Laser-Etching Flexible Sensors For Robotic Touch Recognition

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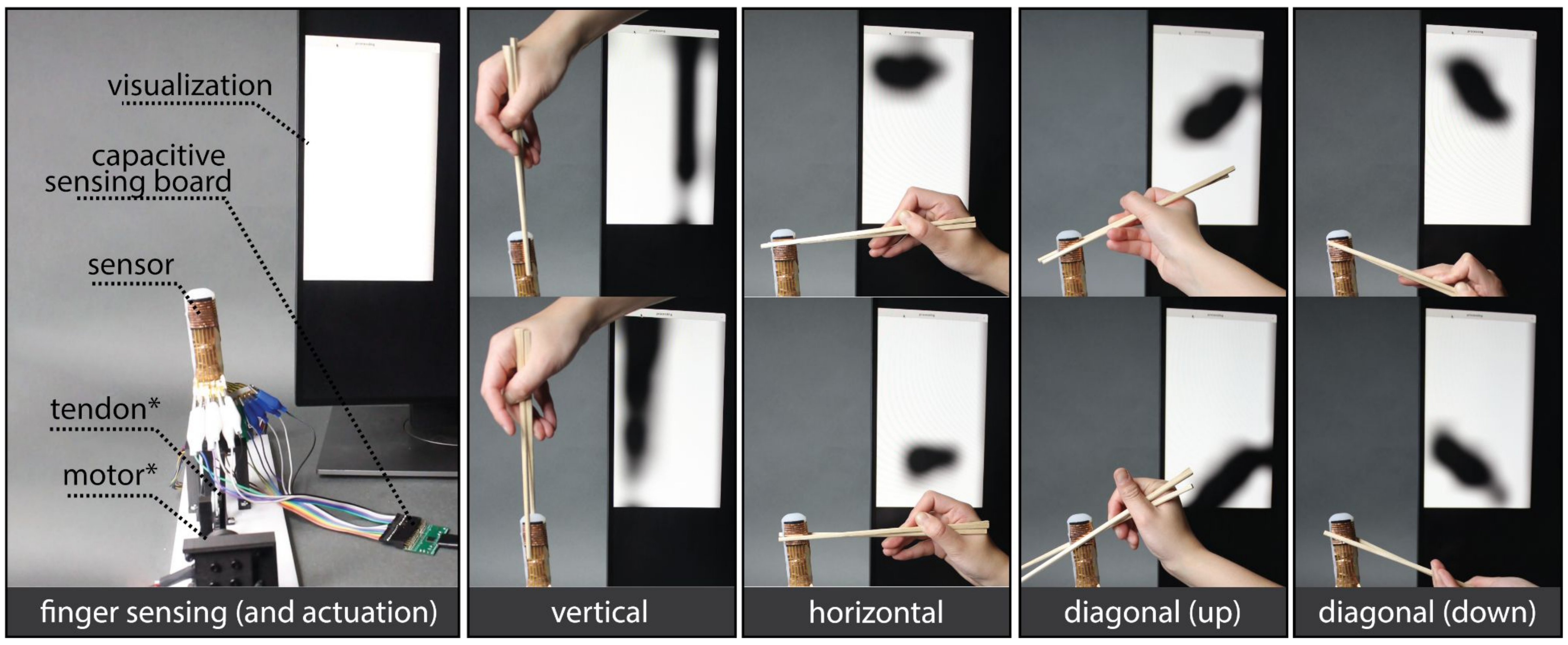
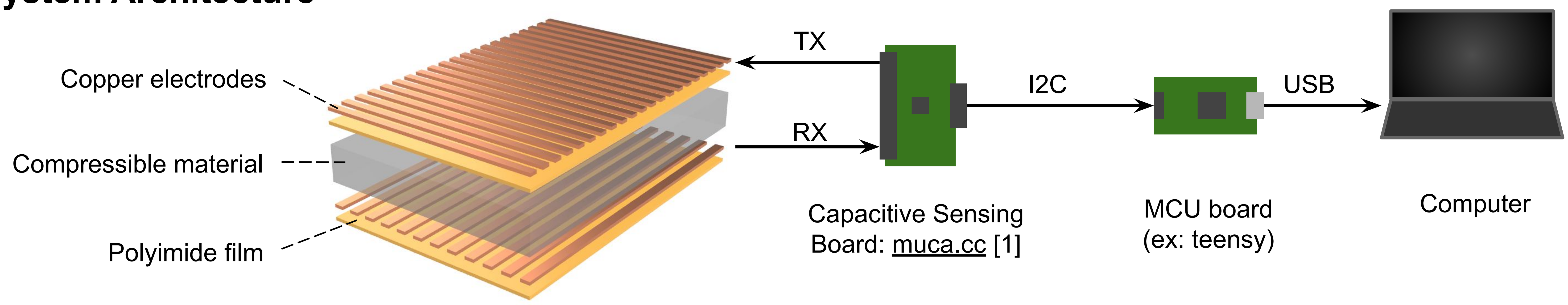
Abstract

