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3D Interaction Glove: Virtual and Physical Space Realization Through Data Glove

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Abstract-
As smart devices become pervasive, vendors are offering rich features through the wearable devices to enhance the user experience. In this paper, we present the hand gesture recognition based data glove for 3D interaction. Our glove provides the 3D user interface for both a physical space and a virtual space. We demonstrate the feasibility of our proposal for enhancing the user experience by obtaining control of both a physical device and a virtual representation.

Keywords: Wearable device, Human Computer Interaction, 3D interaction

Introduction

Over the past twenty years, many smart devices have become pervasive; vendors are offering rich features supported by wearable devices to enhance the user experience. Various wearable devices such as Google Glass, Galaxy Gear, and Fitbit Charge are proposed and attracted attention in healthcare field and communication field [1-4]. Among the various wearable devices, we expect the wearable device in the shape of glove to generate new wave for improving user experience. The wearable device based on data glove has been developed for human-computer interface by dealing with intentional and intuitive information of user compared to conventional devices such as keyboard and mouse. For example, the data glove that recognizes simple hand gestures including intend of user is used to replace a remote control, which controls household appliances, for the disabled [5].
Gesture recognition systems using a data glove have been proposed, and implementations with the data glove have been done in entertainment [6, 7, 8]. To interpret sign language, the data glove provides alternative by replacing hand gesture with data which means the letters of language [9, 10]. For 3dimensional hand motion tracking and gesture recognition, 3D hand model with data glove was proposed [11]. Using three tri-axis accelerometers on data glove, specific value derived from equation which defines rotation angles of axis according to each joint is applied to input of 3D hand model. In experiment, simple hand gesture recognition is implemented on horizontal and vertical condition to demonstrate 3D hand motion tracking.
In this paper, we express the hand gesture based on the data glove for 3D interaction. Our main contribution is enhancement of the 3D user interface for both a physical and a virtual space through gesture recognition in real-time. The rest of this paper is organized as follows. In Section 2, we give an overview of our 3D interaction system, including implementation of our data glove, protocols, and descriptions of both a virtual space and a physical space. In Section 3, we show the experimental results. We conclude in Section 4 by proposing the future work in this field.

3D Interaction Glove

The 3D Interaction glove system consists of four main units: Data glove, Analog frontend unit, Data processing unit and Applications.

A. Data glove

Figure 1 shows our system flow of the 3D user interface. The data glove includes multiple flex sensors, which are attached on each finger to get voltage value from the movement of finger. The flex sensor measures angle displacement by detecting changes in resistance. When the finger is bent, the resistance value increases. On the other hand, the resistance of flex senor operates reversely. And the measured voltage value from flex sensors is forwarded to the analog front-end unit.
The analog front-end unit is composed of differential amplifiers and analog to digital converter (ADC). We designed differential amplifiers to amplify the output voltage width of flex sensors, because the measured voltage by flex sensors is small. When fingers are unfolded, output voltage of differential amplifier is 0V. On the contrary, when fingers are fully bent, output voltage is close to supply voltage. The output signal from differential amplifiers is converted into digital data through ADC in analog frontend unit. It is transformed into 12bits digital data that represents the position of the fingers.

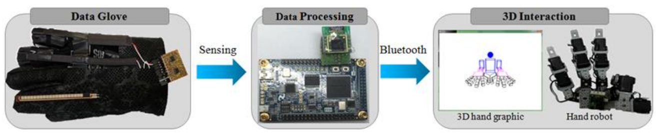

Fig.1. The 3D interaction system

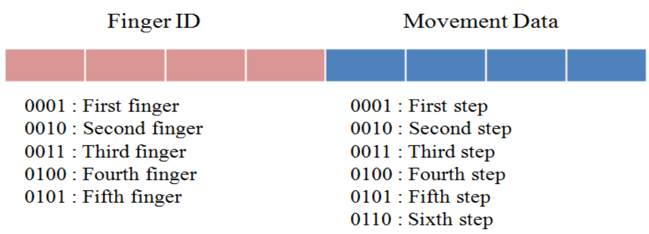

Fig.2. Packet of data processing unit

To implement the data processing unit, we designed and implemented three hardware modules in FPGA: Data capture module, Framer module and Data transmission module. The data capture module take the 12bits data from ADC in the analog front-end unit through SPI (Serial to Peripheral Interface) communication. We designed SPI controller to communicate between the analog front-end and data capture module.

The framer module processes the classification of command data, and determines one of the 6 positions to each finger. Figure 2 shows the command data structure of framer module. The command data is 8 bits data which indicates information that the upper 4bits are ID according to fingers and the lower 4bits are angle of fingers. The movement data is defined by 6 positions. For example, if command data is 0x34, application operates fourth finger in virtual and physical hand model, and makes fourth finger to be the third position.

Figure 3 shows our system block diagram. The command data of framer module is transferred to data transmission module through Bluetooth communication. The data transmission module includes the RS-232C controller to communicate with applications through Bluetooth. Applications are composed of virtual space and physical space. The 3D interaction glove is illustrated as the 3D hand graphic in the virtual space and is represented the hand robot in the physical space.

