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Multisensory Smart Glove for Tactile Feedback in Prosthetic Hand

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Abstract

This paper presents a multisensory glove to allow prosthetic and robotic hand to simultaneously feel the pressure, temperature, and humidity. The low-cost implementation of the flexible glove with multiple sensors presented here will enable gathering of tactile information from grasped objects. The off-the-shelf components such as pressure, temperature and humidity sensors have been mounted on a flexible printed circuit (FPC) board and attached the glove. During validation most of the sensors were in contact with the grasped objects and successfully measured various contact parameters.

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Keywords: Prosthetics, tactile sensors, sensitive glove, flexible electronics;

1. Introduction

Artificial hand is a type of prosthesis to replace the missing limbs, which may have been lost due to disease, accident or congenital conditions [1]. A number of prosthetic limbs have been reported in recent years and allow a varying ability to perform different tasks. However, providing tactile feedback to amputees through sensorized prosthetic hand is still one of the major challenges. Further, there are not many cost-effective options available today [2, 3]. If such sensors could be incorporated as a skin on prosthetic hand then proper interfacing, processing and analysis of data from these sensors can allow amputee to use artificial hand in a much effective way with added functionalities and feedback [4]. Electronic gloves allow to cover robots and humans with multisensory microsystems, as shown in the vision in Figure 1. Pressure sensors can enable better feeling in amputees and could allow them to manipulate objects, whereas temperature and humidity sensors can provide more information about the touched objects, as well as surrounding environment. For example to avoid touching hot objects or handle it faster, as well as the necessary compensation for the pressure sensors [5, 6]. In this work, we report the integration of a cost-effective smart sensory glove to enable tactile feedback in prosthetic hand. The results presented, offer a step forward towards full integration of flexible smart glove in our group, where the ongoing research is to realize bendable silicon-based devices and sensors [7, 8].

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2. Sensors

Figure 1: Off-the-shelf sensors components used for the sensory glove

Pressure, temperature and humidity are three important parameters sensed by our skin. Pressure sensing plays an important function in the human hand for holding, grasping, pushing or pulling objects. It allows us to adjust the pressure applied on objects for better manoeuvring. Temperature sensing is another important function of the human skin enabling controlled manoeuvring of the objects with different temperatures and avoiding potential damage to the arm. Humidity sensors in human skin will help to perceive the relative humidity level of the atmosphere and dryness or wetness of the objects during tactile sensing. Sensors which were used on the glove are presented in Table 1.

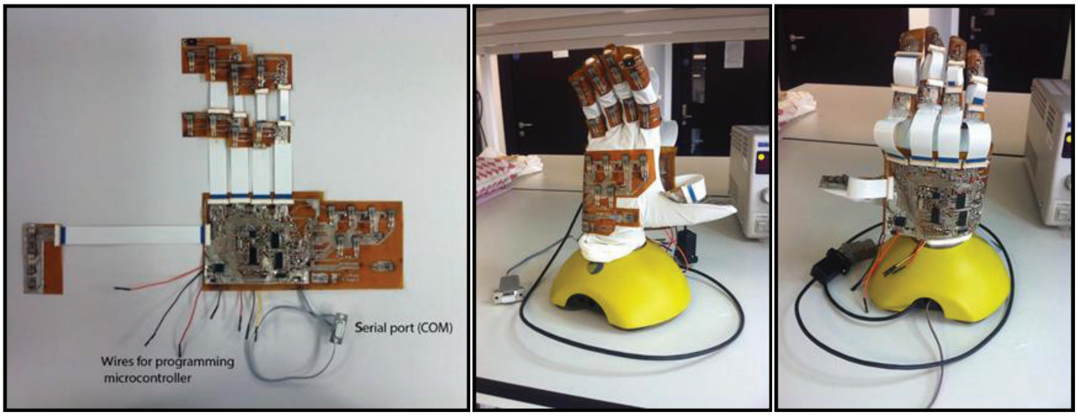
Table 1: Off-the-shelf sensors used in this work

Sensor type	Name of the sensor	Quantity
Pressure	Interlink Electronics 0.2" Diameter Short Tail Force Sensing Resistor (FSR)	18
Temperature	TC77	9
Temperature and Humidity	Silicon Labs Si7006-A10-IM1 6-Pin	6
High-resolution Pressure Sensor	Honeywell 0.24mm	1

Minimum pressure that can be detected by pressure sensor is 0.2N (20.4 g) with 5.08mm^2 active area, while the maximum force is 20N (2kg). This could be compared to the human hands sensitivity or grasp force range which has a minimum of 0.68N (0.07g) and a maximum grasp force of around 6N for the objects with 1kg weight.

