A Prototype of Flex Sensor Based Data Gloves to Track the Movements of Fingers

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Abstract

In this paper, we propose a flex sensor-based data glove to track the movements of human fingers for virtual reality education. By putting flex sensors and utilizing an accelerometer, this data glove allows people to enjoy applications for virtual reality (VR) or augmented reality (AR). With the maximum and minimum values of the flex sensor at each finger joint, it determines an angle corresponding to the bending value of the flex sensor. It tracks the movements of fingers and hand gestures with respect to the angle values at finger joints. In order to prove the effectiveness of the proposed data glove, we implemented a VR classroom application.

Keywords : virtual reality | education | data gloves | flex sensors | finger tracking

I. INTRODUCTION

Recently, with the development of virtual reality devices, data gloves have been developed at low-cost for various applications. The application of data glove can be categorized as a virtual reality input/output device, communication interfaces for visual/auditory abilities, motion recognition for rehabilitation, an object remote control, and others.

The data glove has been developed using various sensors such as flex sensors, cameras, IMUs. The resistance value of the flex sensor changes according to the bending, and the bent angle can be estimated using the resistance value. There have been many flex sensor-based data gloves for tracking hands [1,2]. However, most of the research activities do not consider how to support people who have different sizes of hands. For example, let us assume there are 20 students in a classroom, and we want to use the data gloves for all students in the class. Without a calibration process, some students' hands may not be adequately tracked.

In this paper, we propose a flex sensor-based data glove for tracking the movement of hands. The proposed data glove embeds several flex sensors, an accelerometer, and a button. We insert flex sensors on each finger of the glove. The button is for reset of the hand position, for example, when the accelerometer gives wrong values. To track the movement of fingers of users' hands, our data glove collects the maximum and minimum values of the flex sensors of each, and it calculates the angle according to the values.

The purpose of this research is to allow young children to interact within a VR space in a classroom. Preliminary experimental results show that this method can be applied effectively to reduce errors in finger tracking. We believe that using these gloves will enable young students to use an optimized data glove in their own hands easily. However, there are many technical problems, such as difficulty in tracking the thumb, so we need more investigation on this project.

II. RELATED WORK

With the recent introduction of virtual reality equipment at low cost, data glove is being developed for use in various applications. We can divide virtual reality input/output devices into communication for visual/auditory abbreviations, motion recognition for rehabilitation, remote control between objects, and others classifying the application of data glove as a function

The glove for use as an input/output device of virtual reality plays a role in controlling the movement of the avatar in the virtual reality or control of other tools. VRGluv's VRgluv [1] uses proprietary sensor technology built into the gloves to track the position,

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orientation and finger movements of the hand in real-time, and can track 360-degree in the case of a thumb. Neruodigital Technologies' 'Glove One' can deliver a soft fluttering feeling of a butterfly, a feeling of rain, or even a hot feeling of fire in virtual reality. Developed by Vivoxie in Mexico, 'PowerClaw' is implemented with a headset to create a realistic feel to the tactile sensation in virtual reality. Notably, it can measure the hardness of the object with the function of preheating the temperature of the finger on the cold or hot temperature, and it enables a more realistic VR experience.

The data glove for visual/auditory abbreviations performs sign language and gesture interpretation. It is divided into a method of recognizing a predetermined hand gesture as an alphabet and converting it into a character, or a method of recognizing and translating a hand gesture character.

The mobile lorm glove [2], developed at the University of the Arts, Berlin design research lab, translates 'Loam', a form of communication commonly used by people with hearing and vision impairments, into text and vice versa. Professor Lee Tae-yoon of Yonsei University developed a smart glove [3] that recognizes sign language. This glove is designed to allow the characters to communicate on the screen in a way that recognizes the hand gestures that represent the English alphabet.

It is a smart medical glove that has been attracting worldwide attention. It is a Rafael Smart glove developed for people who have difficulty in the movement of hands due to stroke after stroke [4]. This smart glove allows the sensor mounted on the glove to react and move the virtual hand on the computer in such a way that the patient is watching the computer monitor while wearing the hand. The movement of the hand is recorded digitally so that the physician and the patient can confirm the effectiveness of the rehabilitation treatment, and it is advantageous to give motivation and necessary feedback. The smart glove developed at the University of Rhode Island's wearable biosensing laboratory [5] is for patients with Parkinson's disease. When wearing this glove, the sensor mounted on the glove senses the movement of the hand and transmits it so that the doctor can monitor it in real-time. That is, the patient has the advantage of being treated in a comfortable environment such as a home, and the abnormal prescription of the motion can be immediately taken by the doctor. Such medical gloves are expected to be developed in large numbers, but they are rarely exposed to the outside because of concerns about technology leakage.

The product that can control the application of the external device is mainly the function to run and manipulate various apps of the smartphone. The motion recognition sensor built in the smart glove recognizes specific hand movements or finger movements, Transmission, and execution. BlueBusiness Technology's "The BearTek Gen II" is one of the world's most attention-grabbing data globes that can control essential functions of the phone, GoPro camera, music app, SNS and more.

