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A Multi-modal Interaction Glove for Immersive Education

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ABSTRACT

The virtual reality systems may be used as a new educational tool because a user can be provided immersive sensation as he/she experiences a real object. One of the most important factors in developing educational tool based on virtual reality is to make a user naturally interact with a target object and to convey the sense of reality to a user. The sense of the reality means that a user feels or experiences an object in virtual world as the object exists in real world. In order to increase the sense of the reality, this paper addresses a multimodal interface device that allows a user not only to naturally interact with virtual objects but also to sense graphic and haptic feedback according to his/her interaction. The proposed system measures a user's motion based on IMU (an inertia measurement unit) and then re-creates haptic feedback by the proposed multimodal interface device. To generate the haptic feedback in response to user's interaction with virtual objects, our system consists of a haptic part for creating haptic information, a motion sensing part to measure user's motion input, and a virtual environment part. We have also implemented educational contents in the virtual environment and have manipulated the educational contents with the proposed multimodal interaction device.

KEYWORDS: Haptic, Kinesthetic, Virtual environment, Immersive education

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1. Introduction

The education system based on the virtual reality technology can be a solution for immersive teaching because VR systems enable users to experience phenomena in virtual environment which are difficult to illustrate in real world. Furthermore, users can learn how to operate a machine or a target device in virtual world. This education platform based on the virtual reality have been developed in the form of simulator due to the advancement of graphic hardware and rendering technology [1,2,3].

Even though the simulator systems allow users to indirectly experience target objects in virtual environment, there is a gap of experience between direct and indirect. To minimize the gap of experience, the simulator systems which started at 2D graphics have been expanded to the game with 3D or stereo graphics and have adapted natural motion interfaces. Through the natural interface, a user intuitively investigates and manipulates graphic contents. Solina *et al.* designed a simple simulator system where user's motion was grasped by an infrared stereo camera [4]. Sugarman *et al.* developed a motion sensing platform which captures a user's motion input using two pressure sensors [5]. Microsoft developed a motion game system (Kinect), which is the first controllerless motion game device, for Xbox 360 video game console and Windows PC [6]. One of the impact factors of the Kinect is to adopt the natural user interface paradigm instead of conventional user interfaces.

Even though the above systems allow a user to naturally interact with virtual environment, they still have limitation for providing immersive sensation to users. The completely revolutionizing way the users immersively interact with virtual environment is to provide haptic feedback to the users. Nintendo^{TM} developed Wii which is a natural interface to capture a user's motion input by an accelerometer and infrared camera [7]. Since an accelerometer and infrared camera are embedded into a stick-type input device, the system easily captures a user's motion and allows the user to intuitively enjoy the virtual environment. Furthermore, the user senses vibrotactile feedback due to a vibration motor in the Wiimote which is a primary controller for Wii console.

S. Andrews et al. presented a game which acts as an experimental framework for assessing vibrotactile effects in 3D games [8]. M. Faust and Y. H. Yoo proposed a haptic game where a player provides command input to the virtual environment with two bats and senses vibrotactile feedback [9]. Haptic feeling consists of kinesthetic and tactile sensation. Kinesthetic and tactile information refer to sensory data obtained through receptors of joints, muscles, ligaments, and etc., and through receptors of skin, respectively [10]. A user recognizes the stiffness of an object through the kinesthetic information and discerns the texture of an object through the tactile information. However, above systems focused on creating tactile sensation because the tactile actuators can easily be constructed in small size. Among others, vibrotactile modules have been most widely studied to reproduce button sensations on touch screens by generating short vibration feedbacks [11,12,13], and they have been successfully commercialized in many devices. However, these modules mainly provide tactile feedback to users for tactile sensations (surface roughness, textures, etc.) by creating small vibratory motions. Thus, they are not sufficient to convey comprehensive or proper haptic sensations for certain applications, particularly kinesthetic-feeling-dominant applications such as button-click or pressing feeling for buttons. In this paper, we construct an interaction hardware that senses human gesture and creates kinesthetic feedback as he/she touches and manipulates real objects. The constructed system recognizes human motion and checks the collision between the human and virtual objects, and furthermore, the system creates the haptic information (based on kinesthetic feedback) and provides it to the human.

This paper is organized as follows. In Section 2, we will describe the overall system. After that, the proposed haptic glove will be presented in section 3. Finally, section 4 concludes the paper with brief summary of main issues.

