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Flexible Force Sensor Based Input Device for Gesture Recognition Applicable to Augmented and Virtual Realities

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Abstract – With the development of smart devices supporting VR (Virtual Reality) and AR (Augmented Reality), users' input devices are changing to wearable devices. The existing input devices for gesture recognition were relatively rigid. In this research, we propose a gesture recognition device by using a flexible substrate to manufacture a device that can be used in close contact with a user's wrist. An array of flexible resistive strain gauge sensors was fabricated for sensing spatial muscle movements of the wrist. The fabricated strain sensors showed a linearly varying output characteristic, and a sensitivity of 0.05143 Ω/g was obtained for a load test from 0 to 500 g. A circuit board for processing sensor data was fabricated and a program was coded for collecting the sensor data from the circuit board. With this system, it was confirmed that the average recognition rate per gesture is 94.6% after applying these input devices directly to five basic wrists gestures on five test subjects.

Keywords – AR (Augmented Reality), Flexible, Gesture Recognition, Input Device, VR (Virtual Reality).

1. Introduction

With the development of smart devices supporting virtual reality (VR) and augmented reality (AR), users' input devices are also changing. Gesture recognition has been applied to VR and AR devices in the changing user interface environment in place of existing input devices such as the mouse and keyboard. These input devices have been developed as commercial products, such as Myo [1] worn on the arm, Oculus Touch [2] used as a stick type, and HTC Vive [3], and they are used as input devices in the VR environment. However, most of these input devices are fabricated on a non-flexible substrate, and hence, there are limitations when one wants to utilize these devices as a wearable sensor on a curved surface like an arm or wrist. Some of the previously reported researches on the input devices for gesture recognition have been conducted using Wii [4], EMG (Electromyography) [5, 6] or 3-axis Accelerometer sensors [7] attached to the arm as a prototype.

In this paper, we report a developed input device to reduce the fatigue of users and to provide a comfortable fit by using a flexible substrate based sensor. Principle of this input device is to sense the resistance change of each sensor in the strain sensor array that was attached in the shape of the wristband, according to the typical wrist muscle movement of hand gestures. We fabricated a circuit board to measure the signals of these sensors and implemented a flexible sensor array in the form of a silicon-based band. Finally, we extracted sensor data that changes according to the movement of the wrist muscles, and we have applied the SVM (Support Vector Machine) learning technique on the extracted data. With this developed flexible input device, the hand gestures were recognized successfully, and the data was correlated with the wrist movement for the various defined motions in real time.

2. Gesture Recognition Sensor Fabrication and Gesture Definition

2.1 The Operation Principle of the Gesture Recognition Sensor

The gesture recognition sensor developed in this research reads the physical deformation of the sensor following the movement of the wrist as a change of electrical resistance in a strain gauge sensor. Unlike the Myo and Oculus touch devices worn on the arm or held in the user's hand, the flexible sensor array used in this research is a flexible band type sensor worn on the wrist. The commercial sensors acquire the data generated according to the movement in the muscles of the wrist and proceed to recognize the gesture. Therefore, a design that optimizes the position and number of sensors suitable for movement in the wrist muscles is a necessary part of the flexible sensor array design. The initial designed sensor array was fabricated with an array of sixteen sensors. However, it was confirmed that other muscles except the main muscle movement used for motion recognition did not significantly affect the gesture recognition rate. Therefore, the flexible force sensor array was designed with an array of nine sensors by adjusting the position of the sensors and focusing on the extensor pollicis longus for the thumb movement and the flexor pollicis longus for the fingers.

2.2 Input Device Fabrication for the Gesture Recognition Sensor

The gesture recognition sensor array was fabricated on a flexible polyimide to improve the fit for the surface of the user body. First, metal deposition was performed with

Ni-Cr and Cu in order to make a resistor whose resistance changes according to the movement of the wrist on a flexible substrate (polyimide). In the following, a coating was made using DFR (dry film photoresist) to achieve a uniform PR (photoresist) coating. After the exposure process, PR developing and Cu etching were sequentially performed. After etching, the DFR coating, exposure, and development were performed one more time, and then Ni-Cr was etched. Finally, the cover layer was formed on the exposed metal to protect the sensor. The fabricated sensor was packaged with silicone to protect the sensor and induce better wrist movement (KE-12, Shin-Etsu Co.). The fabricated flexible sensor array showed bending characteristics up to a curvature radius of 5 mm. Depending on the movement of the wrist, the resistance value of the flexible array sensor is processed by a circuit and converted to a digital code value (ADC value, analog-to-digital converting value), and this coded value is used for gesture recognition. Figure 1 shows a flexible sensor array that has been manufactured using the above process, and image was taken with an optical microscope.

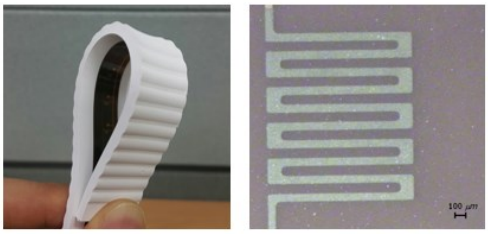

Fig. 1. Fabricated Flexible Sensor Array and Sensor image taken with an optical microscope (Scale bar, 100 μm).

2.3 Gesture Recognition Motion Definition

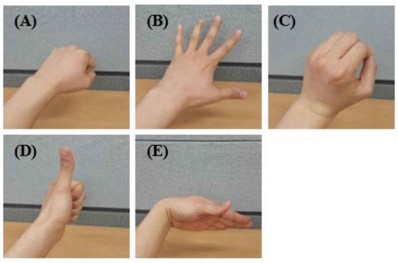

Fig. 2. Five Motions Defined for Gesture Recognition.

