Research Paper: soft composite materials for shape changing interfaces and flexible circuits

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ABSTRACT

We demonstrate three different types of shape-changing interfaces and soft composite materials. Each of these interfaces expand the soft robotics field and have potential to be integrated into may other fields. The materials we explore integrate the capabilities of both input sensing and dynamic shape changing output.

Keywords

Soft Composite material; haptic technology; Pneumatic System; Soft Robotics; Human-Material Interaction; Shape Changing Interface; Organic User Interface

INTRODUCTION

Innovative shape changing interfaces are being explored by MIT Media Lab researchers. In their paper which has just this year been released, *PneUI: Pneumatically Actuated Soft Composite Materials for Shape Changing Interfaces* they experiment with various materials to create dynamic texture change. We used their work as inspiration and re-created and expanded their research. We believe that there is an increasing importance to develop soft computational interfaces for Human Computer Interaction since approaches and techniques in soft robotics have not been fully explored in HCI. (Yao et al.)

Our hypothesis is that we can create soft composite materials for shape changing interfaces and flexible circuits.

DYNAMIC TEXTURE CHANGE

Two approaches of particular interest are their tests to create dynamic textures on soft surfaces.

The picture below illustrates the method these researchers implemented. They fabricated silicon with air bubbles to make different channels. To create a tactile output they inflated air into each of the air channels so that when holding the mould, one would be able to feel each of the air bubbles either inflated or deflated.

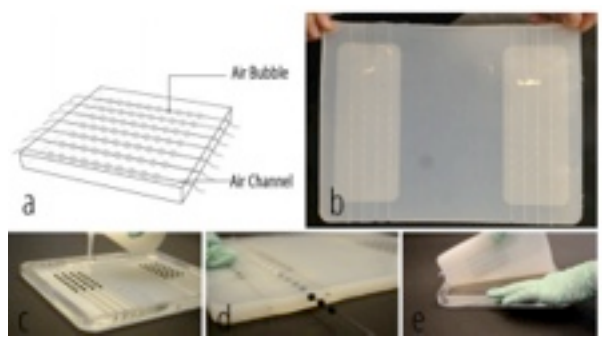

Figure 1: (a, b) Structure of the composite material. (c, d, e) Fabrication process. (c) Pouring pre-mixture of silicon into a mold with threads of beads suspended in the mid-air. (d) Thermally curing the silicon and peeling it off the mold. (e) Pulling the beads out of the silicon for the final sample. (Yao et al.:6)

The density, frequency and sequence of the texture can be altered by pumping and vacuuming the air into the separate columns at different times. (Yao et al. :6) Using this method, bigger air bags could be used, and bigger holes made, so that the scale of this application could work on both micro and macro levels.

Applications of this kind of technology could be to enhance gaming or mapping technologies- giving you directional signals and speed, and also 3D modeling textures and patterns.

The second approach to create the dynamic texture was creating a composite material which utilized cut stretch fabric to create the texture. As the air pressure inside the surface increased, the texture was able to be seen on the surface of the silicone, from “global to local region” (Yao et al.: 6)

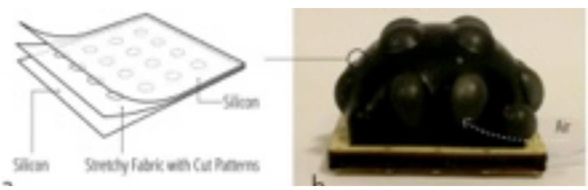

Figure 2: a) Structure of composite material. (b) Fabric constraints of deformation in local areas of surface.

Figure 3: As the air pressure increases the surfaces deform.

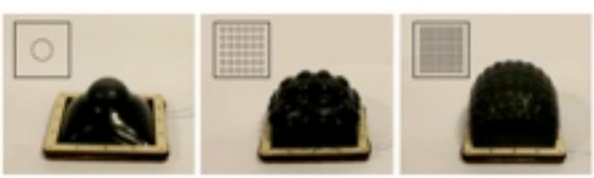

Figure 4: Different textures generated due to different cutting patterns.