2. System Structure

We constructed a multimodal interface prototype system (<Figure 1>) that allows a user to naturally interact with virtual environment. The constructed multimodal interface system consists of a haptic glove, a motion sensing module, and a virtual environment. The virtual environment was implemented in a PC with an i5 processor. The graphic programming was carried out by a program written in Unreal® Development Kit. The motion sensing module was constructed by a stereo camera system with IR filters (BP 850) controlled by PC. The haptic glove was developed to create kinesthetic sensation and to convey it to a user. The haptic glove includes small actuators, an inertia measurement unit (IMU), and flexible sensors controlled by a micro-processor. The small motors are used to create kinesthetic feedback and the flexible sensors serves as an angulation modules of user's finger.

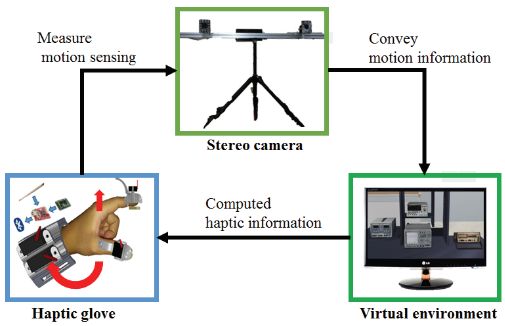


그림 1. 멀티모달 인터페이스 시스템

Figure 1.Multimodal Interface System

The translation motion of the haptic glove is recognized by the motion sensing module which is controlled by the main PC, and the rotation motion of the haptic glove is measured by the IMU. Wireless communication (a bluetooth) was used for data communication between the main PC and a microprocessor in the haptic glove. The wireless communication was achieved with 115200 baud rate. If a user wears a haptic glove and moves his/her hand, his/her motion is measured by the motion sensing module and it is conveyed to the virtual environment in order to be displayed on the virtual environment. If there is a collision between a user's hand position and a virtual object, haptic information is computed in accordance with the amount of the user's interaction and the mechanical property of the virtual object. After that, the computed haptic information is transferred to the haptic glove so that a user feels the haptic information.

2.1 Motion Sensing Module

The developed motion sensing module is achieved by a stereo camera system. The stereo camera system recognizes a target object in 3D space by composing 2D images obtained by two single cameras so that there is a possibility to produce errors. Therefore, we calibrated the two cameras. After correcting a distorted image using the camera calibration, we used a triangulation to compute the depth (z-axis) of a target object as shown in <Figure 2>. In <Figure 2>, P is measuring point, p and p' are images obtained from two cameras.

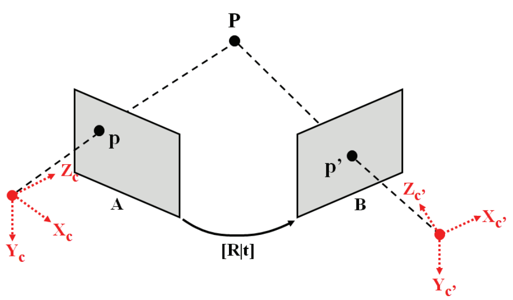


그림 2. 삼각측량모델

Figure 2. The model for triangulation

In order to evaluate whether the motion sensing module can precisely measure the position of a haptic glove, we investigate position errors of the motion sensing module. We measured four positions (lower left, lower right, upper left, and upper right) in the front side, four positions in the back side, and a middle position in the work volume (1m x 1m x 1.5m) as shown in <Figure 3>.

