Force Sensing Resistor (FSR): a brief overview and the low-cost sensor for active compliance control

Conference Paper · July 2016

DOI: 10.1117/12.2242950

3 authors, including:


Jamaludin Jalani
Universiti Tun Hussein Onn Malaysia


J.A. Sukor
Universiti Tun Hussein Onn Malaysia

Force Sensing Resistor (FSR): A Brief Overview and the Low Cost Sensor for Active Compliance Control

A. S. Sadun*[a], J. Jalani*[b], J.A. Sukor[c]

[a,b,c]Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.

ABSTRACT

Force Sensing Resistors (FSR) sensors are devices that allow measuring static and dynamic forces applied to a contact surface. Their range of responses is basically depending on the variation of its electric resistance. In general, Flexiforce and Interlink are two common types of FSR sensors that are available, cheap and easily found in the market. Studies have shown that the FSR sensors are usually applied for robotic grippers and for biomechanical fields. This paper provides a brief overview of the application of the FSR sensors. Subsequently, two different set of experiments are carried out to test the effectiveness of the Flexiforce and Interlink sensors. First, the hardness detector system (*Case Study A*) and second, the force-position control system (*Case Study B*). The hardware used for the experiment was developed from low-cost materials. The results revealed that both FSR sensors are sufficient and reliable to provide a good sensing modality particularly for measuring force. Apart from the low-cost sensors, essentially, the FSR sensors are very useful devices that able to provide a good active compliance control, particularly for the grasping robotic hand.

Keywords: Force Sensing Resistors (FSR), Force Sensor, Flexiforce Sensor, Interlink Sensor, Tactile Sensor, Multifingered Robot Hand, Active Compliance Control.

1. INTRODUCTION

Force sensors are widely used in the robotic field, particularly for robot interaction control application. They are made from plastic and the connection tab is crimped on a delicate material. The force sensor is usually mounted on the wrist of a robot arm to measure the force acting on them (i.e. usually detecting pressure, squeezing and weight)[1]. Recently, new types of force sensors have emerged and used in robotic applications. The thin film piezoresistive, strain gauge, piezoelectric force and optical force are examples of new force sensors that currently being used [2]. A summary of studies has been carried out to demonstrate various purposes of FSR sensors [2]. In 2007, a muscle monitoring information was developed for which the Interlink FSR sensor was mounted on the arm for gesture recognition[3]. The results showed that by combining FSR sensors with the accelerometer and gyro in the closed loop system, the parameter detection accuracy can be improved by 1% to 29%. In 2008, a study has been conducted to utilize the piezoresistive which involved the Tekscan Flexiforce and the Interlink FSR sensors in robotic and biomechanical applications [2]. The researchers have recorded the sensors dynamic behavior and nonlinear properties to identify their system modeling. Figure 1 shows the relationship between Applied Force (N) and Output Voltage (V) for Flexiforce and Interlink sensors which can be used for other applications. Based on Figure 1, the linearity results obtained from Flexiforce sensor is better as compared to the Interlink sensor. The researcher also found that both of sensors finely worked in the high magnetic field environment [2].

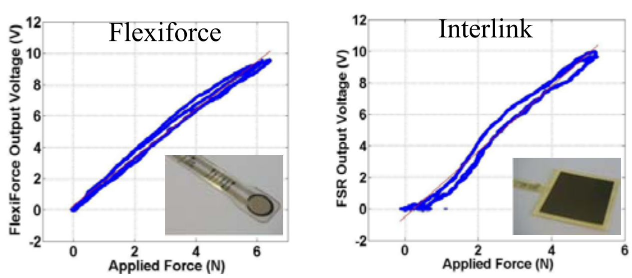

Figure 1. Flexiforce versus Interlink FSR

*a.s.sadun: E-mail: amirul@uthm.edu.my ; phone: +6(0)111 660 2509; fax: +6(0)7 4536025

* j.jalani: E-mail: jamalj@uthm.edu.my; phone: +6(0)19 730 6435; fax: +6(0)7 4536025

Moreover, in 2010, Flórez and Velásquez [4] have discussed the method of calibrating the Interlink FSR sensor to obtain accurate and reliable force sensing data. They have compared the measured data obtained from FSR and from the calibrated load cell. The results showed that there was a significant difference of data measurement produced by FSR sensor at different hardware applications. They have suggested that the calibrations are required before starting the experiment to ensure the repeatability and reliability of the acquired data. Moreover, the FSR sensors tend to produce a non-linear relationship within the 0 N to 4 N force range. As such, some difficulties may occur in measuring data for a higher force range test.