Material Research

We conducted experiments to test composite flexible surfaces with silicone reproducing the second approach. Using a 12v air pump, we blew air into the air tight box and tested different fabrics and materials inside the silicon to create different textures and to test resistance of the conductive materials.

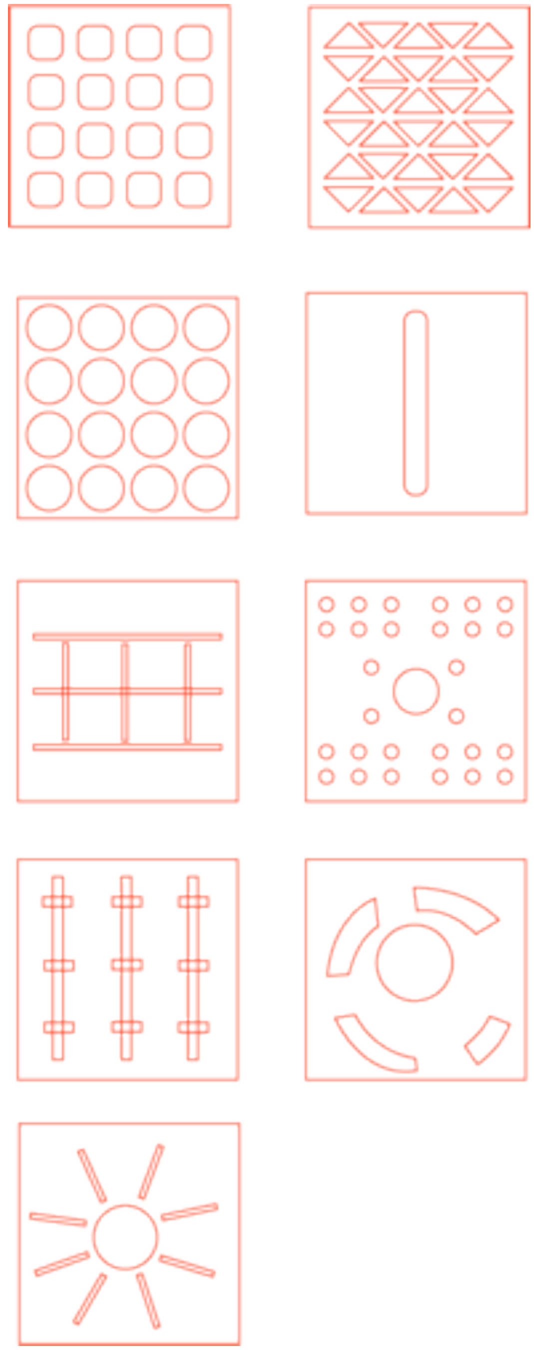

Figure 5: Adoble Illustrator laser cut designs.

Procedure:

1. Make an air tight box (approx. 3 x 3in.) with an empty space for the tubing from the air pump & a space on the top (approx. 80% of the center empty) which will be covered with the silicone mould.
2. Cut an extra flat square of plexiglass with 80% cut out of the middle so these can fit on the top of your box (we will be clamping this down on top of the silicon mould).
3. We suggest using Adobe Illustrator, a laser cutter and plexiglass to create your box.
4. You will also need to cut out patterns on the spandex or whichever material you choose, we used a laser cutter for this also.
5. Create or buy ready made moulds (approx. 5x5 in.) you're going to use these pour in the silicon.
6. Create your silicone moulds by mixing the silicone (parts=1:1) with enough silicon to fill each of your moulds by approx. 3mm.
7. Place your fabric into the mould and pour in the silicon, make sure all parts of the mould are covered.
8. Leave to cure on a level surface.
9. Remove when cured and place onto your box.
10. Use clamps to keep the silicon in place underneath your extra square of plexiglass.
11. Turn on your air pump and watch your textured silicone come to life!

Figure 6: Creating the box.

Figure 7: Creating the box.

Figure 8: Creating the box.

Figure 10: Composite silicon experiments: conductive fabric.

