Human Machine Interface Glove Using Piezoresistive Textile Based Sensors

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Abstract. Human machine interface technology is focused upon new ways of interaction between human beings and machines. Gesture recognition gloves are getting increasingly popular as human-machine interface devices. Conventionally, these gloves use electronic sensors to sense different hand gestures. As electronic sensors are bulky and uncomfortable, we propose a glove with textile based piezoresistive yarn sensors. This glove is flexible, more comfortable and cheap as compared to the conventional human machine interface gloves. We have examined that this glove can effectively sense our gestures and can be used for teleoperations, sign language to speech conversion systems and gaming.

Keywords. Piezoresistive, Textile Sensors, Human Machine Interface Glove.

1. Introduction
Machines have been close companions to human beings for decades. The rapid increase in a number of machines means more interactions with us. The recent developments in human machine interface technology are focused on developing more efficient ways of communication between humans and machines. As we use hand gestures extensively in our everyday communication with human beings, these gestures can also be used to communicate with the machines. In order to recognize these gestures and use those to control machines two main approaches are used; the first approach is to use visual based recognition systems that extract gesture data from graphic images; the second approach is to use haptic data recognition glove based systems. The latter glove based systems are better than the visual based systems because these are cheap, portable and require less processing power.

The glove based gesture recognition systems are applicable in design and 3d modeling, manufacturing, healthcare, robotics, device control, sign language recognition etc. For 3D modeling and design, glove based systems are used with computer-aided design software that can be used by engineers, architects, and industrial designers. Glove based systems are a better way to interact with robots with natural hand movements. In medicine and healthcare, electronic gloves are used for the rehabilitation and assessment of hand motion by acquiring gesture data. For sign language recognition and conversion to speech or text, gloves are used to recognize different gestures that are programmed to produce a specific letter or word with the help of a computer program. For data management, glove based systems are used for visual representation of data and images and improve the interaction between users and the data. The
Data glove was used by NASA to interact with the simulated airflow around an aircraft at NASA laboratories [1].

In past various attempts were carried out to measure analog haptic data using gloves and then use it to control machines, the first prototypes of glove based systems were made in the 1980s, such as the MIT-LED glove which was used to track the position of the hand and then show it as a computer graphics animation [2]. The digital data entry glove [3] used touch, proximity, tilt and inertial sensors to measure finger joint flexion and wrist tilting and was able to convert these motions into 96 ASCII letters and numbers. The Data glove [4] commercialized in 1982 was based on plastic tubes and light sensors that were able to measure and store joint angles. The Cyber Glove [5] consists of 22 piezoresistive sensors for measuring finger flexion, including software for virtual modeling. The Human glove [6] uses 20 Hall-effect sensors to measure joint bending angles for motion analysis and medical applications. Most of the aforementioned gloves use electronic sensors mounted on the cloth supports. A common drawback in this approach is a lower level of comfort and obtrusive nature of the glove. Real time implementation of these systems requires a lot of work in this area.

In this work a conductive yarn with piezoresistive properties is integrated into a glove, the yarn is integrated in such a way that it is stretched and compressed with the movement of finger joints. The resistance of this yarn changes as it is stretched or compressed, this change is notable and can be used to monitor hand gestures. Scanning electron microscopy (SEM) is used to study morphology and understand the working of piezoelectric yarn. A portable system was designed to monitor analog data for each gesture. The raw data was processed in MATLAB computation software. A 3d printed robotic hand was controlled with the glove to demonstrate its application in teleoperations.

2. Methods
The piezoresistive yarn was imported from Sparkfun USA, it has a blend of 20% stainless steel and 80% polyester fibers. It was noticed that for a specified length, the resistance of this yarn was decreased as the yarn is stretched. To understand this phenomenon Scanning Electron Microscopy (SEM) was done using COXEM CX-200 SEM to understand the piezoresistive nature of this yarn.