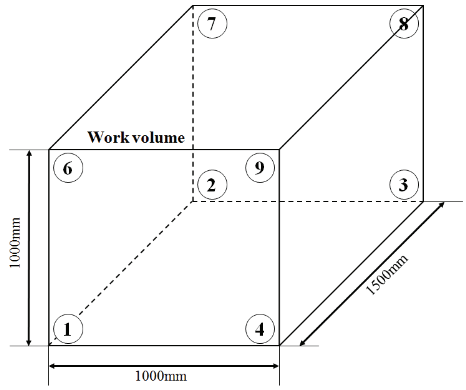


그림 3. 동작 영역 및 측정한 위치

Figure 3. Work volume and measured positions

2.2 Virtual Environment

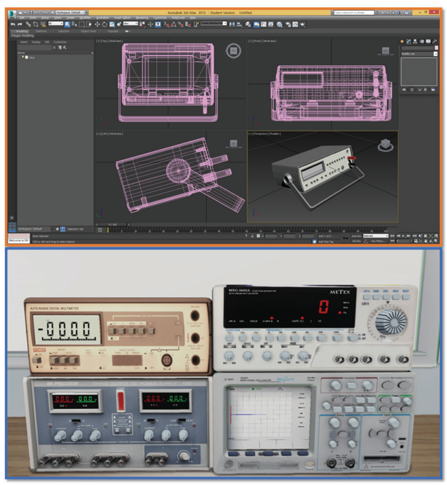


그림 4. 개발한 그래픽 환경

Figure 4. Developed virtual environment

<Figure 4> shows the developed virtual environment. The virtual environment was developed by UDK (Unreal® Development Kit). Unreal Script was used to easily connect to the UDK. Virtual objects in the environment were modeled with 3D Max software. Unwrap UVW mapping texture technique in 3D Max was applied to created models.

2.3 Haptic Glove

Many interaction devices transfer only visual information to user. To enhance the realism in interacting with virtual objects, haptic information coupled with the visual information must be transferred to users. Therefore, in this paper, we developed a haptic glove to generate feedback force from virtual objects. We will explain the proposed haptic glove in next section in detail.

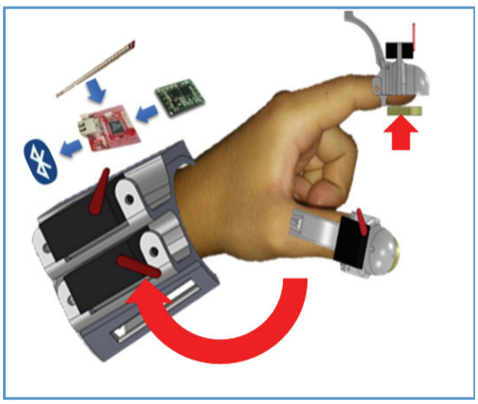


그림 5. 제안하는 햅틱 글러브

Figure 5. The proposed haptic glove

3. Haptic Glove

<Figure 6> shows the hardware structure of the developed haptic glove consisting of servo motors, an IMU, and flexible sensors. All sensors and actuators in the haptic glove are controlled by a microprocessor.

Flexible sensors are attached to the thumb and to the index finger of a user in order to measure the amount of bending of the two fingers. Servo-motors are also attached to the same two fingers to create haptic information. We proposed two mechanisms for creating haptic feedback. One is a finger haptic module and the other is a joint movement limitation system.

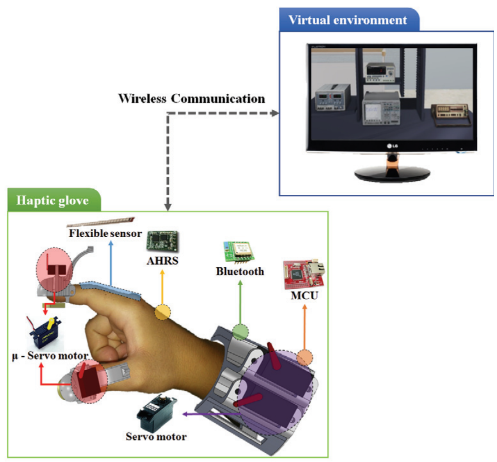
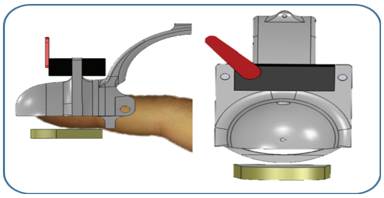


그림 6. 제안하는 햅틱 글러브의 구조

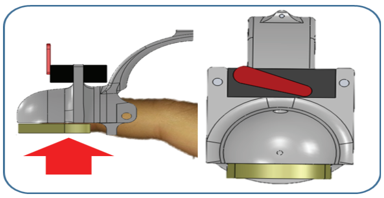
Figure 6. Structure of the developed haptic glove

<Figure 7(a)> and <Figure 7(b)> show the mechanism for the finger haptic module which creates haptic effect on a user's finger pad. The finger haptic module consists of a plate, a small motor, and a wire. The plate and the small motor are connected with the wire. If a user's finger collides with a virtual object, the motor draws the

plate to the user’s finger pad to generate feedback force. <Figure 7(a)> shows a free state and <Figure 7(b)> shows a state where a user feels the feedback force.