In this paper, we use a low-cost fabrication method using a flex sensor among various data glove manufacturing methods. The resistance value of the Flex sensor changes according to the bending, and the bent angle can be estimated using the resistance value. This sensor is cheap and has the advantage of being applied to various sizes of hands.

III. Design of Flex Sensor Based Data Gloves

The proposed data glove consists of a motion recognition unit with sensors to track fingers and hand movements, and a network unit for data processing and transmission (see Fig. 1). The motion recognition unit consists of flex sensors for each finger and accelerometer to track the movement of the children's hands. The network module consists of a processor and a network chip for data processing.

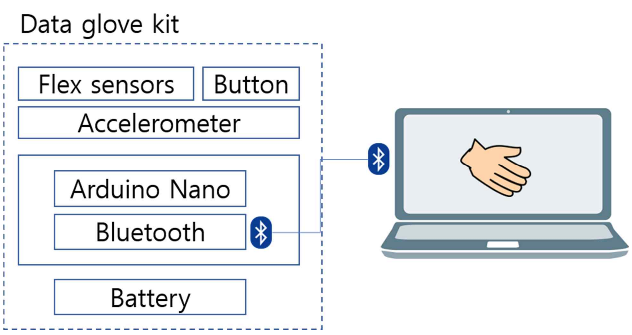

Fig. 1. System diagram

The motion recognition unit measures the bending angle of each finger by identifying the bending angle of the flex sensor. However, since the length of fingers varies from person to person, the maximum value and the minimum value of a finger bending is calculated and mapped to the bending angle of the finger. We use the Eq.1 for this calculation. F_{max} and F_{min} are the maximum and minimum values collected from the flex sensor, and A_{max} and A_{min} are the maximum angle and minimum angle of the finger joint, respectively. The critical point here is that the values of A_{max} and A_{min} are approximately 0 and 90 degrees, respectively. Consequently, F_{max} and F_{min} can be measured for each person, and the values are applied to make a personalized data glove.

$$(x - F_{min}) \times \frac{\{A_{max} - A_{min}\}}{\{F_{max} - F_{min}\}} \qquad \text{(Eq. 1)}$$

We place flex sensors with 2.2 inch and 4.5-inch lengths. The thumb and ring fingers have a small 2.2-inch sensor, and the index finger has a long 4.5-inch sensor. The middle finger has two 2.2-inch sensors. The reason for this arrangement is that each finger has a different length and role. We also think that by placing two flex sensors on the middle finger, we could implement personalized gloves for people with varying lengths of a finger in the future.

Finally, we attach an accelerometer and a button to identify a hand gesture. The tilt can be measured accurately using an accelerometer, but it is difficult to grasp the travel distance of hands by accumulating the error. So, with the accelerometer, we design a button for initialization so that users can restart the sensor.

Ⅳ. Implementation

We chose a glove that has non-elastic material to fix the flex sensors on the data glove properly. If the glove is stretchable, there could be a problem that the sensors are not appropriately adjusted. The reason is that the flex sensor is a solid material that does not stretch, and the glove is a fabric material that can stretch, so it is hard to combine these two materials. Thus, we firmly fixed the sensors to the glove using a thread.

The data glove is implemented based on an open-source Arduino platform. The initial model attached all the equipment to the glove, so the weight was heavy, and it may interfere with gestures. So, we moved the heavy parts like a battery and an Arduino-nano into a wristband to distribute the weight. We attached Arduino nano, Bluetooth module, MPU6050, two AAA size batteries to a user's wrist using a breadboard, and we attached the sensors to the glove to disperse the weight. We used a flexible breadboard so that it makes hands movement comfortable.

We used three 2.2-inch flex sensors, two 4.5-inch flex sensors. We put a 2.2 inch-sensor on the thumb and 4.5 inches on the index finger and the ring finger. In particular, 2.2-inch length sensors were superimposed on a middle finger with a longer length, as shown in Fig. 2.

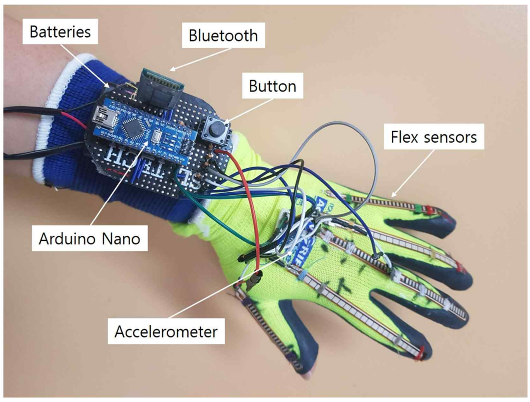

Fig. 2. Implementation of our Data glove hardware

We used Bluetooth for data transmission between our data glove and VR applications. The transmitted values are the values of five flex sensors, three values of the accelerometer, and the button on/off. The three values of the accelerometer are tilting angle of each axis.

