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Haptic Gloves with Strength Measurement and Force Feedback

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Abstract

This paper proposes a haptic glove that supports force measurement and force feedback to improve space constraints when using cameras or controllers, response speed and accessibility to haptic devices. The device consists of a servomotor to implement force feedback on each finger, an FSR sensor to measure force, and a Hall Effect sensor to track finger movement. The haptic glove is wireless and wired and provides force feedback to each finger. It adapts to different hand sizes and can be synchronized with virtual reality using the Unity engine. In our tests, we found that finger tracking can be measured to 0.09mm and force can be measured in 5g increments, starting at a minimum of 20g.

Keywords: Haptic, Virtual Reality, Force Feedback, Metaverse, Augmented Reality, Mixed Reality

INTRODUCTION

The recent rise of the metaverse has led to the growth of virtual reality (VR), augmented reality (AR) and mixed reality (MR).

VR is an artificial environment that resembles the real world and is based on human interaction [1]. It interacts directly with the user's five senses to create a spatial and temporal experience.

AR is a technology that overlays virtual information in real space and interacts with it in real time [2]. It has recently been in the spotlight with the release of Apple's Vision Pro and NREAL AIR.

MR is an appropriate convergence of VR and AR, such as building an artificial environment in reality or overlaying virtual information in an artificial environment, and is the basis of each technology's direction or metaverse [3].

As the basis of these technologies is direct interaction with the user, human behavior is tracked by controllers or camera recognition. However, these devices are limited in their fine handling and range of action, which is why haptic gloves, a wearable haptic device, are a promising area of research.

The human hand is a combination of sensation and movement. It is an important part of providing information and performing tasks [4]. The haptic glove can track the behavior of the user's hand like a controller, as well as track each finger individually depending on its shape [5]. They can also provide force feedback, measurement of force on the fingers, or simulation of virtual objects or forces on the hand. For this reason, they can be used for creating virtual objects in virtual reality, for remote control and manipulation, and for rehabilitation through the active movement of haptic gloves. However, the high cost of these devices makes them inaccessible and difficult to use and disseminate.

Therefore, in this study, we propose haptic gloves with Strength measurement and force feedback based on LucidVR's LucidGloves Prototype 5 BETA [6], an open project that lowers the price and increases the accessibility.

Related Works

Research on haptic gloves has been around for a long time.

M. Bouzit et al. [7] use a direct-drive pneumatic actuator located in the palm of the hand. It provides up to 16 N of force to the user's thumb, index, middle, and ring fingers, is compact and lightweight, but has limited range of motion, difficulty handling real objects, and fails to render force to the little finger.

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J. Blake et al. [8] study a haptic glove that uses MR brakes rather than actuators, which is different from previous studies. The use of MR allows the device to be miniaturized, improve responsiveness, and deliver force feedback. However, unlike devices that use actuators, they cannot provide feedback for pushing or pulling fingers.

Z. MA. et al.'s [9] work is a haptic feedback glove using an exoskeleton. It provides individual force feedback to every finger and can simulate tactile sensations, forces, and torques generated in a remote or virtual environment. The exoskeleton does not restrict movement and supports a wide range of motion. In this study, it can control a mobile robot and be remote in both directions.

P. Ben-Tzvi et al.'s work [10] is an exoskeleton haptic glove that measures and supports hand motions. Like Z. MA. et al.'s work, it can support a variety of hand sizes and has a wide range of motion. It also has great potential in rehabilitation therapy and virtual reality applications.

The work of M. W. Uddin et al. in [11] is a haptic glove that uses air pressure to provide force and tactile feedback. The air pressure is regulated by a PWM controlled solenoid valve. It is characterized by low cost and good portability.

M. Hosseini et al [12] is a lightweight haptic glove using Twisted String Actuation (TSA). It was shown to be suitable for simulating virtual spring stiffness using HTC's Vive. They showed that TSA provides realistic force feedback without the need for gears or large actuators.

The work of R. Kovacs et al [13] is a haptic glove that provides tactile sensations and forces in the palm instead of the fingers. It is designed to hold virtual objects in the hand and scored high in the realism evaluation.

Hardware Implementation

Position Sensing Method

Figure 1: SS49E Hall Effect Sensor

The haptic glove proposed in this work uses magnets and SS49E Hall-effect sensors to track fingers, like the base model LucidGlove Prototype 5 BETA [6].

