Deformation Sensors Building Instructions

For TEI 2018 Studio:

Deformable Controllers: Fabrication and Design to Promote Novel Hand Gestural Interaction Mechanisms

http://cil.csit.carleton.ca/deformable-controllers

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Welcome! In this studio you will learn to use deformation sensors as an organic and tangible means of human-computer interaction. You will fabricate some deformable sensors, then design and build your own deformable controllers.

The goal of this studio is to provide a platform to share resources and transfer knowledge of deformable sensors/materials, to foster creativity in using deformable devices as input controllers that harness the wide range of gestures that deformation enables, and to move beyond recreating touch/click inputs in deformable device interactions.

This document provides the building instructions for making bend/pressure sensors. We have also included an appendix in the end detailing the materials as well as from where we source them.

General Hardware/Software List

Here is a list of the basic hardware and software required to build and test the sensors.

Resistance-based Bend/Pressure Sensor

- Processing 3.0 or above (https://processing.org/download/)
- Arduino IDE (https://www.arduino.cc/en/Main/Software)
- Arduino UNO circuit board
    - USB cable, Breadboard, M/M jumper wires, alligator clips, resistors, hook-up wires
- Plastic sheet
- Copper tape
- Velostat sheet

Optical-based Bend Sensor

- Processing 3.0 or above (https://processing.org/download/)
- Arduino IDE (https://www.arduino.cc/en/Main/Software)
- Arduino UNO circuit board
    - USB cable, Breadboard, M/M jumper wires, alligator clips, resistors, hook-up wires
- Optical fiber cable
- LED
- Photo sensor
- Heat shrink
- Heat gun

Common Supplies

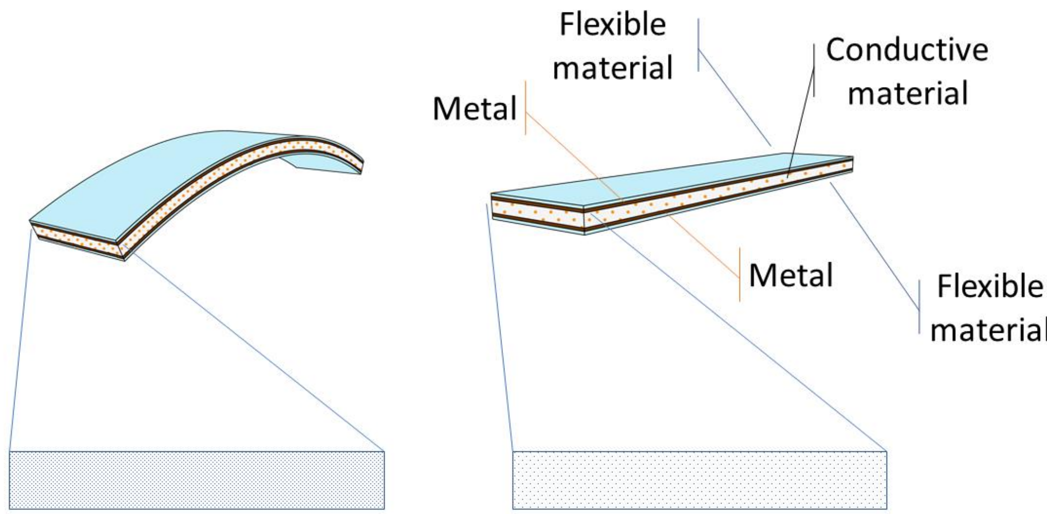
- Electric tape
- Glue gun + glue sticks
- Multimeter
- Soldering supplies

Online Resources (Instructions and code)

https://github.com/CreativeInteractionsLab/DeformableControllers

Resistance-based Bend/Pressure Sensors

By measuring changes in resistance of a conductive layer, one can determine the degree of bend as well as amount of pressure applied to the layer.



Resistance changes when the sensor is bent because the conductive molecules in the pressure sensitive separating layer are forced closer to each other, increasing conductivity across the layer. This change in conductivity is measured as change in resistance and can be translated into a bend/pressure measurement.

Assembly Instructions

Step 1: Prepare all the layers

There is a total of 5 layers in the sensor (from outside):

1)	non-conductive flexible material	Plastic sheet
2)	Conductive metal	Copper tape
3)	Pressure sensitive conductive material	Velostat
4)	Conductive metal	Copper tape
5)	Non-conductive flexible material	Plastic sheet

We are using a copper tape with adhesive on one side, making it easier to attach to the flexible layer.

