A Three Sensing Points Tactile Finger Tip
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Abstract: A design for a robotic finger to manipulate small scale objects using a 3-DOF Micro Force Moment Sensor is presented. It provides the ability to recognize the edge distribution using three sensing points while benefiting from a multiplexing circuit to decrease the number of signal wires. Customizing the protecting PDMS soft finger tips tailors the range of operation. The measured overall sensitivity is higher than 40 mV/N.

1 Introduction: Touch is a common but important action of everyday life. It permits the approximate determination of the surface properties and facilitates picking tasks. Recent robotics research about dexterous manipulation has sought to imitate the natural touch mechanism, as well as the anatomy, of human fingers to optimize the ideal anthropomorphic artificial hand. Nowadays, the developments in MEMS (Micro Electro Mechanical Systems) technology allow for miniaturized, multifunctional and integrated tactile systems [1-3].

Fig. 1. The schematic of one sensing point and overview of the whole chip

This paper describes design, fabrication, and calibration of small-scale tactile soft fingertip with three sensing points. Each sensing point is a 3-DOF MFMS (Micro Force Moment Sensing) chip [4] which can detect normal force and two in-plane moments. The overall dimensions of the chip are 2 mm x 2 mm x 0.8 mm (length x width x thickness) based on measurements of change of resistance of the piezoresistors diffused on a single crystal Silicon substrate. Three chips are placed on a compact circuit board with integrated electronic circuits, such as offset cut-off and multiplexer. Ultimately, the three small soft hemispheres cover three sensing chips to form a complete soft tactile fingertip (see figure 1).

2 Design: Three sensing points are distributed on three corners of a planar equilateral triangle with the length of each side being 6 mm. This is to assure the symmetry, surface recognition and edge detection functionality. All signals from the three MFMS chips are led to the multiplexer circuit through an offset-cut off variable resistor. The multiplexers reduce the number of signal wires to that of a single sensing point. The desired sensor chip is picked at a specific time by the two logic bits which is generated using a DAC (Digital to Analog Converter) PCI card. Outputs are amplified with definite gain and wired to an ADC (Analog to Digital Converter). Furthermore, a data acquisition software was built to control the multiplexer circuit, collection of the data and implementation of digital filtering.

To transfer force to the sensing chip, a 2mm long Silicon transmission pillar is inserted into the plate of the MFMS. For this purpose a micro precision stage has been designed which is employed to glue the Silicon pillars to a built-in cavity on the MFMS surface (Fig. 2).

The last step is to place the soft PDMS domes which function as finger tips on top of the pillars as schematically has been shown in Fig. 1. The stiffness properties and dimensions of the polymer can be tuned to obtain the desired characteristics. These dome shape finger tips are built separately and care should be taken about their respective dimensions.

3 Results: Firstly, the calibrations of three MFMS chips were carried out after being attached to the PCB. This phase was performed using a micro indenter (SHIMADZU HMV-200, Japan) in which the sensor was put on a three-axis linear stage with resolution step of 2 μm, and under a micro indenter tip. Figure 3a shows the obtained results applying a 500 mN force at 250 μm distance from the centre of the chip. After the insertion of the Si pillar (Fig. 2) the sensor is tested with the same method. However the force is applied to the upper face of the pillar and the applied distance is limited to 140 μm (Fig. 3 bottom) which decreases the applied moment using the same force.

After the PDMS hemisphere tip installation, the characterization of the sensor is done in a custom made 2-DOF stage which incorporates a NITTA PDS-32 force moment sensor with a suitable tip for the soft polymer finger tip. The stage uses two stepper motors with 2μm precision. Figure 4 below shows the output of the sensor for applied normal force and moment.

Fig. 2. The pillar is glued to the MFMS chip

Fig. 3. The measured output of MFMS before (top) and after (bottom) the insertion of the pillar

Fig. 4. The measured output of MFMS after insertion of the pillar and dome finger tip. Above the application of normal force. Below the application of moment

References