3-axis Soft Magnetic Force Sensor

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***Abstract*—We present a low-cost, soft and easy to fabricate 3-axis force sensor, based on magnetic technology. The sensor design, fabrication and characterization are described, together with a simple real object manipulation experiment.**

I. Introduction

Tactile sensing is essential to ensure a safe interaction between the robot and its surroundings, which may include both objects and humans. A soft contact surface and the ability to measure the complete force vector (i.e. both normal and shear forces) with high sensitivity, low hysteresis and good repeatability are critical features; moreover, when the sensors are integrated into robotic hands, constraints of size, weight and complexity become important as well.

The sensor presented is composed by a soft elastomer with a permanent magnet inside and a magnetic field sensing element (i.e. Hall-effect sensor), disposed as shown in Fig. 1. When an external force is applied on the elastomer the relative magnet position changes and the Hall-effect sensor detects the magnetic field variation, that can be converted in a measurement of the applied force.

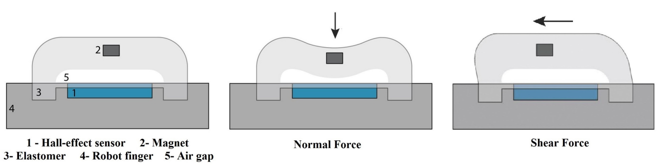


Fig. 1. Sensor design scheme

The use of a 3-axis Hall-effect sensor allows the detection of magnetic field variations in the 3 axis, and consequently the three components of the applied force. The air gap left between the Hall-effect sensor and the elastomer increases the sensitivity of the sensor for small forces. This design is inspired by a recent work [1].

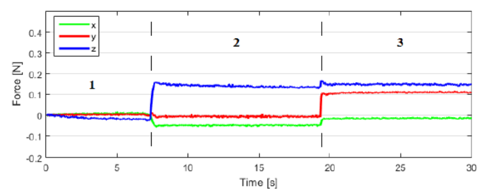
The sensors were fabricated with different geometries using 3D printed molds, PDMS as elastomer, a small neodymium magnet and the tri-axis magnetometer Melexis MLX90393. They were integrated in the hand of the robot Vizzy [2].

II. Results

The sensors were calibrated using a FEM model simulation of the system and validated with experiments using a commercial optical force sensor. This validation was made with the sensors mounted on the robot, where hand movements make different pressures of our sensor against the commercial force sensor, achieving both normal and shear forces.

An experiment with consecutive identical pressures at a rate of 0.6Hz presented accurate repeatable measurements with a recovery time of 0.3s. With the sensor mounted on a precision setup was achieved a minimum normal force sensed of 7.2mN.

(a)



(b)

Fig. 2. a) Lifting a plastic cup in three phases. b) Sensor response in time.

The response of the sensor during a real world robotic task was tested with a grab and lift of a plastic cup. Two fingers were used to perform a claw grab. In the phase 1 the fingers are closing. The contact occurs in phase 2, where a normal force is detected. Finally in phase 3 the cup is lifted and the sensor detects a shear force due to the weight of the cup.

III. Conclusion

A soft 3-axis force sensor was developed, implemented and tested. Our analysis show accurate and repeatable measurements of both normal and shear forces, short recovery time and state-of-the-art minimum sensed forces. Experiments of object manipulation showcase just one among many advantages of having 3-axis tactile measurement in a robot hand. Future work will include compensation of sensor rotation and external magnetic fields. More details can be found in [3], accepted publication that will be presented at ICRA 2017.

References

[1] L.Jamone *et al.*, "Highly sensitive soft tactile sensors for an anthropomorphic robotic hand," *IEEE Sensors Journal*, vol. 15, no. 8, pp. 4226-4233, 2015.

[2] R. Nunes *et al.*, "Vizzy: A humanoid on wheels for assistive robotics," in *Second Iberian Robotics Conference*, ROBOT, 2015.

[3] T. Paulino *et al.*, "Low-cost 3-axis soft tactile sensors for the human-friendly robot Vizzy," to be published.