Step 2: Adhere the copper tape to the plastic sheet.

The flexible material (plastic sheet) provides both rigidity and protection to the bend sensor. It should be at least as big as any of the other components.

Step 3: Stack the layers

Stack all the layers together in the following order:

Plastic sheet – Copper Tape – Velostat – Copper Tape – Plastic Sheet

Make sure the conductive material completely separates the metal layers (the copper pieces should not touch directly).

Shift the layers to expose the metal components on both ends.

Expose the metal components in preparation for alligator clips.

From top to bottom:

- Plastic Sheet
- Copper tape
- Velostat
- Copper tape
- Plastic Sheet

Fasten everything into place using tape.

Step 4: Test it with Arduino

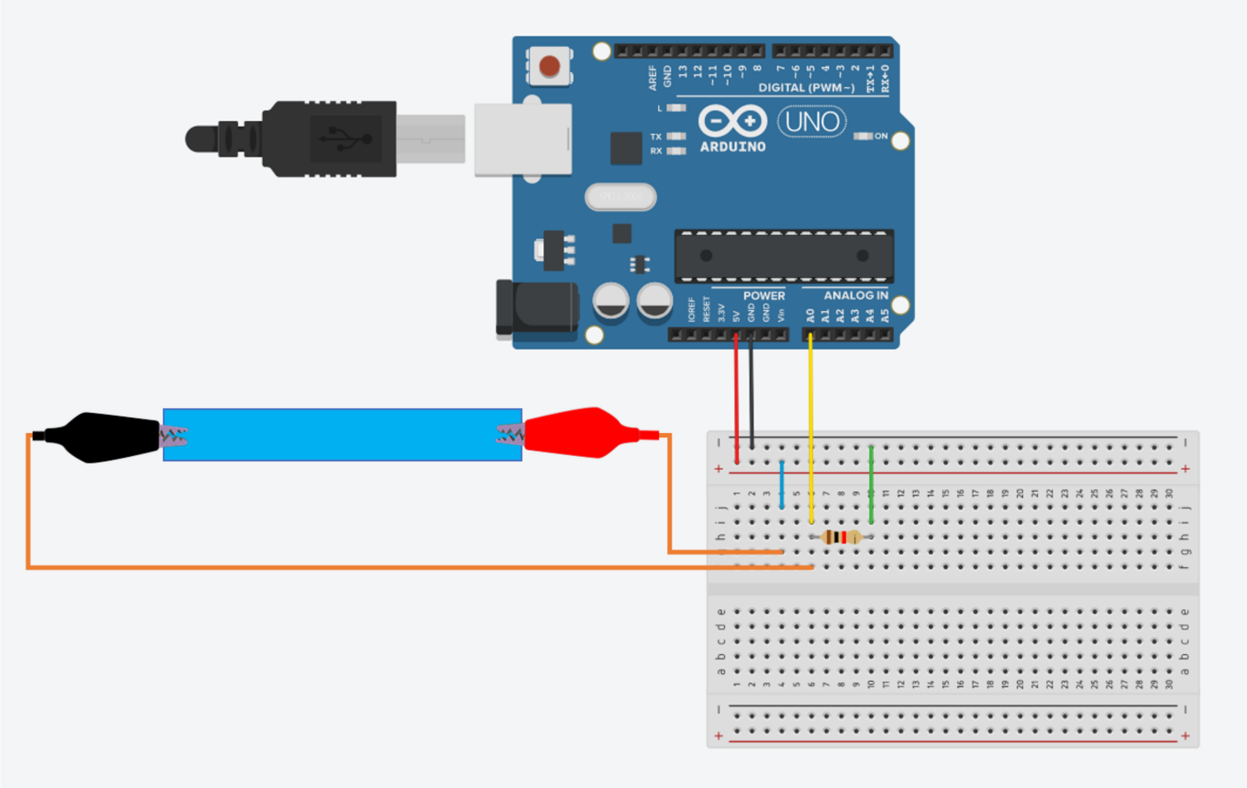
At this point the resistance-based bend/pressure sensor is finished. We can test this by connecting it to an Arduino board. The Velostat's resistance decreases as it is compressed, that is, the more bending/pressing, the lower the resistance.

