Selection of Equipment for the Force Sensitive Resistor 0.5 Sensor

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***Abstract* — To solve some problems of terrain mapping, it is necessary to sensory probe the territory itself and the objects located on it. For this, manipulators with force sensors installed on them are used to obtain the necessary information. The accuracy and reliability of force sensor measurements depends on the method of attaching the sensor to the manipulator and the shape of the surface of interaction of the sensor with external objects. The article provides an overview of force sensors and describes experiments to determine the best way to mount the Force Sensitive Resistor 0.5 sensor for sensing applications. The best mounting option turned out to be one with polyethylene foam attached to the sensor on both sides.**

I. Introduction

Resistive force sensors (FSR) can be used for various applications, such as measuring force, including gravity (for example, in scales). Can be used instead of touch buttons, where you can record not only the fact of pressing, but also the strength of this pressing, and the pressing itself can be carried out with gloves, or using any objects [1-3]. In [4], using a resistive sensor, the authors solve the problem of gesture recognition. The system contains 8 FSR sensors to monitor forearm surface force distribution as a basis for detecting muscle contractions associated with gesture. The gesture classification accuracy reaches 90.09% for all tests.

The system developed in [5] consists of an array of force-sensitive resistive sensors embedded in a mat, with electronics that allow the entire mat to be scanned to estimate vertical jump height.

FSRs can be used to monitor everyday activities such as brushing teeth. [6] presents the design of a classic force-sensitive toothbrush that ensures the pressure applied during brushing is within a certain minimum and maximum.

Force sensors can also be used to control robots, where the robot's actions will depend on the level of force applied. For example, in paper [7], a force sensor is used to control the maneuvering of a captured object by a manipulator.

In addition to grippers, robotic arms can use force-sensing probes to sense the surrounding area. For example, for the task of constructing a map, it is necessary to determine not only the location of the obstacle, but also its static and dynamic characteristics. The video camera will be able to tell where the obstacle is, but it will be less likely to determine its weight. Let's say the camera has determined that the obstacle is a log, in which case you need to go around it. And if the log turned out to be dry, then it could be moved and passed without a detour. A manipulator with a force sensor can help determine more detailed information about an object.

FSR sensors can also be used to prevent injury when moving or lifting a patient with limited mobility [8]. In this case, layers of silicone are used to create a layer between the FSR layer and provide physical security to the FSR layer, as well as to evenly distribute any applied normal forces to each of the FSRs.

To classify objects with unusual shapes or with protruding sharp parts, soft grippers with an FSR sensor are used. Where the sensor is covered with protective layers of various materials [9].

When using a sensor on the grip of a manipulator for sensory exploration of the environment, the safety of the sensor, as well as the accuracy and reliability of the measurements obtained from the sensor, also depend on the method of mounting the sensor. For example, if the sensor is attached to a flat and hard surface, then identifying objects with non-convex elements will be difficult. Therefore, the purpose of this work is to review force sensors and find the best way to mount the sensor for its further use in sensing tasks.

This article is organized as follows. Section II provides an overview and comparison of resistive force sensor models. Section III provides a more detailed description of the Force Sensitive Resistor 0.5 sensor, and Section IV describes the experiment and the results obtained. Section V summarizes the results and presents a plan for future work.

II. Review of resistive force sensor models

Power sensing resistors are piezoresistive sensing technology. This means that they are passive elements that function like a variable resistor in an electrical circuit. The resistance of this device varies depending on the pressure on its surface. The greater the force, the lower the resistance. If no pressure is applied to the FSR, its resistance will be greater than 1 MOhm [10].

FSRs are thick film polymer devices consisting of two membranes separated by a thin air gap. One membrane has two sets of interdigitated tracks that are electronically isolated from each other (the active region), while the other membrane is coated with a special textured resistive ink that is a semiconductor (Fig. 1.).

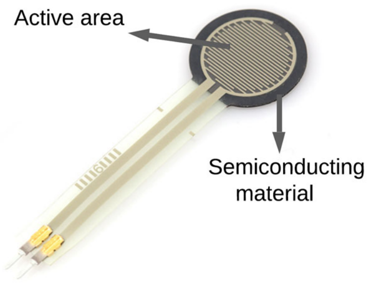
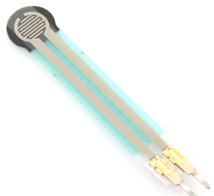
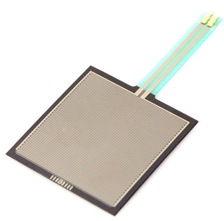


Fig. 1. Basic elements of a force sensor

TABLE I. COMPARISON OF RESISTIVE FORCE SENSOR MODELS [11]