We present a robotic touch sensor fabrication method for flexible and robust sensing applications. We used a repurposed touch screen sensor IC to allow high-level data processing such as blob tracking, which can enable real-time slip detection. To fabricate the sensor, we laser-etch traces in copper tape with a q-switched laser (also called "fiber laser"), and use Kapton tape (polyimide film) as a substrate, which ensures flexibility. The sensor can be strengthened using an encapsulation such as silicone coating, or latex glove finger. Our approach provides a fast, affordable and customizable solution for various sensing applications.



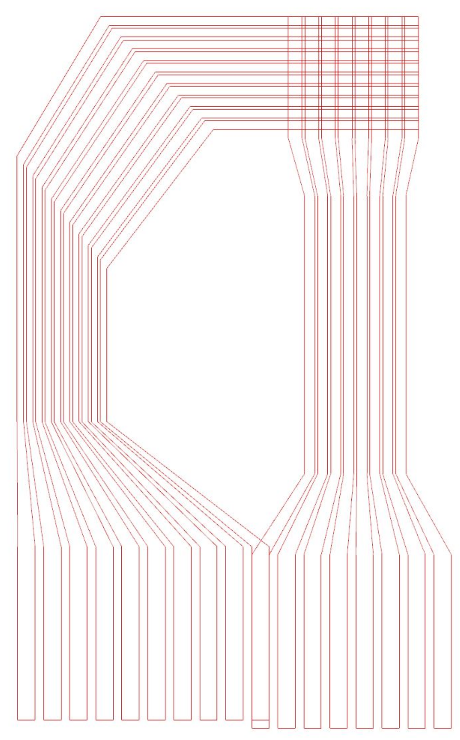
System Architecture

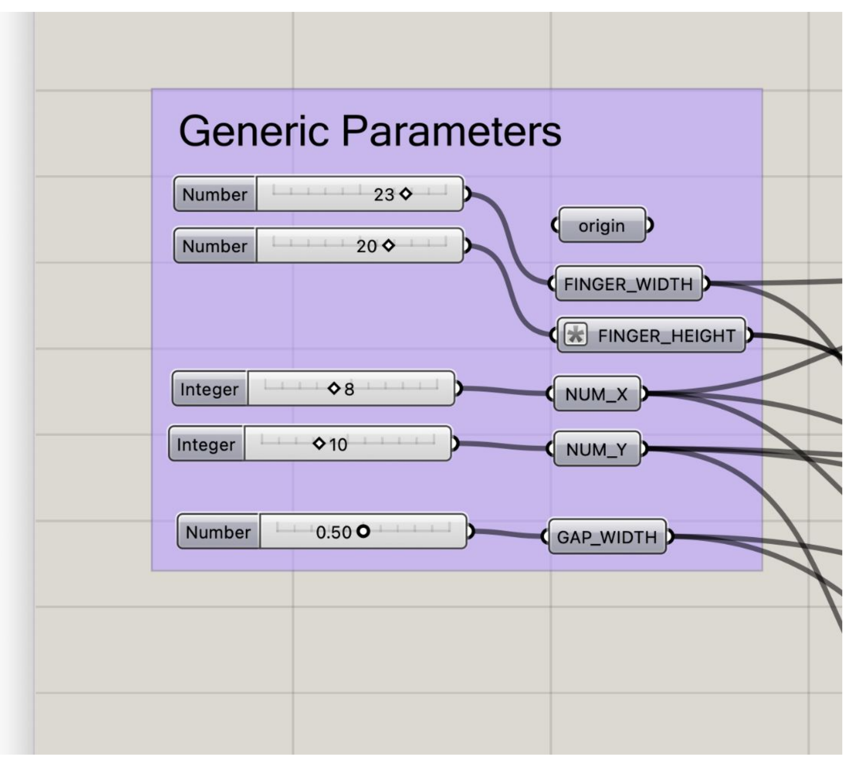


Sensor: 21 x 12 electrodes

Sensor Fabrication

Our sensor consists of five layers: polyimide film, vertical copper traces, compressible material, horizontal copper traces, and another layer of polyimide. The electrodes can be designed using vectorial tools such as inkscape, or generated by custom tools such as the one illustrated on the right (made with rhino - see Design Files link below). The copper traces were laser cut using a fiber laser cutter (with a 1064 nm wavelength - 60W) on a substrate of polyimide tape. This process allows for fast and precise patterning of the copper traces. The compressible material (3d mesh, or spacer fabric) was placed in between the copper traces (and polyimide layers) to allow pressure sensing with variable capacitance measurement. The layers were then assembled together on the surface of a robotic finger [0] (also denoted with a star* in the photos), creating a robust and flexible sensor that can be used in a wide range of sensing applications.





Design Files and Software (Signal Processing + Visualization)

For this demonstration, we connected the electrodes to a capacitive sensing board [1] using alligator clips, but they can also be soldered. The board sends its data to a microcontroller, which can be used to actuate accordingly, and/or display the processed data in a computer.

- The code is open source: **github.com/HCIELab/MuCa_Finger**