The end points and changes of the resistance depends on a lot of factors, for example, the shape of the sensor or the conductive properties of the layers, so calibration is required.

To calibrate, connect the sensor to a multimeter. Take note of the resistances when straight, and then when bent. These can be used in the processing code, with a mapping function.

You will also need a resistor of "comparable resistance" to the sensor. In this example the sensor is about 10kOhm, and the resistor we use is 1kOhm.

Use the following schematic to connect the sensor to an Arduino board.



Optional Step: Solder jumper pins to the metal layer

Do this step to get a more secure connection point to other devices.

Cut two pieces of female jumper pins, leave some wire for soldering.

Determine the ends of the bend sensor, it is best when the ends are further away from each other. Strip away the coating on the jumper pin wires and solder them to the determined end of the sensor.

Tip: The soldering happens in the inside (in contact with the metal layer), while the jumper is on the outside of the flexible material. One can be creative on where and how to perform the soldering.

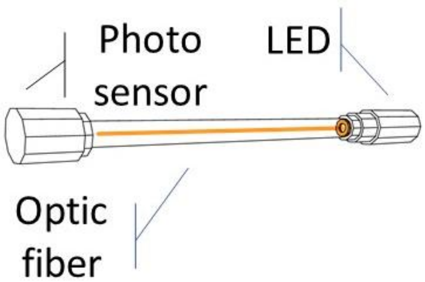
Flux can be used to prepare the surface (useful if it is tarnished or has been handled).

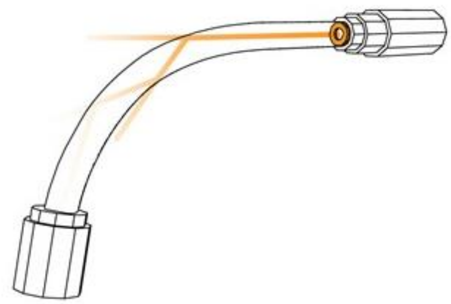
References

Neoprene Bend Sensor: http://www.kobakant.at/DIY/?p=20

Optical-based Bend Sensors

By measuring changes in the intensity of light passing through an optical fiber, one can determine the degree of bend.



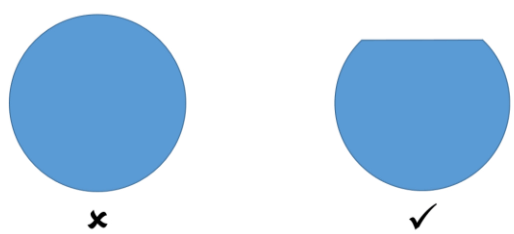


To create fibre optic bend sensors, we modify the cable to allow light to escape when it is bent, this results in less light reaching the end of the fibre. This change in light intensity is measured by a photo sensor and can be translated into a bend measurement.

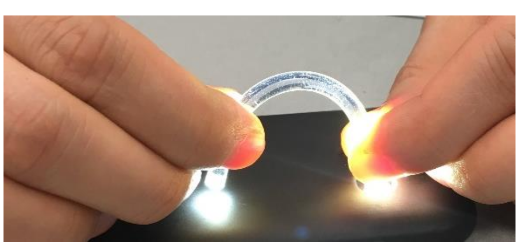
Assembly Instructions

Step 1: Scraping the optic fiber

To facilitate the escape of light when the cable is bent, we scrape or sand down one of its side. The image below illustrates the cross section of the cable.



To do so, scrape the cable along its length using a razor blade (or sand paper). We have fabricated a mold to house the cable for easier sanding. The mold is a piece of wood where we laser-cut a whole that fits in width and length our cable perfectly, and with a depth approximately 2/3 of the diameter of the cable. The images below show a cable before sanding (left), and how it should look like after (right), when placing one end to the flashlight LED of a smartphone.



Before sanding down the fiber cable, it remains transparent when bent.

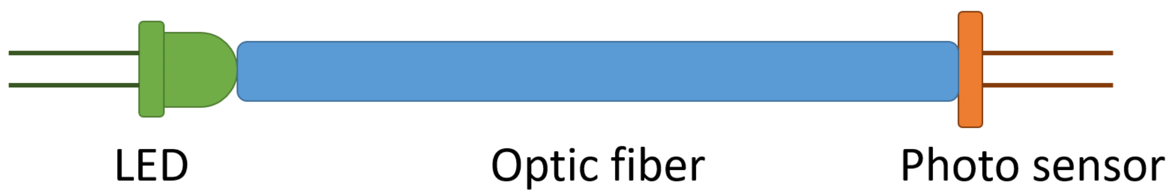
After proper sanding, one side of the fiber cable glows when bent, due to the escape of light.