In 2012, a wearable arm device that equipped with a monitoring system for post-stroke rehabilitation was designed and proposed [5]. The device was equipped with an Interlink FSR sensor along with other sensors such as flex sensor and accelerometer. Based on the results, it was found that during the “no load” condition, the Interlink FSR sensor value can be larger than 1MΩ, while the resistance may be reduced to several kΩ when the pressure on the active surface increased [5]. However, the researcher stated that calibration needs to be frequently carried out to manage the drifting reading of the Interlink FSR sensor.

In 2012, a comparative study has been made and analyzed for the performance of Flexiforce and Interlink FSR sensors by using the Static Drift Test and Cyclic Loading Test [6]. The study concluded that both FSR sensors have a limited performance where the Interlink sensor exhibited substantial nonlinearity, hysteresis (i.e. gaps between loading and unloading cycles) and drift in the readings for initial and final testing cycles [6]. Furthermore, a research was conducted in 2015 investigated the output signal of grasping by using GloveMAP within the range of 50g to 1000g (white glove with Interlink FSR sensors on finger tips) [1]. The results revealed that the small error to allow the touching sensation was not affected by varying weights.

It is worth to briefly describe the Interlink and Flexiforce sensors in this study. The Interlink FSR [7] encompasses of two (2) polymer films, namely a conductive surface and the printed electrodes. Both are facing each other which allows a contact between two surfaces. This result in the conductive layer of the printed electrodes short circuit to reduce the electric resistance upon force pressure. Usually, the resistance dropped from 1 MΩ to 10 KΩ for the applied load of 100g to 10,000g (i.e. approximately 1N to 10N). There are four (4) different shapes of the Interlink FSR sensor available in the market namely two types of round shape, one square and one long FSR [8].

On the other hand, Flexiforce [9] force sensors are constructed of two layers of substrate namely polyester or polyimide film. There are a conductive silver material and conductive ink applied on both layers. The adhesive material is used to laminate the two substrate layers to permit the force sensor. The active sensing area is defined by the silver circle above the conductive ink. Silver extends from the sensing area to the connectors at the other end of the sensor, forming the conductive leads.

Note that FSR sensors show the great potential for various application, including robotic fingers and grippers despite some drawbacks were found. In this study, both Interlink and Flexiforce sensors are employed and integrated with an Arduino or Microcontroller to simplify the data acquisition control technique. The rest of the paper is organized as follows: Section 2 shows the experimental setup; Section 3 provides results and discussion; Section 4 concludes the finding and recommends the future work.

2. EXPERIMENTAL SETUP

This section provides the experimental setup for two different applications of the FSR sensors. First, Case Study A, where the effectiveness of the proposed sensors is tested on different objects to detect hardness levels. Meanwhile, Case Study B set up the experiment to investigate the efficacy of the sensors for force-position control.

Case Study A: Hardness Sensing System

The experiment for the hardness sensing system consists of an interlink FSR sensor, 180˚ servo motor, 360˚ servo motor, Arduino UNO, toggle switch, a conveyer system and bottles as shown in Figure 2. A basic Arduino Integrated Development Environment (IDE) is used as a programming platform. The operation of the hardness sensing system starts when the toggle switch is ON. Then the conveyor moved towards the robot gripper. The object is placed on the moving conveyer before being detected by the gripper. For this, the timer for conveyer is set for 8 seconds before the bottles STOP and the timer for servo motor is set for 5 seconds to allow a gripping (see Figure 3 for the flowchart of overall hardness sensing process). The gripper servo motor was pre-set to a fixed gripping angle for each cycle of the test so that the measured force can be observed and recorded. Moreover, the hardness sensing system is carried out in an open loop system. The system was programmed to segregate plastic bottles into different containers. The bottles have two different ranges of hardness. The term “OK” shows that the hardness level between 0 to 2.5 volts (i.e. the desired range). Meanwhile, “NG” represents the hardness level is above 2.5 V (i.e. not comply).