- A video demonstration and the electrode design generator are available here: **is.gd/MuCa_Finger** => QR code =>

Advantages / Takeaways

- **Robustness:** Conductive ink printing was also explored for the electrode, but our approach is more robust because sintered ink tends to crack when deformed. Using laser patterning on copper, our sensor offer greater durability and longevity, and its stretchability can be enabled using accordion folding structures.
- **Affordability and scalability:** Laser patterning has a negligible set-up cost (and time) compared to other manufacturing processes such as PCB fabrication or 3D electronic functionalization. This affordability makes our approach accessible to a wide audience while allowing production of sensors at a large scale.
- **Computer vision possibilities:** Our capacitive sensing chip enables the implementation of simple computer vision techniques, such as blob tracking. This allows for real-time slip detection, making our sensors useful for applications such as grip force monitoring or slip detection in robotic finger manipulation.

Future work

- **Physical interpolation:** To improve the sensing resolution and allow for more algorithmic possibilities, we can use interdigitated patterns on the electrodes to achieve physical interpolation [2]. This would enable more precise sensing and interpretation of data at the transition between electrodes.
- **Active shielding:** Metal object could interfere with capacitive sensing, but it can be protected using an active shielding [3] system. However, an extra conductive layer would be needed, which may decrease flexibility slightly but conductive textile can maintain a reasonable level of flexibility.

References

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[1] ICRA'21: Human-Like Artificial Skin Sensor for Physical Human-Robot Interaction - doi.org/10.1109/ICRA48506.2021.9561152
[2] TEI '19: Optimizing Pressure Matrices: Interdigitation and Interpolation Methods for Continuous Position Input - doi.org/10.1145/3294109.3295638
[3] MeaSciTech'08: A novel interface circuit for grounded capacitive sensors with feedforward-based active shielding - doi.org/10.1088/0957-0233/19/2/025202