Model	Sensing element size, mm	Strength, kg
Force Sensitive Resistor - Small 	diameter 7.62	0.1-1
Force Sensitive Resistor 0.5 	diameter 12.7	0.1-10
Force Sensitive Resistor - Square 	length 44.45 width 44.45	0.1-10
Force Sensitive Resistor - Long 	length 6.35 width 609.6	0.1-10

There are many options for pressure sensors and several key characteristics to differentiate them: size, shape and sensitivity range. Table I. provides a comparison of different sensor models based on the size of the sensitive area and the measured force. Square sensors are good when a large scanning area is needed. For pinpoint probing of obstacles, a smaller working area is suitable. Therefore, it was decided to choose a round sensor for further experiments. Round sensors differ in the size of the working area and maximum force. When working in a forest area, objects can have either a small weight (less than 1 kg), for example, a stone, or a large one (more than 10 kg), for example, a tree. And to determine the greatest force, the Force Sensitive Resistor 0.5 model is suitable, so this sensor was chosen for further experiments.

III. DESCRIPTION OF CONNECTING THE FSR 0.5 SENSOR

The diameter of the Force Sensitive Resistor 0.5 sensing element is 13 mm, and the operating force range is 0.1-10 kg. The repeatability error does not exceed 6%.

An Arduino Uno R3 microcontroller is used to take readings from the sensor. To conveniently connect the force sensor to the controller, use the Sensor Shield V5 board.

Electric circuit connecting the sensor to the controller is shown in Fig. 2. One terminal of the FRS pressure resistor is connected to voltage (5V), and the other terminal is connected to ground (GND). The sensor must be connected with a constant resistor (R1). In this example, the sensor is connected through a resistor with a resistance of 3.3 kOhm. The required level of sensitivity of the FRS resistor, as well as the limitation of the current flowing through the entire divider, depends on resistor R1.

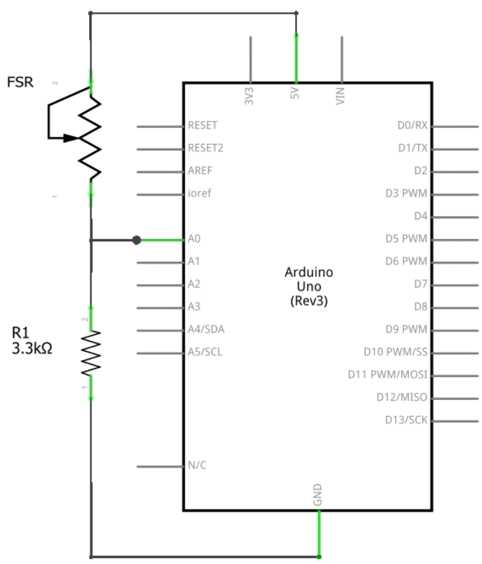


Fig. 2. Circuit wiring diagram for connecting a force sensor

The output voltage of the resistive divider Vout can be calculated using the following formula

$$Vout = \frac{R1 \cdot Vin}{R1 + FSR}, \quad (1)$$

where R1 – the resistor voltage reading, FSR – the resistive force sensor voltage reading, and Vin – the input voltage reading (in Arduino boards it does not exceed 5V).

As can be seen from formula (1), the output voltage Vout increases with increasing force applied to the pressure resistor FRS. The voltage from the output of the resistive divider Vout can be read using any input of the analog-to-digital converter (ADC) of Arduino microcontrollers, for example A0.

IV. Experiments with a resistive force sensor

The sensitive area of the resistor is limited by a black round frame. If you place a solid flat object on the resistor that extends beyond the sensitive area of the resistor, it will only touch the bounding box and its weight will not affect the resistance of the resistor. Therefore, the goal of the study is to determine a method for attaching a resistive sensor, which will help determine the strength of interaction with the largest number of objects.

Let's consider 5 equipment options of the force sensor (Fig. 3.). A force sensor was placed on a table and the weight of objects was measured using it. The first equipment option was the absence of any additional layer between the sensor and the table, the sensor and the object. In the second equipment option, a layer of 6 mm thick polyethylene foam was laid between the table and the sensor. In the third equipment option of the sensor, a layer of polyethylene foam was placed between the sensor and the table, and a shape made with a glue gun, convex towards the active area of the sensor, was attached on top. In the fourth equipment option, the sensor lay on the table, and on top was attached a shape convex towards the active area of the sensor, made with a glue gun. In the fifth equipment option, the sensor lay on a layer of polyethylene foam with a small hole for the sensor, and another layer of foam was attached on top.