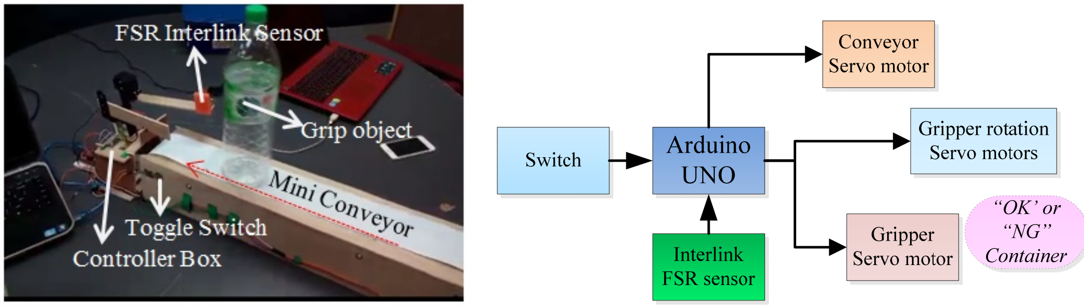

Figure 2: Hardware Setup and System Block Diagram for Case Study A

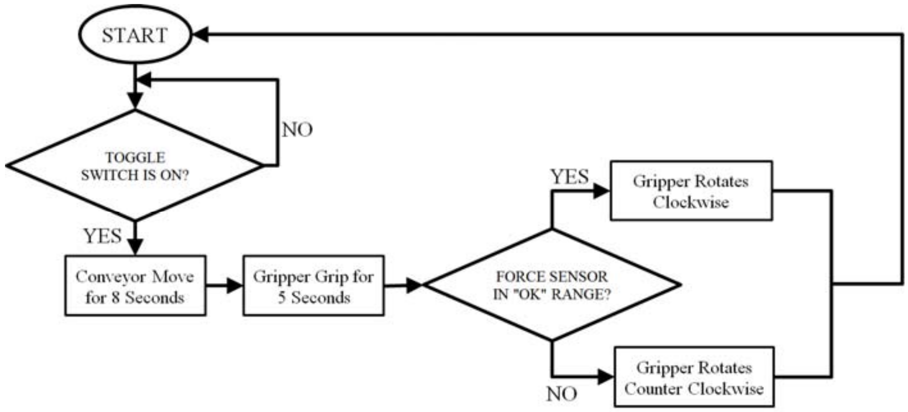

Figure 3: Flowchart of Overall Hardness Sensing Process

Case study B: Force-Position Control System

The experiment for the force-position control system consists of both flexiforce and interlink sensors**,** a modified servo motor with analog position feedback, a shaft, and a plastic extension rod. The motor shaft was attached to a plastic extension rod. The Interlink and Flexiforce sensors were then placed on the tip of the plastic rod and facing each other. The system is switched ON by using the toggle switch manually. In contrast to the Case Study A, a closed system is developed here for positioning control. In order to detect the pressure, finger force is exerted on the sensor. A Matlab Simulink - Arduino IO package is used as the programming platform where the Arduino UNO performs analogously to the DAQ device. The performance of Interlink FSR and Flexiforce sensors were monitored and recorded. The desired position of the servo motor was set to 100 degrees and the input data from the FSR sensor were also converted to angle. A simple control technique via a Proportional (P) controller is used with the value of parameter P = 0.5. Figure 4 illustrates the overall hardware setup for Case Study B.