B. 3D interaction in virtual space

We use the OpenGL for representation of the 3D hand graphic in the virtual space. This graphic uses some functions that the depth buffer, the buffer clear function, the rotate function and the perspective function in the OpenGL API.

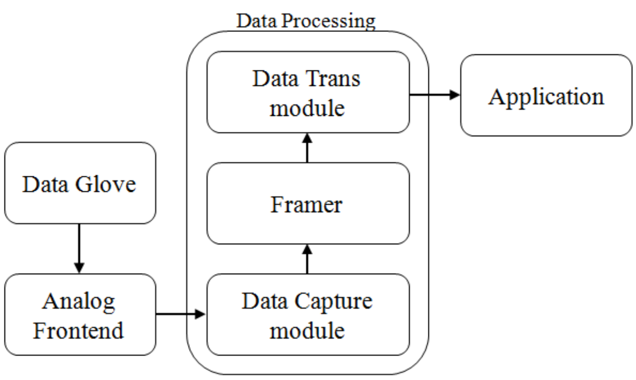

Fig.3. System flow of the 3D interaction

The depth buffer stores the value of the z-axis in the 3D graphic that value used to arrange the 3D graphic. Without using this buffer some graphics overwrite other graphics that according to programmed order.

The buffer clear function erases the value of the depth buffer and color buffer. When the 3D hand graphic takes a gesture, the OpenGL redraws the new graphic on the previous graphic. The previous graphic is remained and stacked in the buffers, the OpenGL shows the afterimage with the 3D hand graphic. If we empty the buffer value, the afterimage is erased and the new graphic is remained. In addition, our 3D hand graphic uses the perspective function. Without this function, 3D object usually seems like two-dimensional image, however we use that function for 3D object to give the three-dimensional effect.

We reproduce finger movement using the rotate function, which makes objects to rotate on a fixed point that is chosen by programmer. Object rotates according to the value of the rotate function that appears the variation of *x*, *y* and *z* axis. We use the rotate function to realize the joint of the finger. Each fixed point of the rotate functions place to each finger joint. This function realizes the movement of each finger joint as movement of the data glove. And our 3D rendering program has a multidirectional observe function. We are able to monitoring from all directions to the object for the exact observation to the movement and the form.

Application in the Host PC receives 8 bits data from data transmission unit through RS-232C communication that using Bluetooth. The program embodies the index data and 3D object as uses library function of OpenGL. The 3D object of the hand is changed according to the shape of the user hand by OpenGL library. In addition, we increase the readability by using in wire draw method and painting each side of finger texture as white color.

C. Hand robot in physical space

Figure 4 shows the optimized controller board for accelerating the movement of hand robot. This board includes an ARM Cortex M3 microprocessor and Bluetooth module. To control the hand robot through RS-485 communication, the designed controller board has 15 I/O pins that are consist of power, ground, and signal lines.