3. System Implementation

For optimal covering of the fingers and palm of prosthetic hand (i.e. i-limb), and to enable the use of all sensing functionalities, a 150-µm-thick double polyimide layer based FPC board was used. The designed circuit was etched on the board and coated with tin alloy 99C to protect the board from oxidation. The electronic/sensing components were the soldered on the board. To cover various parts of the glove, the board was cut in to pieces of various sizes, placed on the glove, and then connected together with flat flexible connectors (FFC) cables as shown in Figure 2. An Atmega8 microcontroller was used for interfacing with the smart glove since it has all required functionalities namely, I2C, 4 ADCs, I/Os for addressing multiplexers/sensors and serial port for communicating with PC. Various pressure sensors were interfaced to the analogue-to-digital-converter (ADC) of the microcontroller through two analogue multiplexers (HEF4067BT). The high precision index pressure sensor was interfaced to two ADCs (1st and 2nd Channel) of the microcontroller to readout the output from the sensor in Wheatstone bridge configuration. Various temperature sensors (TC77) and temperature/humidity sensors (Si7006-A10-IM1) are connected to the



(a) (b) (c)

Figure 2: (a) Fabricated flexible PCB before assembling on the glove. i-limb prosthetic hand with smart sensitive glove, (b) front view (showing the sensors) and (c) back view (showing the circuits).

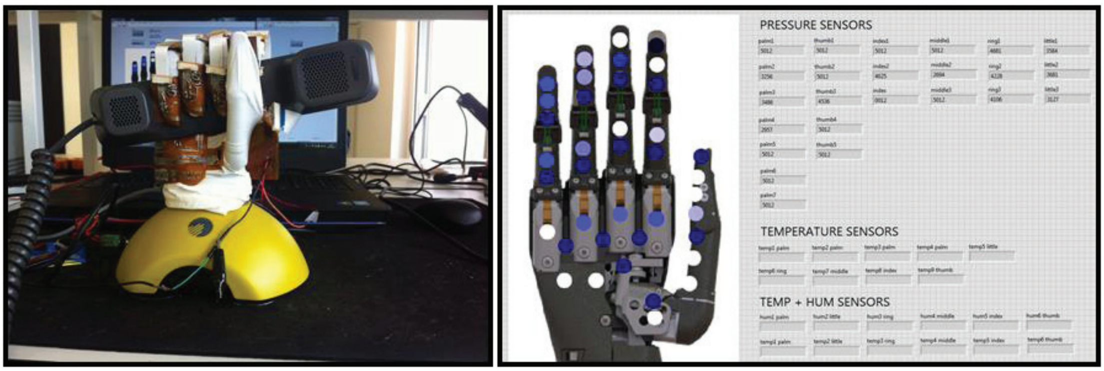
microcontroller through I2C interface. The sensors were addressed individually by selecting low level in corresponding $\overline{CS}$ pin of the sensors through a decoder (CD74HC154M).

4. Experimental Results

To test the working of the glove and its interface (created in LabVIEW), it was placed on i-Limb prosthetic hand and various objects were grasped. For example, Fig. 3(a) shows grasping of a phone receiver by artificial hand equipped with presented smart glove. The LabVIEW interface created for this purpose is shown in the Fig. 3(b). It receives data from microcontroller through the serial port (RS232) and changes the colour of dots corresponding to various sensors, which are shown at corresponding points in the image of the hand, for pressure, temperature and humidity sensors. Pressure sensors are graded from 0 to 5V. Temperature sensors are presented in the same way, where the range is from -40 to $+125^0$C as minimum and maximum temperature range of the sensor. Humidity is shown as numbers from 0 to 100 percentage on the same interface. Experiment were conducted using pressure sensor to determine minimum pressure and response time. The Fig. 4(a) shows the changing resistance of the pressure sensor during the applied pressures. Fig. 4(b) shows the measured output voltage from sensors on the glove when phone receiver was grasped.