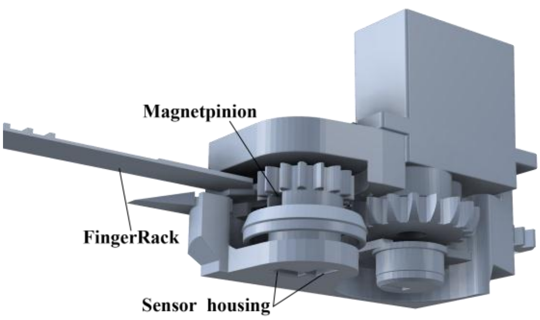

Figure 2: Position Sensing Architecture

The finger tracking feature is realized using a neodymium magnet and an SS49E Hall Effect Sensor. The MagnetPinion meshes with the FingerRack to rotate with the finger movement, and the SS49E sensor mounted on the SensorHousing changes its value as the magnet on the MagnetPinion rotates.

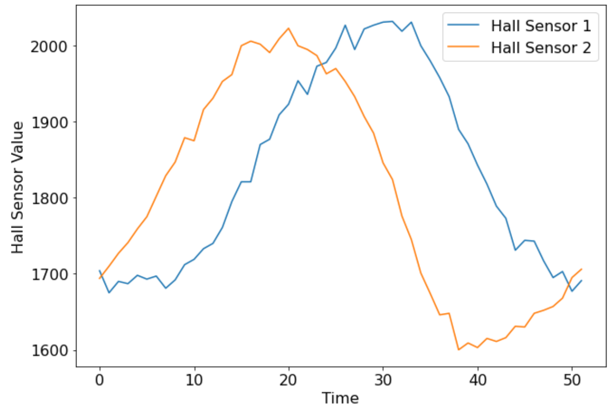

Figure 3: Graph of Hall sensor values

According to finger movement

As the finger moves, the values of the two Hall sensors in the SensorHousing change, and the combination of the two values allows for accurate tracking. When the FingerRack component moves through its full range of motion of 4 cm, the difference between the maximum and minimum values of the Hall sensor is 423. Therefore, the tracking resolution of the finger movement is 0.09 mm.

Strength Sensing Method

Figure 4: DF9-40 Force Sensitive Resistor

The DF9-40 Force Sensitive Resistor (FSR) sensor measures the force applied to the finger.

Figure 5: Finger EndRing with DF9-40 FSR Sensor

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The DF9-40 FSR sensor, which will measure the force applied to the finger, is attached to the EndRing component and transmits the force applied by the fingertip to the MCU.

Wiring Diagram

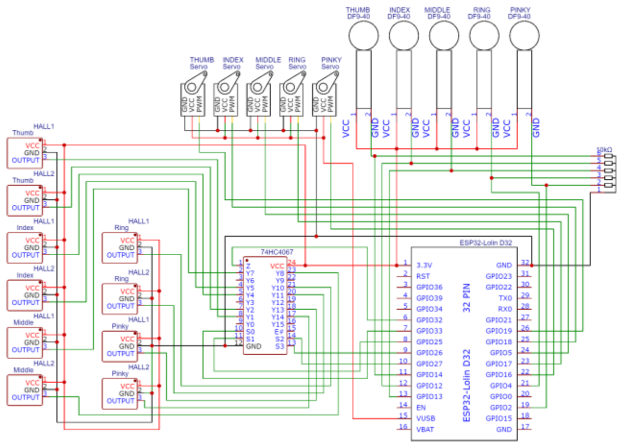

Figure 6: Haptic Glove Schematic

An ESP32-based MCU is connected to a Hall sensor for finger tracking, a servo motor for force feedback, and an FSR sensor for measuring the force applied to the finger.

The MCU receives the values from the Hall sensor connected to the CD74HC4067 multiplexer (MUX) in sequence. The PWM line of the servo motor is directly connected to the MCU to realize force feedback, and the voltage value that changes according to the force applied to the sensor is input to the MCU through a pull-down circuit using the FSR sensor and array resistor.

The Hall sensor, FSR sensor, and MUX use a Vcc of 3.3V, and the servo motor uses a Vcc of 5V.

RESULTS

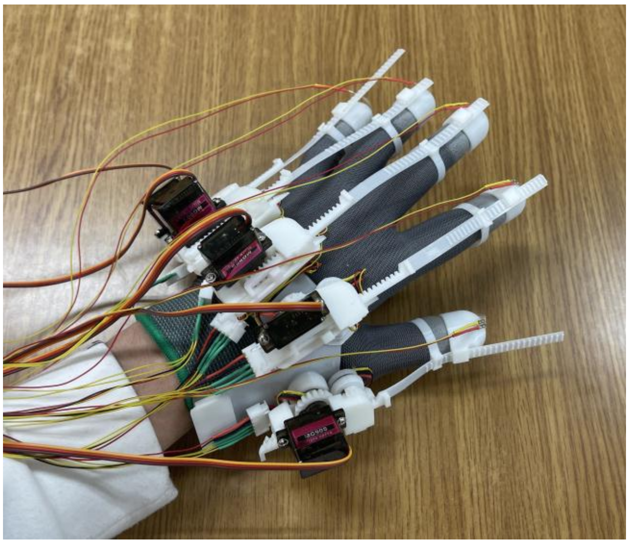

Figure 7: Haptic Gloves with Strength Measurement and Force Feedback

The haptic gloves proposed in this study were tested using the Unity engine, SteamVR, and Oculus Quest 2.

