glove" (Nejad, Punjiya, & Sonkusale, 2017).

Thread Background

Composition

The smart threads start out as a Polybutylene terephthalate (PBT) puffy thread which is essentially just a regular stretchy thread. The threads then get coated with graphene ink, which is conductive, meaning the threads can now conduct electricity. This conductive, graphene coated thread is then layered further with a material known as Polydimethylsiloxane, or PDMS for short. PDMS is essentially a stretchable plastic, and it makes the threads more durable by making them waterproof. The PDMS also keeps the graphene ink from degrading and falling off the thread as it is stretched. In summary, the threads start as stretchy PBT puffy threads and then have a conductive layer and protective layer added. These materials are all low-cost and easy to acquire thus leading to a very low overall material cost for these thread sensors (Sadeqi et al., 2018).

Measurement

How and what do these smart thread sensors measure? They are classified as piezo-resistive sensors which means as they are stretched their resistance changes. The most common way that this change in resistance is detected in applications is by keeping the current steady through the sensor. Then, based on Ohm's law which is Voltage = Resistance * Current, as the thread is stretched and the resistance increases, the voltage also increases because the current is constant. The resistance increases by the properties of the material and the fact that resistance = resistivity*length/cross-section of the area. The reason the voltage is useful is because many microcontrollers, like Arduino, can easily read in voltages. What makes the threads especially useful is that they operate in the kΩ range which means that the current needed to get a useful voltage reading is in the μA range. Thus, it takes very little power to get readings off the threads.

Washable Characteristics

The threads are coated with PDMS to make them waterproof and washing-machine safe. One of the main applications for these threads is on clothing so it is important that the threads can survive multiple washing machine cycles. *Fig 1* shows the result from an experiment that washed the threads and tested their performance after each wash. It is evident that the threads performed consistently after every wash.

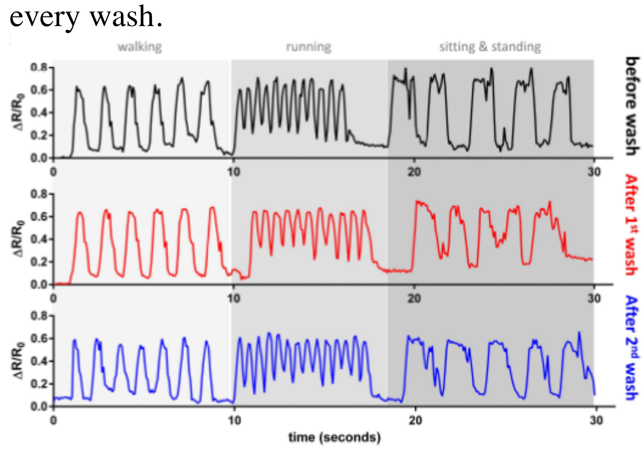

Figure 1. Thread performance after 2 washing machine

cycles (Sadeqi et al., 2018).

Glove Application

For the salmon team data glove senior project, these threads are used to detect hand movement. Specifically, there are threads attached to each finger on a glove which can detect the movement of each individual finger. The threads start on the back of the hand attached to a 3.3 volt source on an Arduino microcontroller. Each thread then runs down the finger, loops around at the nail, and comes back to the back of the hand where it is grounded on the Arduino. Each thread has a current source which supplies a constant current to the threads no matter how much the thread is stretched. This is important because since the threads are resistors, their resistance is what changes with strain. An Arduino cannot read in resistance, instead it reads in voltage. Given Ohm's Law (V = IR), if the current is constant and the resistance changes, this results in the voltage only varying with resistance and leads to easier and more consistent readings of the thread strain.

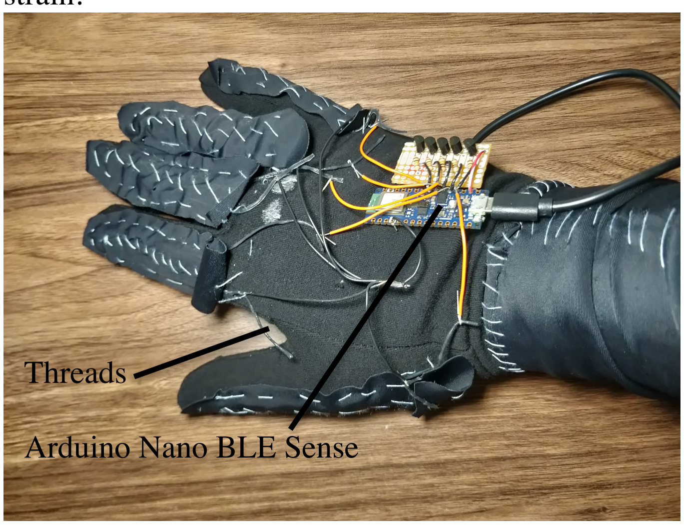

Figure 2. The salmon team data glove with smart threads running down each finger and Arduino on the back of the hand. (Photo by Aaron Epstein)

Future Glove Applications

Currently, the data-glove has 5 threads with each spanning on finger. As the data-collection and interpretation is further developed, more threads can be added to further measure hand movements. For example, a thread can be placed between the fingers to measure whether someone's hand is stretched and open as far as possible, or if all the fingers are close together and touching each other. A lot of the technical challenges involving the data glove don't involve the threads and reading in data, instead it is filtering this data and assigning it to specific hand movements. Solving some of these challenges is beyond the scope of team salmon's work for this project.

Conclusion

The smart threads developed in the nano-lab at Tufts were applied to a "data glove." The data glove uses the threads to measure how much a finger is flexed or straightened. This allows for the hand to be modeled digitally which has different applications such as control of 3-dimensional object on a screen. Furthermore, the threads are made with inexpensive materials and are inexpensive and easy to produce. They can also be washed without major loss in their performance.

References

Nejad, H. R., Punjiya, M. P., & Sonkusale, S. (2017). Washable thread based strain sensor for smart textile. *2017 19th International Conference on Solid-State Sensors, Actuators and Microsystems (TRANSDUCERS)*, 1183–1186. https://doi.org/10.1109/TRANSDUCERS.2017.7994265

Sadeqi, A., Rezaei Nejad, H., Alaimo, F., Yun, H., Punjiya, M., & Sonkusale, S. R. (2018). Washable Smart Threads for Strain Sensing Fabrics. *IEEE Sensors Journal*, *18*(22), 9137–9144. https://doi.org/10.1109/JSEN.2018.2870640