Figure 11: Composite silicon experiments: nickel particle ink.

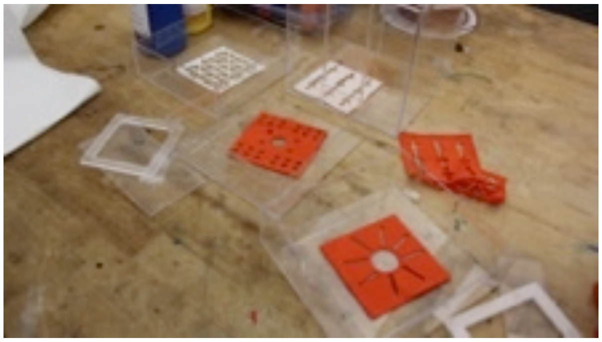

Figure 12: Composite silicon experiments: laser cut spandex.

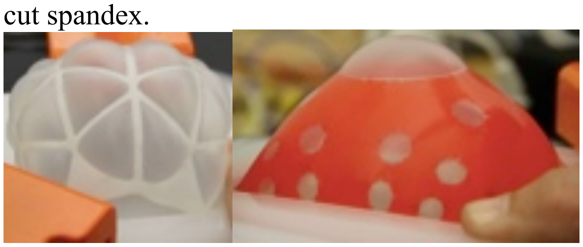

Figure 13 & 14: Composite silicon experiments: Pneumatic textiles.

Results

The experiment was successful, we were able to use air to explore a number of different textures we had designed. We also discovered that experiments with the conductive fabric were unsuccessful since the silicone had penetrated the fabric so electricity could no longer pass through the material. Further information on this can be found below in “Sensing Through Silicon Structures”.

Application/ Functionality

These dynamic textures could be used as an output for a data stream, with the data controlling the input of the air. It could be used both for visual output and tactile output, for example for educational tools, interactive art, games, and so on.

COMPOSITE SENSORS ON PAPER ENGINEERED STRUCTURES

Compositing copper tape on linear-paper engineered structures, the change in length of a structure can be sensed and measured. The change in length of the structure can be caused by direct human manipulation or another force factor. The building and measurement process for this methodology is outlined below:

1. Construct a 3D structure with distinct folds equidistance apart
2. Place rectangular electrodes made of copper tape horizontally along the side of the paper, equidistant apart
3. Connect the top electrode to a form of voltage output to pass a square wave of voltage
4. Connect the additional electrodes to Arduino digital pins set up as capacitive sensors
5. Connect the capacitive sensors to one small capacitor and large resistor each
6. Stimulate the top electrode with a square wave of voltage
7. Read induced capacitance on the other electrodes at time, T, after the rising and falling edges of the square wave
8. Average the measurements over 24 cycles and use these values to map a digital model of the physical model

As seen in Figure 1, as the distance between the electrodes decreases, the induced capacitance decreases towards zero.