Caution: Sanding can produce very fine dust, wet your sandpaper occasionally and, when finished, wipe up the work area with damp paper towel.

Tip: You can also cut notches at equal distances along the fiber, so that some light will escape when these notches widen during a bend.

Step 3: Connect the components using heat shrinks

The three main components of the sensor are 1) LED, 2) optic fiber and 3) photo sensor. They need to be connected together into one piece.



Tip: To get as much light into the fiber as possible, the ends need to be smooth. To do so, use a lighter to heat up the ends to the point where they are almost melting, thus forming a smooth surface. Alternatively, it can be sanded with increasingly fine sandpapers.

To connect the three components, first thread the fiber through a piece of heat shrink, cut long enough so that it covers the fiber, LED, and photo sensor, but leaves the leads exposed.

Then on each end, use 1-3 heat shrinks of increasing sizes to secure the LED and photo sensor in place.

Once everything is in place, use the heat gun on the heat shrink, this will hold everything tightly together.

Tip: You can also use heat shrink of different colours (if available) to better distinguish the LED end and photo sensor end.

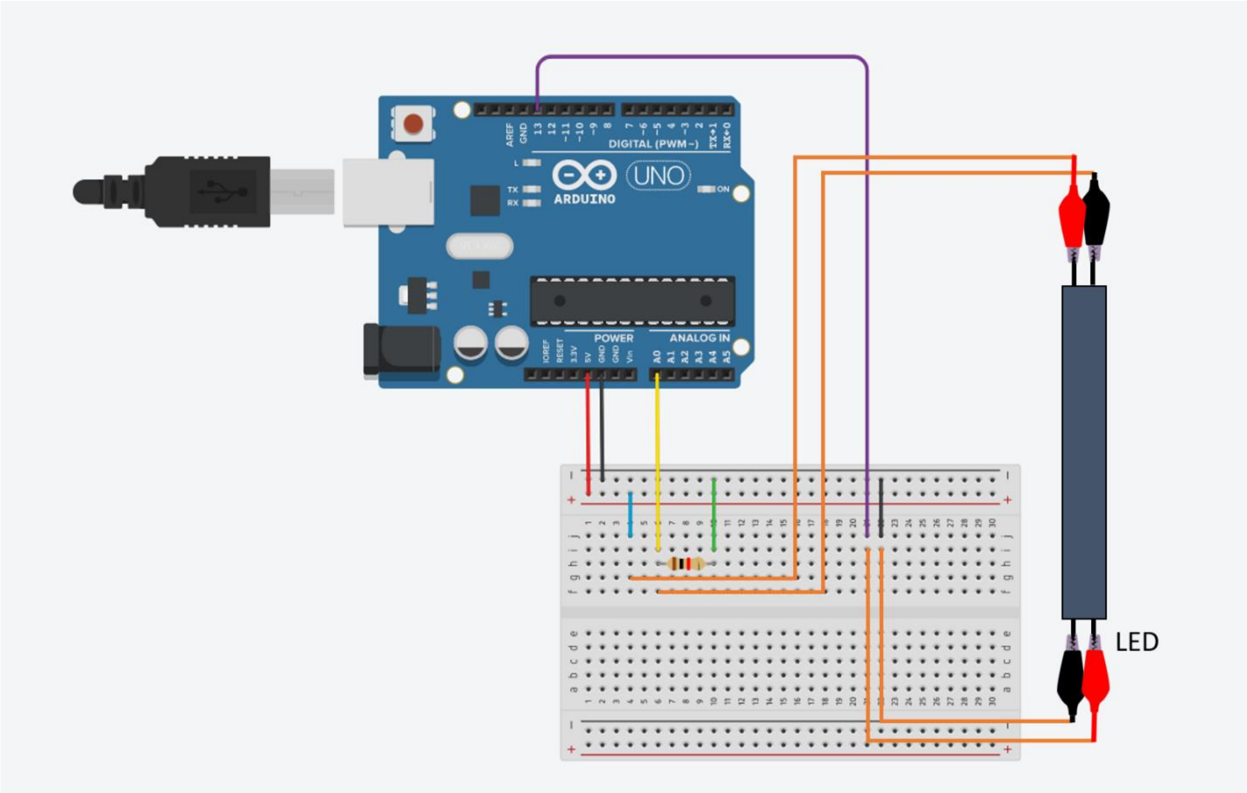
Step 4: Test it with Arduino

At this point the optical-bend sensor is finished. Now it is time to test it by connecting it to an Arduino board. The photo sensor's resistance increases as the light intensity it receives decreases, that is, the more bending, the higher the resistance.