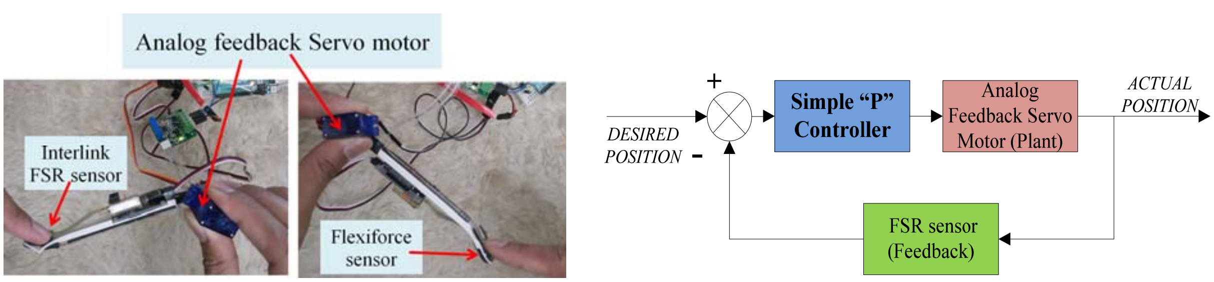

Figure 4: Hardware Setup and System Block Diagram for Case Study B

3. RESULTS AND DISCUSSION

Case study A shows good results where the plastic bottles were successfully segregated according to its hardness level. The soft bottle is pushed into the container 1 (0 < **OK < 2.5 V)** while the hard bottle is sent to a container 2 (**NG > 2.5)**. See Figure 5 for the gripping performance of an interlink FSR sensor. The graph illustrates that the measurement of five (5) different bottles are successfully recorded. In particular, three (3) different bottles and two (2) different bottles are captured below 2.5 volts and above 2.5 volts respectively. On the other hand, for Case Study B, the result is shown in Figure 6. When there is no external force, the position of the motor remains at position 100 degrees. Two (2) different measurements are recorded when the external force exerted on the Flexforce and Interlink sensors. It is to note that the amplitude of the captured signal is slightly higher (approximately 60 degrees) when employing the flexiforce sensor. On the contrary, the amplitude of the captured signal is slightly lower (approximately 40 seconds) when using the interlink sensor.