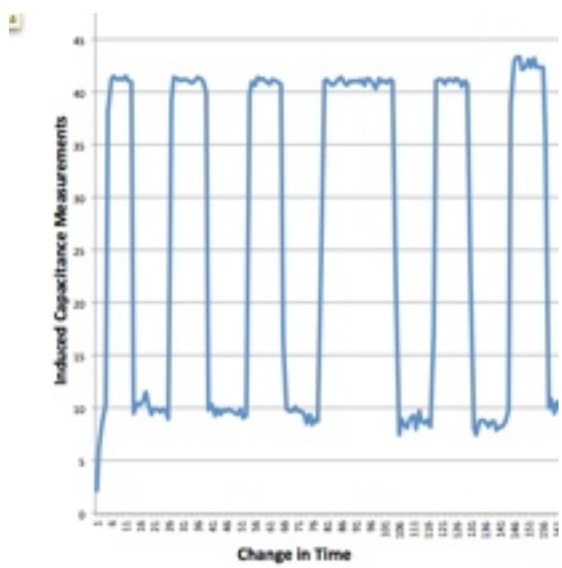

Figure 15: Induced Capacitance Measurements on a Single Electrode

In order to obtain this successful methodology, multiple experiments and iterations using paper engineered structures and copper tape were conducted. The data collected in these iterations were analyzed to formulate the above methodology, and key deductions from those iterations were utilized. Key deductions are as follows: i) To measure longer paper engineered structures, more electrodes are necessary and vise versa ii) As the number of electrodes increases, the induced voltage on the top electrode must increase for successful measurements iii) To stabilize the induced capacitance values being measured, a small capacitor should be placed in parallel to the resistor and digital pin used as the measurement pin. Figure 2 displays the set up.

Figure 16: 3D Physical Structure Composed of Composited Sensors & 2D Digital Representation

The horizontal stripes of copper tape on the folds represent electrodes. The top electrode is being stimulated with a square wave voltage, and the induced capacitance on the bottom capacitor is being measured continuously. In the background, the blue box is the 2D digital representation of the 3D physical box.

Application/ Functionality

This tool bridges the physical and digital realms, and therefore, this methodology can be used as a digital modeling tool for physical structures. With such a basic functionality, this tool can be used in multi applications: learning tools, architectural modeling, games, tangible and interactive art, etc.

This methodology presents a computational composite material, and with such a short timeframe, the presented methodology is successful. In the future, there is room for exploration and experimentation to utilize more complex 3D structures and expand upon the sensor material utilized. Additionally, with the appropriate equipment, stimulating all four sides of the physical structure in order to transform the 3D physical structure into a 3D digital structure should be explored.

SENSING THROUGH SILICONE STRUCTURES

The aim of the series of experiments conducted was to collect data on how composite materials, such as silicone structures embedded with various sensors, can act as inputs.

Procedure:

1. Make a mold and place one copper tape contact and conductive fabric strip inside.
2. Pour in silicone and allow it to cure.
3. Cut a hole in the silicone where the contact is placed and place the second contact on the other end, so when compressed, the two contacts act as a switch.
4. Connect the two ends of the contacts and conductive fabric to the Arduino digital pins using a 10 K resistor for each switch.
5. Press the buttons on each side and observe the 0 and 1 values on the serial monitor fluctuating.

Results:

The switches were successful at sending data when pressed, but the conductive fabric wasn't sending data when stretched, as silicone is not the appropriate medium for it to be immersed in.

Figure 17: Silicone mold

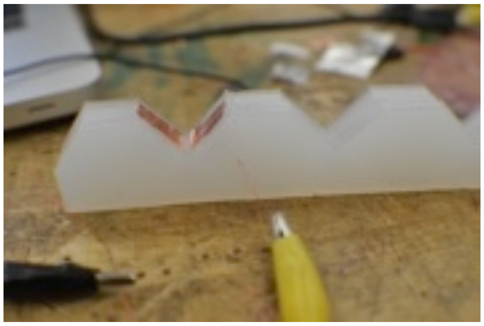

Figure 18: First silicone controller with copper tape switches embedded in it

Figure 19: Second silicone controller with copper tape switches outputting data to the web

Web Communication:

The data collected from the buttons and the conductive fabric. The data is send through a wifi shield to a platform called Xively platform. Xively is a platform that acts as a middleman, receiving data from devices, like the Arduino, and produces an API for them to be used in websites as a method to parse data. This was a convenient way for wireless communication to the web. See Fig 4. To view data printed from the two button sensors onto Xively.

Figure 20: Data printed from the sensors to Xively

Applications:

Molded silicone structures could be used as controllers that output to the web, as tangible interface, such as in games or as educational tools for modeling structures on screen.

CONCLUSION

We have demonstrated three different types of shape-changing interfaces and soft composite materials. Each of these interfaces expand the soft robotics field and have potential to be integrated into may other fields. Our hypothesis of fusing sensing and actuation using soft composite materials has been proved correct and we propose that these materials be further experimented with for more specific uses in education, tangible interfaces, modelling 3d structures, architecture and art installations.

ACKNOWLEDGEMENTS

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