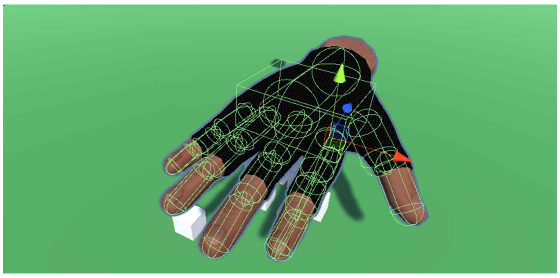

Fig. 3. Implementation of our Data glove 3D model

The value received by the PC using Bluetooth was visualized using unity3D. Resistance values extracted from each finger (see Fig. 3) were converted to Euler angles and applied to finger joints. Currently, the flex sensor does not capture all joint angles because one (or two) sensors are assigned to one finger. Moreover, we applied the slope values of x, y, z-axises among the acceleration sensor values to reflect the hand postures.

We implemented left and right 3D hand-models. As shown in Fig. 3, a finger in each hand model has three joints. So it has fifteen joints in one hand.

V. PRELIMINARY EXPERIMENT

We measured the errors of converting the value of the Flex sensor to the Euler angle to verify the effect of the proposed data glove. We applied a finger tracking algorithm that uses the same formula applied to all hands instead of the proposed method (Eq.1). We measured the flex sensor values of 5 fingers of 20 to 22-year-old students who have different hand sizes. The value obtained from the representative one is applied to the other four measured values by using Eq.1, and the average of the error at 0 ° and 90 ° is shown in Fig. 4.

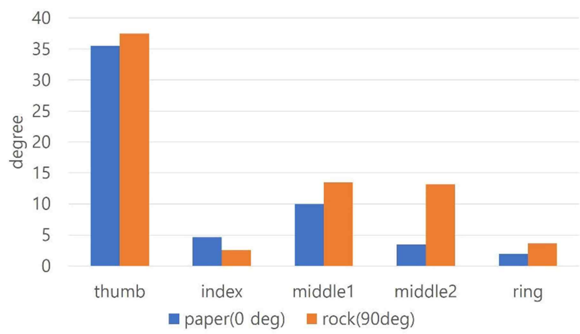

Fig. 4. Average errors of each finger(degree). The blue bar means the error when a user opens his/her hand, and the red bar is the error value when t user holds their fist.

According to the measurement results, it can be seen that a data glove optimized for one person is difficult for others to use. The error of thumbs was the largest, and the errors of index fingers and ring fingers were small. The values of the two flex sensors attached to the middle finger were also relatively large, but small compared to the error of thumbs. In the case of thumb fingers, the current method needs to be improved, and for the middle finger, we should consider a method for reducing error.

Finally, we have combined HTC VIVE controller to our data gloves to verify usability. Our data glove can measure finger movements and hand tilt by sensors. We can calculate the moving distance with a 3-axis acceleration value using acceleration sensors. However, in general, the acceleration value is significant in error so that it does not track the exact moving distance. So we attached the HTC VIVE controller to the user wearing gloves as shown in Fig. 5. It is an inconvenient method, but it is the only way possible at this time.

With this VIVE controller and our data glove combination, we development a math classroom VR application. Fig. 6 is an application that can learn various mathematical three-dimensional graphs. Typical virtual reality applications do not have input devices configured to use the data glove. So participants were not able to pick up things by hand, but they could draw numbers and equations and see how their fingers were moving.

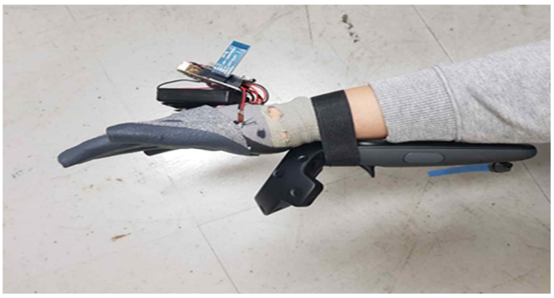

Fig. 5. Our data glove and HTC VIVE controller

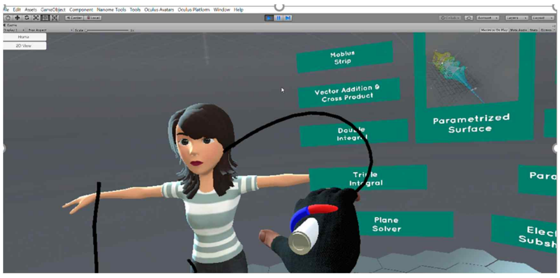

Fig. 6. A classroom application with our data glove. A user wrote a text on the space with our data glove.

VI. CONCLUSION AND FUTURE WORK

The flex sensor-based data glove is presented to track the movements of the fingers of various sizes. The primary functions of this data glove were implemented at the cost of a few tens of dollars, but additional features can be developed by attaching new hardware devices. Experimental results show that there are many points to improve for accurate tracking of thumb. In the future, we plan to develop an algorithm that uses two flex sensors to track the movement of one finger and an algorithm that can measure the finger movement using Electromyography (EMG). We also found that the material of the gloves was relevant during the experiment. If it has flexibility, there is a danger of being separated from the sensor, and if it has not flexibility, the feeling of fit is terrible, so it is necessary to worry about the material.

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