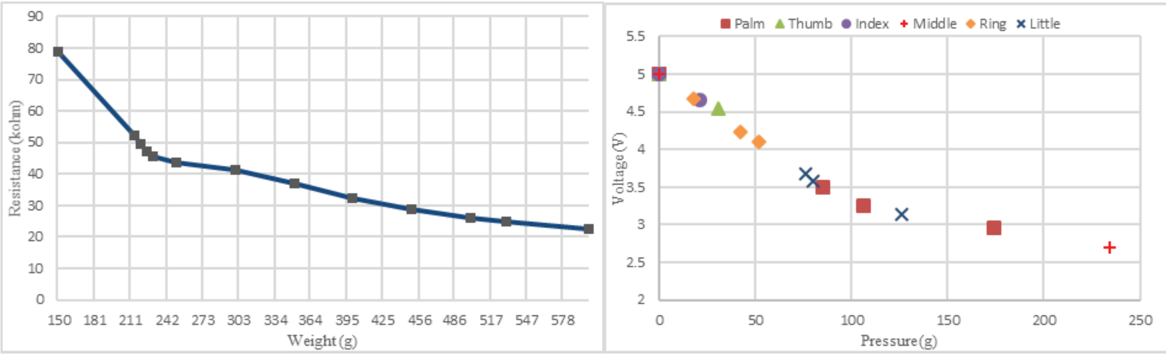
5. Conclusion

This work presents a low-cost implementation of the glove with multiple sensors which can give information



(a) (b)

Figure 3: (a) Holding a phone with the prosthetic hand with sensitive smart glove and (b) corresponding result in the GUI



(a) (b)

Figure 4: (a) Changing resistance of the pressure sensor during applying different pressure, and (b) Applied pressure on the glove during holding the phone.

about grasping objects. It was chosen to use pressure, temperature and humidity sensors available on the market. To mount the sensors chips and other discrete components on the glove, a flexible PCB was fabricated and used. It allows smooth movements of the hand and full functionality of the sensors. Suitable position and placement of the sensors are defined for optimal covering the prosthetic hand “i-limb”. It is essential that most of the sensors are in contact with the objects during grasping. Interface for visualization of sensors in this work provides the information about applied pressure on the hand and it helps in the calibration of feedback from sensors to prevent unstable grasping. Due to the low price and simple implementation of the glove, this product can be used for to advance the low-cost prosthetics.

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References

[1] S. Raspopovic, M. Capogrosso, F. M. Petrini, M. Bonizzato, J. Rigosa, G. Di Pino*, et al.*, "Restoring natural sensory feedback in real-time bidirectional hand prostheses," *Science translational medicine,* vol. 6, pp. 222ra19-222ra19, 2014.

[2] R. Dahiya, W. T. Navaraj, S. Khan, and E. O. Polat, "Developing Electronic Skin with Sense of Touch," *Information Display,* vol. 31, pp. 6-10, 2015.

[3] S. Khan, S. Tinku, L. Lorenzelli, and R. S. Dahiya, "Flexible tactile sensors using screen-printed P (VDF-TrFE) and MWCNT/PDMS composites," *IEEE Sensors Journal,* vol. 15, pp. 3146-3155, 2015.

[4] W. T. Navaraj, H. Heidari, A. Polishchuk, D. Shakthivel, D. Bhatia, and R. Dahiya, "Upper limb prosthetic control using toe gesture sensors," in *IEEE SENSORS Conf.*, 2015, pp. 1-4.

[5] S. Gupta, H. Heidari, L. Lorenzelli, and R. Dahiya, "Towards Bendable Piezoelectric Oxide Semiconductor Field Effect Transistor Based Touch Sensor," in *IEEE Int. Symp. on Circuits and Systems (ISCAS)*, 2016, pp. 345-348.

[6] R. S. Dahiya, G. Metta, M. Valle, and G. Sandini, "Tactile sensing—from humans to humanoids," *IEEE Transactions on Robotics,* vol. 26, pp. 1-20, 2010.

[7] H. Heidari, E. Bonizzoni, U. Gatti, F. Maloberti, and R. Dahiya, "CMOS Vertical Hall Magnetic Sensors on Flexible Substrate," *IEEE Sensors Journal,* vol. PP, pp. 1-1, 2016.

[8] N. Yogeswaran, W. Dang, W. T. Navaraj, D. Shakthivel, S. Khan, E. O. Polat*, et al.*, "New materials and advances in making electronic skin for interactive robots," *Advanced Robotics,* vol. 29, pp. 1359-1373, 2015.