Based on the above-mentioned phenomenon, this yarn was integrated into a glove. As shown in Figure 1(a) the yarn has 3 plies, Figure 1(a-b) show the embroidery design and yarn placement on the glove. The yarn was embroidered over each finger in a glove so that the yarn is stretched or released with the finger movements causing a change in resistance. Snap buttons were used to create electrical contacts with the yarn.

![Figure 1: (a) 3 ply conductive piezoresistive yarn (b) Embroidered sensor design (c) Integration and placement of piezoresistive yarn in the glove.](image-url)
Figure 2 shows the block diagram of the working of entire human machine interface systems employed in this work. Hand gestures are sensed by the piezoresistive yarn sensors by measuring resistance for repeated gestures. This change in resistance is acquired in the form of analog data by an Arduino Nano Board with in-built 8-bit Analog to Digital Converter (ADC). This analog data has random noise, and overshoots occur as a finger is moved rapidly. The raw data needs to be filtered before it can be used to recognize gestures. A five point moving average filter was applied to filter out high frequency component in the signals.

Figure 2: Block Diagram for the gesture recognition glove system.

The Arduino board is controlled with a MATLAB script. Arduino IO package works as a server program that allows Arduino control with MATLAB commands. The acquired data for each finger sensor is stored in a separate MATLAB vector.

A robotic hand was used to demonstrate the application of gesture recognition gloves in teleoperations. This robotic hand was 3d printed using an open source CAD design from InMoov. The robotic hand was assembled, and 5 servo motors were used to move each finger.

3. Results

SEM was used to observe the morphology of the piezoresistive yarn. Figure 3(a) shows the 500 times magnified SEM image of this yarn. The SEM results show that the fiber has a diameter of 18 to 20 micrometers. And Figure 3(b) shows that the interfiber space is around 20 to 40 micrometers. This shows that the yarn has high porosity. As the yarn is stretched the interfiber spaces are reduced and as the steel fibers come in contact with each other the overall resistance of the yarn decreases. And when the yarn is unstretched interfiber spaces are increased again.
Figure 3: (a) Scanning Electron Microscope (SEM) image of piezoresistive yarn showing fiber diameter. (b) Scanning Electron Microscope (SEM) image of piezoresistive yarn showing interfiber spaces.

Figure 4(a) shows the changing resistance of the conductive yarn for continuous bending and releasing of the five fingers. Figure 4(b) shows filtered resistance signal for the yarn. Each of the finger sensors is responsive to movement of the finger. It can be seen that there is a significant change in yarn resistance of the order of K Ohms.
The above results show that the piezoresistive yarn sensors are sensitive to even minor finger movements, in addition to this the yarn sensor’s signal shows overshoots as the finger is moved rapidly. To filter out the overshoots and fluctuations in the signal additional signal processing techniques are required. The filtered output from the 5 points moving average filter is smooth and can be used to recognize gesture or control other machines effectively. The filtered output was used to control the servo motors that control the InMoov robotic hand. Figure 5 shows the robotic hand and HMI glove; the robotic hand could mimic the movement of the person wearing the glove. This shows that this glove can be easily used in teleoperations.

4. Conclusion
As wearable gesture recognition devices are gaining popularity, a gesture recognition glove is developed with piezoresistive yarn as a sensor. This yarn has 20% stainless steel and 80% polyester. The SEM images show that the fiber has diameters of 18-20 micrometers. And the inter fiber spaces are in the range of 20-40 micrometers in normal condition. As pressure is applied across the two ends of the yarn the inter fiber spaces in the yarn start decreasing. This yarn is integrated into the glove in such
a way that with the movement of each finger a corresponding yarn sensor experiences pressure. The inter fiber spaces decrease as pressure is applied across the yarn and as the stainless steel fibers come in contact with each other the overall resistance of the yarn decreases. An Arduino board with 10 bit ADC is used to measure the resistance of this yarn with the help of a voltage divider circuit. This signal is transmitted to a PC and then it is processed. 5 points moving average filter was applied to filter out the overshoots and random noise signals. Results show that the piezoresistive yarn sensor is sensitive to finger movements. The gesture recognition system was used to control a robotic hand remotely which demonstrates the capability of teleoperations using this type of glove.

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