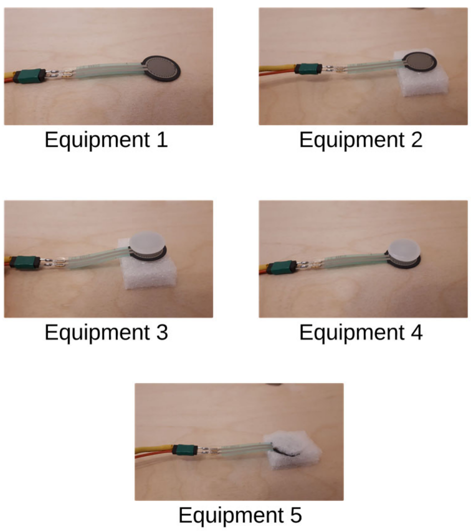


Fig. 3. Various surfaces (equipment) for sensor used in experiments

For each equipment options, two experiments were conducted. In the first experiment, pressure was applied to the sensor by pressing a finger. The following steps were taken:

1) The sensor, with its equipment option, is placed on a flat, hard surface.
2) The program for collecting data from the sensor is launched.
3) Place your finger on the sensor perpendicular to the sensitive area.
4) Pressure is applied for a couple of seconds.
5) The pressure stops and data collection from the sensor stops.

In the first experiment with a soft object, the most accurate force values were shown by the design with equipment option 5 (Fig. 4.).

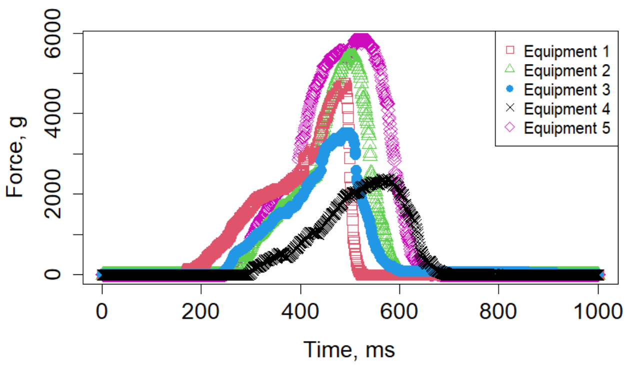


Fig. 4. Force sensor readings when pressing with a finger

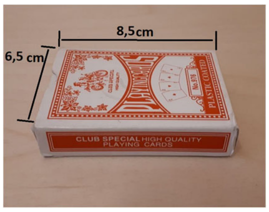
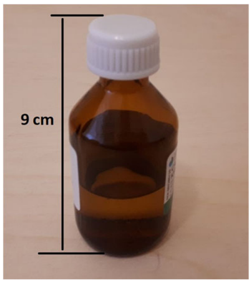
In the second experiment, pressure was applied to the sensor using solid objects of various shapes and sizes (Table II.).

The following steps were taken:

1) The sensor, with its equipment option, is placed on a flat, hard surface.
2) The program for collecting data from the sensor is launched.
3) Place an object on the sensor so that the line drawn through the center of mass is perpendicular to the sensitive area.
4) Pressure is applied for several seconds.
5) The pressure stops and data collection from the sensor stops.

Points 2 to 5 are repeated for each object from Table II.

TABLE II. DESCRIPTION OF OBJECTS USED IN EXPERIMENTS

Number	Object	Weight, g
1		207
2		102
3		82
4		69
5		41
6		41

In Fig. 5. The readings of the force sensor in contact with object number 4 are presented for all equipment options. You can notice that for equipment options 3, where the sensor lies on a piece of foam plastic, and a shape convex towards the active area of the sensor, made with a glue gun, is attached on top, the sensor readings are the highest, and they do not coincide with the actual weight of the object. Also, for equipment options 3 and 4, when the weight of the object being measured was large, the convex shape was pressed into the sensor so much that even after removing the object, the sensor showed small force values. For the second equipment options, where the sensor lies on a piece of polyethylene foam, the sensor determined the force well only when the object was placed with its convex part on the active area. And when the surface of a light object was flat, the sensor did not show any values. For equipment options 1, when the sensor lies on a hard surface and has no additional surface contact, the signals from the sensor showed zero force values for all experimental objects, i.e. no contact was found. For equipment options 5, although the sensor showed rather small values, it turned out to be the most stable.

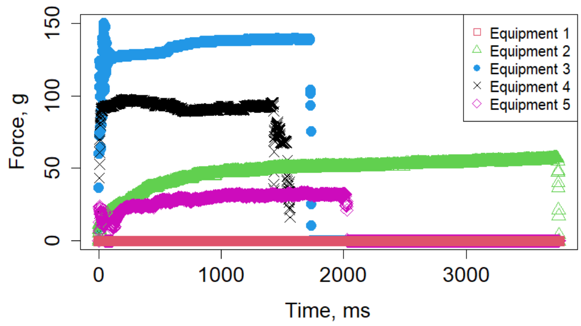


Fig. 5. Force sensor readings upon contact with object number 4

So, equipment option 1 did not detect contact for any object from Table II. Equipment options 3 and 4 give a false force value for objects larger than 102 g. Equipment option 2 does not detect contact when interacting with small objects ($\leq$ 41 g). Equipment option 5 turned out to be the most reliable. Therefore, to use the sensor for sensory examination of objects, it makes sense to use the fifth version of the sensor equipment, in which the sensor is surrounded on both sides by a layer of polyethylene foam.