(a)

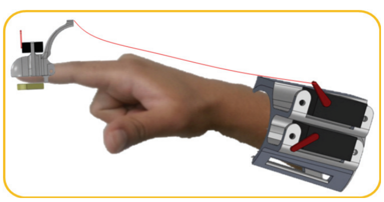


(b)

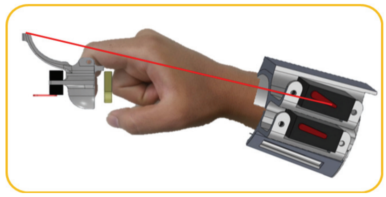
그림 7. 접촉력제공을 위한 손가락 햅틱 모듈

Figure 7. Finger haptic module for creating contact force

Another wire is connected between the finger haptic module and an actuator which is embedded into a user’s arm as shown in <Figure 8(a)> and <Figure 8(b)>. When a user does not touch any virtual objects, the actuator embedded into arm is not actuated (<Figure 8(a)>). However, in touching the virtual objects, the actuator is operated to pull the finger haptic module to limit the finger’s bending as shown in <Figure 8(b)>.



(a)

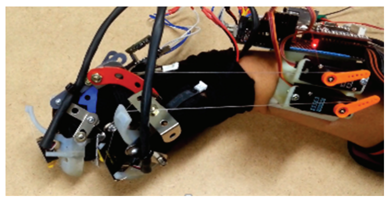


(b)

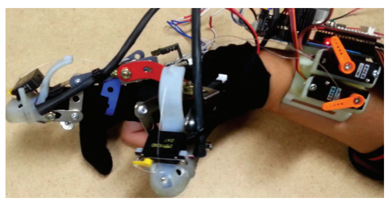
그림 8. 관절 움직임 제한 모듈

Figure 8. Joint movement limitation module

<Figure 9> shows the constructed actuator prototype. <Figure 9(a)> shows the actuators’ state when a user joins his/her fingers (a thumb and an index finger) and <Figure 9(b)> is with his/her two fingers apart. In order to investigate the haptic behavior of the developed device, force sensors are attached to the actuation module.



(a)



(b)

그림 9. 관절 움직임 제한 모듈

Figure 9. Constructed actuator prototype

The peak force of the developed device is 9.5N and force resolution is 0.09N. It is widely known that just noticeable difference (JND) for force that human can reliably discriminate is about 10% over a force range of 0.5~200N.

Therefore, we can conclude that the proposed module can create realistic force feedback in the range of 0 ~ 9.5N.

4. Conclusions

In this paper, we presented a multimodal interface system based on haptic technology that provides various haptic feedbacks to users. The developed system consists of a haptic glove for creating haptic feedback, a motion sensing module for measuring the motion of the haptic glove, and a virtual environment. The haptic glove was constructed using motors and flexible sensor and it limits the motion of a user's finger and conveys haptic information to the user's finger. The proposed system can be applied to various simulators based on virtual reality technology.

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실감 교육을 위한 멀티 모달 인터랙션 글러브장치에 대한 연구

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한국기술교육대학교 컴퓨터공학부

요 약

최근 들어 가상현실 시스템은 교육의 도구로 활용되어, 교육도중에 사용자는 가상의 물체를 마치 실제 물체처럼 조작하는 느낌을 전달받을 수 있다. 가상현실 기반의 교육도구를 개발하는데 있어서 가장 중요한 요소 중 하나는 사용자가 자연스러운 움직임을 이용하여 가상의 물체와 상호작용하며, 발생하는 조작감을 생성하여 실제물체와 인터랙션 하고 있는 것과 같은 현실감을 사용자에게 되돌려주는 것이다. 이러한 현실감을 증가시키기 위해 본 연구에서는 사용자가 가상의 물체와 자연스럽게 인터랙션을 할 뿐 아니라 인터랙션에 따른 시각과 촉각 피드백을 전달받을 수 있는 멀티모달 인터페이스 장치를 제안한다. 제안한 시스템에서는 관성측정유닛을 이용하여 사용자의 움직임을 측정하며 움직임에 따라 햅틱 피드백을 재 생성하여 사용자에게 전달한다. 가상의 물체와의 인터랙션과 맞는 햅틱 감각을 생성하기 위해, 제안하는 시스템은 햅틱정보를 생성하는 햅틱 부, 사용자의 움직임을 측정하는 모션생성 부, 그리고 가상현실 부로 구성하였다. 또한 가상환경 내에 교육 콘텐트를 구현하였으며 제안하는 멀티모달 인터랙션 장치를 이용하여 교육 콘텐츠를 조작할 수 있는 환경을 구축하였다.

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