The amount of light actually received by the photo sensor depends on a lot of factors, e.g., how much scraping, purity of the fiber, brightness of the LED... etc, so calibration is required.

To calibrate, connect the LED end to a power supply, and the photo sensor end to a multimeter. Take note of the resistances when straight, and then bend. Then use them in the Processing code (if a mapping function is included).

Use the following schematic to connect the sensor to an Arduino board (note the similarity between this and the above at the resistance-measuring part). Pay special attention to the polarity of the LED.



Advanced

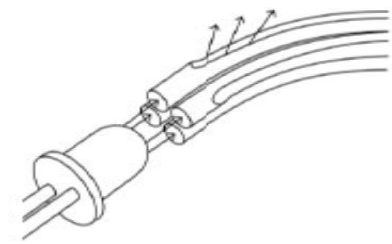
Option 1: Preparing the optic fiber (only if needed)

The optic fiber often comes in a spool, so it can have a slight curve. This can be a problem if you want it's resting state to be straight/flat. To straighten the fiber, use clamps or other means to secure it in a straight position, heat it up with hot water or a heat gun for several minutes to soften the optic fiber. When it cools, it will remain straight.

Some fibers come with a sheath and must be removed before sanding down one side. In this case, cut open the sheath and remove it first.

Option 2: Multiple sensors for multi-direction bending

Each optical-based bend senor can detect a bend in one direction, to be able to detect all directions, one needs to bundle 4 such sensors together.



References:

Optical Flex Sensors: http://www.instructables.com/id/Optical-Flex-Sensor/

Fellion, N., Eady, A.E., Girouard, A. FlexStylus: A Deformable Stylus for Digital Art
CHI EA 2016: ACM Conference on Human Factors in Computing Systems Extended Abstracts

FlexStylus: Leveraging Bend Input for Pen Interaction
UIST 2017 ACM Symposium on User Interface Software and Technology

Appendix

This section provides the list of materials for making bend/pressure sensors in this workshop, and where we found them. The sources listed are mostly Canadian based, though some would do international shipping. Note that most of our materials are easily available through other suppliers. You can also look for alternatives in size, colours, amounts.

Material	Notes	Source
Optical-based Bend Sensor		
Optical fiber	We are using single strand filament with 5.0mm diameter (~ 7/32"). Other diameter sizes would work too (we choose a large size for illustration purposes).	https://thefiberopticstore.com/product/5-0mm-scsg-25-ft/
LED	We are using 5mm but 3mm works better in size when the fiber is thin.	https://www.robotshop.com/ca/en/3mm-5-differentcolors-led-50pk.html
Photo sensor		http://www.robotshop.com/ca/en/mini-photocell-light-sensor-5pk.html
Heat shrink	Get the assorted ones for reinforcing the connections. Need a specific size (3/16in) for the fiber we are using.	https://www.digikey.ca/product-detail/en/qualtek/Q2-Z-QK1-01-6IN-180/Q2Z1-KIT-ND/754916
Resistance-based Bend/Pressure Sensor		
Copper tape	We are using the 2in rolls but can also get 1in rolls for narrower sensors.	https://www.amazon.ca/Copper-Conductive-Adhesive-1inch-12yards/dp/B018RDZ3HG/ref=sr_1_3 https://www.amazon.ca/Shielding-Repellent-Electrical-Repairs-Grounding/dp/B01I1XNY1E/ref=sr_1_5
Velostat sheet		http://www.robotshop.com/ca/en/pressure-sensitive-conductive-sheet-velostat-linqstat.html
Ready-made Sensors		
Bend sensors	We use these to build additional build controllers with ready-made sensors. Contact the manufacturer to see if educational discount is possible. There are also other manufacturers.	http://www.flexpoint.com/
Stretch sensors	We use these to build additional build controllers with ready-made sensors.	https://www.robotshop.com/ca/en/1m-flexible-stretch-sensor-cord.html