V. CONCLUSION

Force sensors are used in various fields: robotics, healthcare, etc. Moreover, if this is work with objects of unusual shape and/or with sharp parts, then sensor protection is necessary. To do this, the sensor is attached using protective layers.

FSR sensors can be used to sense the environment. In this case, the accuracy and reliability of measurements will depend on the method of mounting the sensor and the shape of the contacting object.

The article provides a review of force sensors. They differ in shape, size of the sensitive area and maximum measuring power. For the task of sensory probing the territory, a round Force Sensitive Resistor 0.5 sensor was selected.

To determine the best method of attaching a force sensor, experiments were carried out with different versions of the Force Sensitive Resistor 0.5 equipment and objects of different weights and contact areas.

The results showed that for a more accurate and reliable measurement, additional surface contact is required between the sensor and the object to which it is to be attached, as well as between the sensor and the contact surface with external objects. Polyethylene foam is suitable as such an intermediate layer.

By equipping the manipulator probe with a Force Sensitive Resistor 0.5 sensor with intermediate layers of foam, and measuring the pressure force on various objects, you can obtain additional information useful when performing various automatic operations, for example, when moving the robot over rough terrain, when the robot performs agricultural operations, etc.

Further research will be aimed at studying the nature of the interaction of the probe with a force sensor attached to it, installed in the grip of an autonomous robot manipulator, with objects of the external environment.

REFERENCES

[1] A. Munakata, Y. Sugiura, “Prediction of Impulsive Input on Gamepad Using Force-Sensitive Resistor”, *in Proc. Tangible, Embedded, and Embodied Interaction Conf.*, February 2020, DOI: 10.1145/3374920.3374992.

[2] J. Byrne, P. Sweetser, “Prototyping a Grip Pressure-Sensing Controller for Video Games”, *in Proc. CHI PLAY '22: Extended Abstracts of the 2022 Annual Symposium on Computer-Human Interaction in Play Conf.*, November 2022, DOI: 10.1145/3505270.3558349.

[3] M. Wang, G. Qin, M. Sun, J. Zhao, J Qin, “An exploration of pressure input with bare finger for Mobile interaction in stationary and Mobile situations”, *Multimedia Tools and Applications*, February 2023, pp. 1-21, DOI: 10.1007/s11042-023-14503-0.

[4] B.B. Atitallah, M. Bilal Abbasi, R. Barioul, D. Bouchaala, Derbel N., O. Kanoun, “Simultaneous Pressure Sensors Monitoring System for Hand Gestures Recognition”, *2020 IEEE Sensors*, DOI:10.1109/sensors47125.2020.9278884.

[5] E. Vanegas, Y. Salazar, R. Igual, I. Plaza, “Force-Sensitive Mat for Vertical Jump Measurement to Assess Lower Limb Strength: Validity and Reliability Study”, *JMIR Mhealth Uhealth*, 2021, vol. 9, no. 4, DOI: 10.2196/27336.

[6] M. Akhtaruzzaman, “Force-Sensitive Classic Toothbrush: System Analysis, Design, and Simulation”, *Electrica*, 2021, vol. 21, no. 2, pp. 189- 202, DOI: 10.5152/electrica.2021.21007.

[7] M. Costanzo, “Control of robotic object pivoting based on tactile sensing”, *Mechatronics*, 2021, vol. 76, DOI: 10.1016/j.mechatronics.2021.102545.

[8] S. Cramp, C. Maccoll, R. B. Wallace, “Preliminary Results for Novel Shear Force Sensor using Force Sensitive Resistors”, *in Proc. 2020 IEEE International Instrumentation and Measurement Technology Conf.*, April 2020, DOI: 10.1109/I2MTC43012.2020.9128858.

[9] L. Chin, J. Lipton, M. C. Yuen, R. Kramer-Bottiglio, D. Rus, “Automated Recycling Separation Enabled by Soft Robotic Material Classification”, *in Proc. 2019 2nd IEEE International Conference on Soft Robotics (RoboSoft) Conf.*, April 2019, DOI: 10.1109/ROBOSOFT.2019.8722747.

[10] Tekscan official website, Blog article “How Does a Force Sensing Resistor (FSR) Work”, Web: https://www.tekscan.com/blog/flexiforce/how-does-force-sensing-resistor-fsr-work.

[11] Sparkfun official website, Online store, Web: https://www.sparkfun.com/