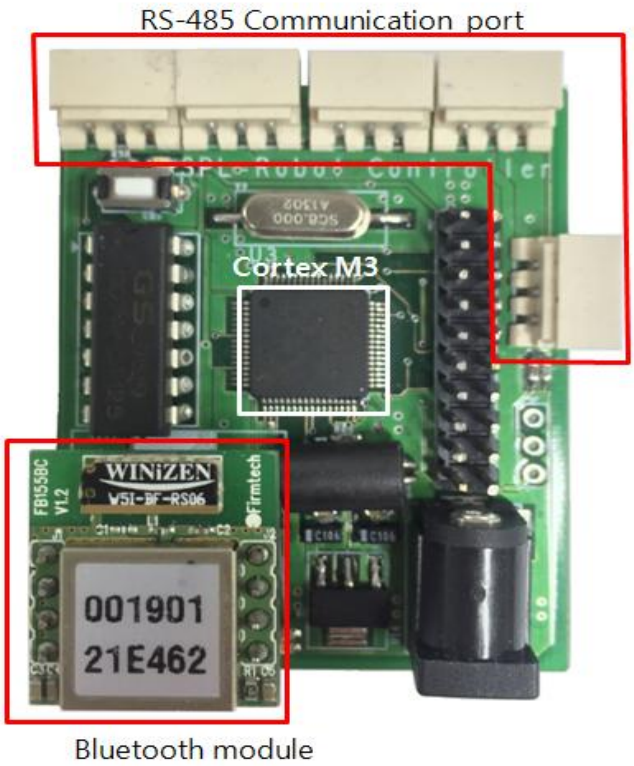

Fig.4. Robot hand controller

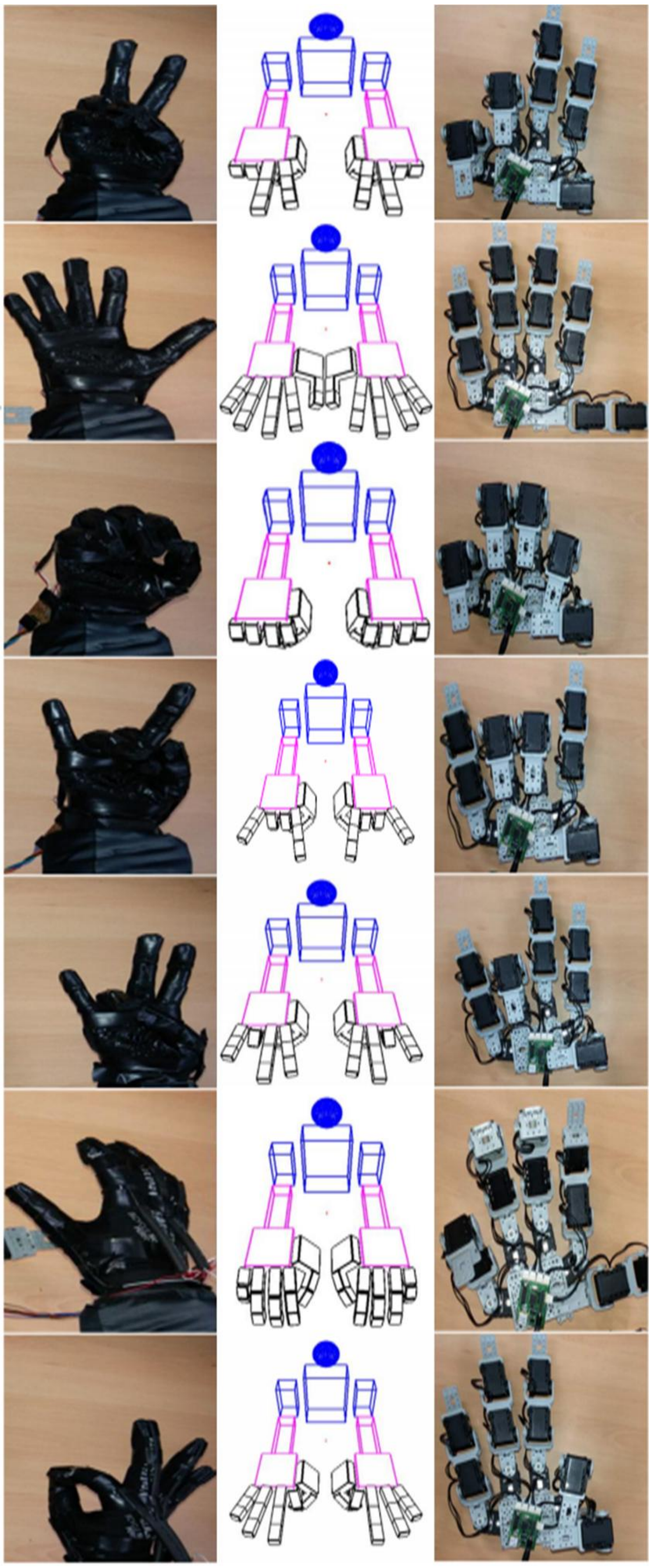

Fig.5. Realization of hand gestures

The Bluetooth module receives the command data from data processing unit and passes the command data to Cortex M3 microprocessor. The microprocessor confirms the command data, which is consist of fingers ID and movement data. When the microprocessor confirms the upper 4bits of command data, it selects finger of hand robot and checks the lower 4 bits of command data to transmit a movement data to hand robot.

The microprocessor sends a command that has two kinds of information through the RS-485 communication. One of the information is motor ID. All of the motors have a micro controller unit (MCU). MCU in the motor receives the command from processor and compares command ID information with own ID. If motor ID does not match ID information, it ignores the command. On the other hand, if the motor ID matches ID information, it receives not only finger ID but also motor movement data.

Experimental Results

We performed experiments on virtual space and physical space to demonstrate our system. We controlled 3D graphic object by doing various hand gestures with the data glove. The first row shows the gesture of data glove, which is the input of 3D interaction glove. The second and third rows represent the realization of hand gesture in virtual and physical space, respectively. In experiment, we succeeded to control 3D hand graphic and robot hand using the data glove. When the user spreads out a hand with the data glove, the 3D hand graphic and robot hand proceed on the hand gesture. As a result, we confirmed the correct movement of data glove in the 3D interactions in real-time as shown in figure 5.

Conclusions

In this paper, we introduced a wearable device for real-time 3D interactions in virtual space and physical space. We showed that the 3D user interface using the hand gesture can control both the 3D hand graphic and the hand robot. In experimental results, our data glove recognized the user's hand gesture, and controlled the 3D hand graphic and the robot hand successfully. We expect that our data glove will be applicable to the augmented reality interface or the virtual reality systems such as 3D games, and 3D rendering. Furthermore the 3D interaction glove can be applicable to the physical space like a robot control.

We plan to improve the sensitivity of data glove by using the additional sensors such as accelerometer and gyro sensor, which enables the 3D interaction glove to realize the control in both the virtual and physical space precisely.

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