Enhanced Embedded Force Sensing in Sensorized Prosthetic Hands with Multilayered Piezoresistive Arrays

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***Abstract*— Individuals with limb difference can struggle to use prosthetic devices in daily tasks due to the lack of adequate tactile sensing. Tactile sensing in the natural hand is very complicated and represents a myriad of sensations. To this end, we are developing a low-cost flexible pressure sensor capable of measuring a range of tactile sensations for prosthesis control.**

I. Introduction

Tactile sensing is vital for dexterous control during object manipulation. Commercially available prostheses historically lack tactile sensing. Thus, prosthesis users lack the rich tactile sensations necessary for intuitive control. We aim to create a flexible pressure sensor to enhance control systems in prosthetic hands and provide rich haptic feedback to users. This sensor can be embedded at different depths to mimic Meissner, Merkel, and Pacini mechanoreceptors. Our work complements prior efforts in the field to improve tactile sensing in prosthetic hands by developing a method that enables us to adjust their spatial and temporal resolution, while simultaneously reducing the computational power required to process these signals. Osborn et al. demonstrated the efficiency of piezoresistive sensors at detecting disturbances due to slipping during grasping. Likewise, work by Rostamian et al. showed a 8 x 8 piezoelectric sensor that mimics SA-I/RA-I ability to sense static/dynamic skin indentation.

II. Methods

Our approach includes a custom-made piezoresistive sensor, as presented in figure 1, whose 256 readings are preprocessed in a Wheatstone bridge to create 64 sensing zones. Each zone has four copper traces with two output traces connected to a half Wheatstone bridge and two power traces connected to a 5V supply. The output and power traces are separated by piezoresistive material (Velostat) to form an electrical connection at the intersection between any power trace and any output trace. When each sensing zone is pressed its resistance drops. The half Wheatstone bridge amplifies the signal, translating the resistance drop into a readable voltage. Each power trace on the sensor is connected to a 5V source on a microcontroller. Each output trace is connected to an analog port on the microcontroller. By measuring the change in voltage from each Wheatstone bridge configuration, changes in pressure can be resolved and displayed on a virtual grid. Due to our choice of copper traces and piezoresistive material, our sensor is very flexible.

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III. Results

Our results show that 64 different pressure readings can be rendered in our virtual grid. Each square in the virtual grid represents a sensing zone, which at max pressure can determine if an object smaller than 0.13 mm is acting on the surface area. Our high-density, low latency, and computationally inexpensive force sensor accurately track forces moving across the sensing area. The end-to-end latency was approximately 0.25 seconds. This value was calculated with the help of a slow-motion video. The sensor's activation force was non-uniform due to manufacturing imperfections, with a minimum recorded force of 0.49 N, while uniform activation required 1.47 N across its surface.

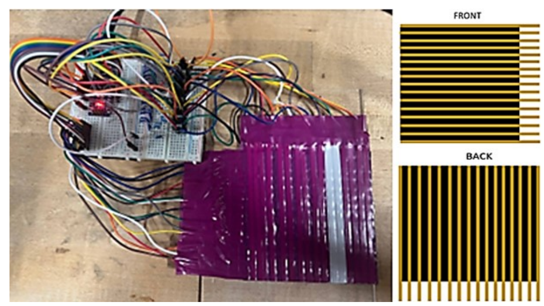

Fig. 1. A flexible force sensor connects to an Arduino Nano with 16 copper traces running horizontally on one face and another 16 running vertically on the other.

IV. Conclusion and Future Work

Our flexible force sensor performance shows the feasibility of a low-profile, energy-efficient sensor that can be embedded in prosthetic devices to restore tactile sensing. We plan to use silicone casting and 3D printing to embed the force sensor and analyze its performance. We expect to determine a depth range where the sensor is functional and place multiple force sensors at different depths. We also plan to explore unique ways for modulating the spatial and temporal resolution of each sensing zone to closely mimic the mechanoreceptors.

References

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