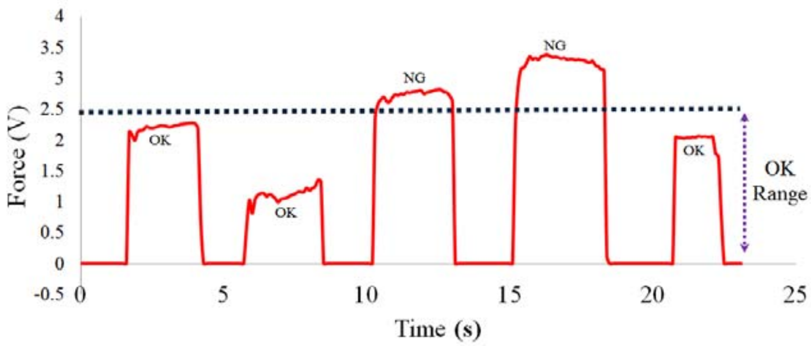

Figure 5: Gripping Force results for case study A

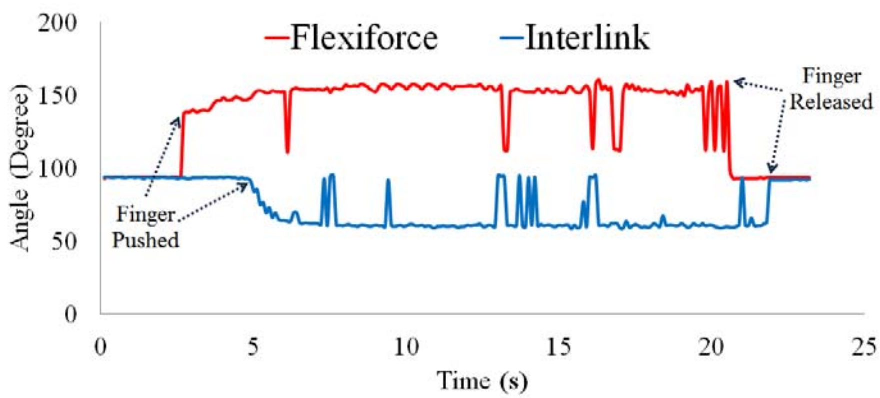

Figure 6: Force-Position control results for case study B

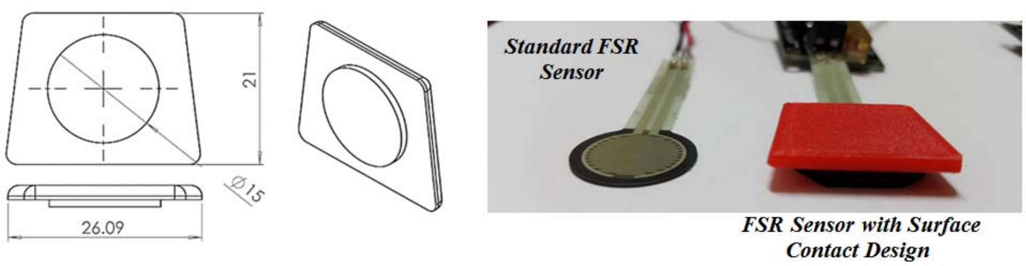

Figure 7: 3D Printed Surface design for FSR sensor

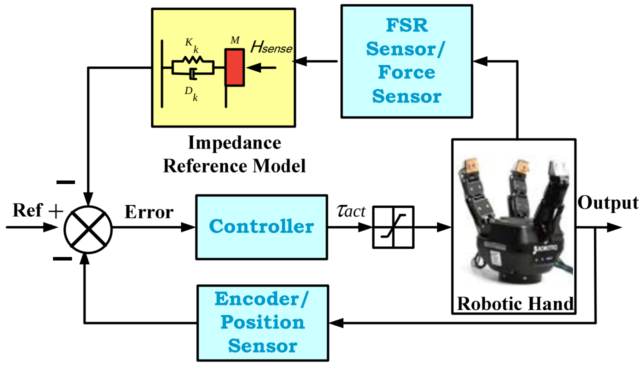

Figure 8: Model Reference Compliance Controller

The results also showed that the calibration process is required before executing the experiment so that the performance of both FSR sensors can be improved. The sensors must be defined, measured and tested to capture a consistent and repeatable reading. However, a problem raised when the sensors are in contact particularly when considering different shape of objects such as a pencil and a needle (it is not shown in this report). Obviously, since the tip of both objects is small, it is difficult for sensors to detect the pressure. This is mainly due to the fact that the surface of the sensors must be approximately 50% in contact in order to capture the force signal. For this, it is recommended to design a surface contact that able to transfer the force from the tips of needle or pencil. Figure 7 illustrates the example of the surface design for the sensors which can be used for future experiment. Moreover, the performance of both FSR sensors is almost similar. Based on these results, both FSR sensors can be considered useful, reliable and applicable to be tested on a more complex of robotic applications. In our case, an active compliant control for the multifingered robotic hand can be realized based on these FSR sensors (see Figure 7).

4. CONCLUSION AND FUTURE WORK

A brief overview of the use of FSR sensor is presented. This paper also investigates the performance of FSR sensors for two (2) different applications, including the open and closed-loop systems. The results show that the FSR sensors are sufficient and reliable devices to measure and record the detected force. However, a proper design of sensor cover for both sensors is required to optimize contact force. This is particularly very important when dealing with different shape of objects so that the force is adequately measured. In conclusion, considering cheap and reliable force sensor, the FSR can be a suitable candidate to measure the force during interaction. It also can be used for a more complex and sophisticated system such as active compliance control for the robotic hand.

5. ACKNOWLEDGEMENT

This topic is part of the project which is funded by the Exploratory Research Grant Scheme (ERGS), Vot E038. The authors also wish to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for providing a platform to carry out the research activities.

REFERENCES

[1] H. E. Nabilah, M. H. Ali, K. S. Talha, N. Farahiyah, K. Wan, D. Hazry, a B. Shahriman, Z. M. Razlan, M. a Ariffin, M. Haslina, and M. Rizon, "Analysis of touching sensation based on weights of rectangular object," *Biomed. Eng. (ICoBE), 2015 2nd Int. Conf.*, no. March, pp. 1–6, 2015.

[2] C. Lebosse, B. Bayle, M. De Mathelin, and P. Renaud, "Nonlinear modeling of low cost force sensors," *2008 IEEE Int. Conf. Robot. Autom.*, pp. 3437–3442, 2008.

[3] G. Ogris, M. Kreil, and P. Lukowicz, "Using FSR based muscule activity monitoring to recognize manipulative arm gestures," *Proc. - Int. Symp. Wearable Comput. ISWC*, pp. 45–48, 2007.

[4] J. a. Flórez and a. Velásquez, "Calibration of force sensing resistors (fsr) for static and dynamic applications," *2010 IEEE ANDESCON Conf. Proceedings, ANDESCON 2010*, pp. 2–7, 2010.

[5] R. Bin Ambar, B. M. P. Hazwaj, A. M. B. M. Ali, M. S. Bin Ahmad, and M. M. Bin Abdul Jamil, "Multi-sensor arm rehabilitation monitoring device," *2012 Int. Conf. Biomed. Eng. ICoBE 2012*, no. February, pp. 424–429, 2012.

[6] J. G. Dabling, A. Filatov, and J. W. Wheeler, "Static and cyclic performance evaluation of sensors for human interface pressure measurement," *Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS*, pp. 162–165, 2012.

[7] A. Hollinger and M. M. Wanderley, "Evaluation of Commercial Force-Sensing Resistors," pp. 1–4, 2006.

[8] Interlink, "Interlink Electronics," 2015. [Online]. Available: http://interlinkelectronics.com/.

[9] Tekscan, "Pressure Mapping, Force Measurement & Tactile Sensors," 1987. [Online]. Available: https://www.tekscan.com/about-us.