The definition of the motion was necessary to proceed with the gesture recognition using the fabricated flexible sensor array. Figure 2 shows the five motions as Twist fist, Spread, Soft fist, Thumb up, and Fold wrist in order of A, B, C, D and E, respectively. Figure 2 defines the five actions based on the flexor pollicis longus, which is used for movement of the thumb and the movement of the fingers, and the extensor pollicis longus, which is necessary to recognize movements of the wrist. SVM (Support Vector Machine) learning was performed using a program that was created to confirm the gesture recognition based on the defined motions. In this way, it was possible to compare gesture recognition of data transmitted from the flexible sensor array in real time. Based on the acquired data, we confirmed the movement and characteristics of the muscles used according to the five motions defined.

3. Experimental Results

3.1 Force Characteristics of the Fabricated Sensor

Prior to the gesture recognition test, various measurements and evaluations were carried out to confirm the characteristics of the produced sensor. As shown in Figure 3, the measurements were carried out while increasing the load from 0 g to 500 g in increments of 100 g. As a result, it confirmed that the value of ΔR changed linearly with the load and the sensitivity was 0.05143 Ω/g.

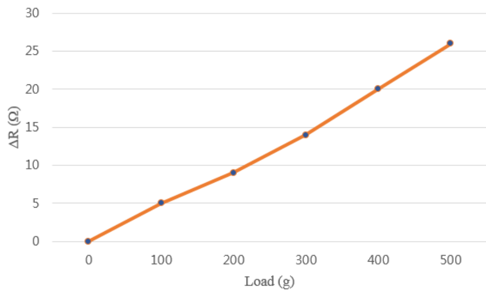

Fig. 3. A graph of ΔR versus the applied load.

3.2 Gesture Recognition Sensor Data Acquired using a Flexible Sensor Array

The sensor data of the five motions was collected by wearing the sensor on the wrist. The program for gesture recognition shows the data measured by converting the resistance of a flexible sensor array, which changes according to the movement of the wrist, into a digital code. The results are shown in Figure 4 as distinct signals. In this way, the change of the data according to the movement of the user's wrist can be easily confirmed, and the gesture recognition ratio is evaluated by applying the SVM learning technique.

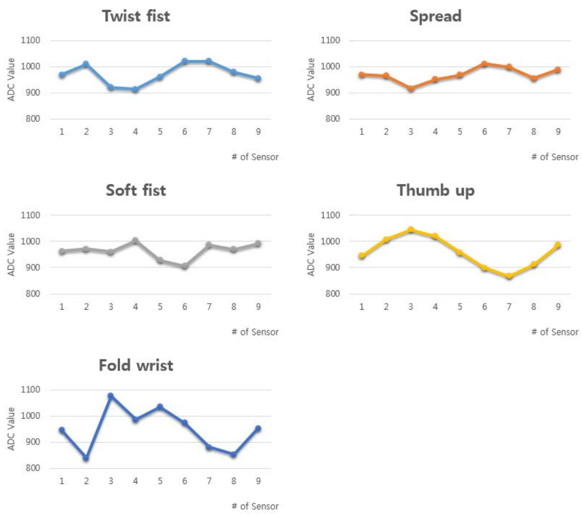

Fig. 4. Gesture recognition sensor data for the five actions.

3.3 Gesture Recognition Rate Evaluation

Figure 5 shows the recognition rates for the five motions to confirm gesture recognition. To obtain the above results, the fabricated flexible sensor array was worn by three males and two females, and then the SVM learning technique was performed according to the defined motions. Experiments of the 20 times have shown that the recognition rate is 85%, 98%, 92%, 98%, and 100% according to the motions of Twist fist, Spread, Soft fist, Thumb up, and Fold wrist, respectively. The final average recognition rate was 94.6%, and the recognition rate of Fold wrist was 100%.

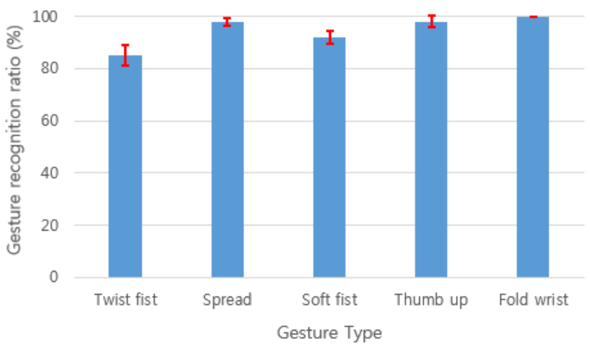

Fig. 5. Gesture recognition ratio for the five actions defined in Figure 2. (Error bars represent the standard deviation of the five subjects for each action.)

4. Conclusion

In this research, gesture recognition ratio was confirmed for the fabricated flexible sensor array that outputs real-time data according to the various motions of the wrist. The fabricated sensor array is a soft wearable band type, and it is a flexible input device to reduce fatigue of the users and to improve the fit. The force sensor can flex to a curvature radius of 5 mm. Characteristics of the different forces were confirmed to trend linearly from zero to 500 g. The sensitivity of the sensor was 0.05143 Ω / g. We extracted data based on the fabricated flexible input device and developed a program using SVM to evaluate the user's motion in real time. We performed real - time gesture recognition experiments wearing the flexible input device on the wrists of five people and achieved a 94.6% recognition rate. It was confirmed that Gesture Recognition using the various movements of the wrist muscle and the user's desired motion can provide the user interface capable of various recognizable gestures. The Flexible Sensor Array fabricated for Gesture Recognition in this research can be used as an input device to respond to a user's movement in various environments such as VR and AR.

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