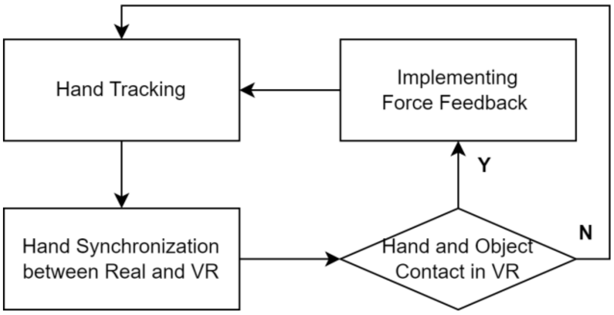

Figure 8: Haptic Interaction Flow Chart

The flow chart of haptic feedback is shown in the photo. The movement of the haptic glove measured by the sensors is sent to the MCU and these measurements are sent to the PC. Based on the transmitted values, the PC estimates the finger movements and synchronizes them on the virtual environment. The moment the virtual hand touches the virtual object, the haptic glove provides contextual haptic feedback.

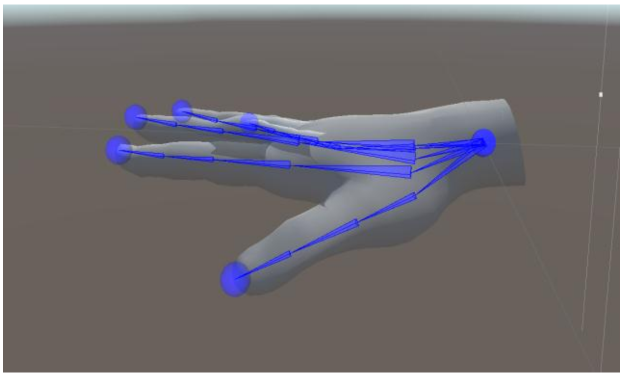

Figure 9: Haptic Glove Tracking Simulation

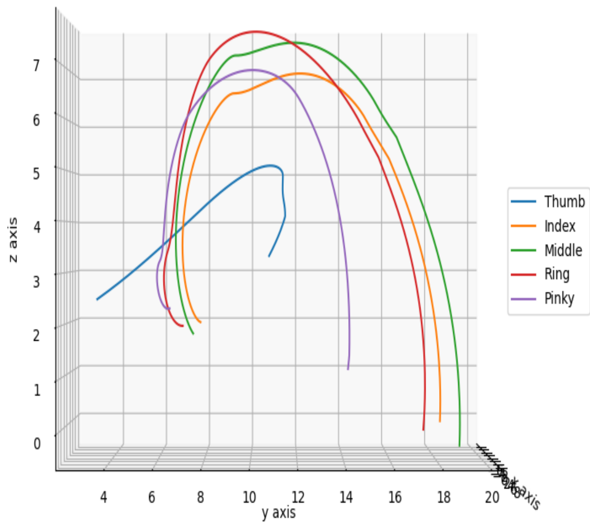

Figure 10: Workspace of Fingers X-axis Direction

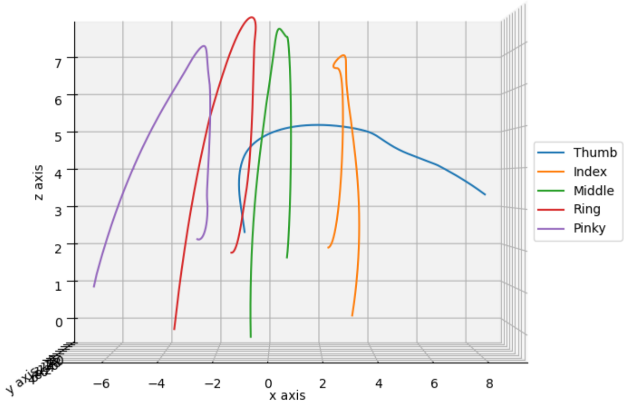

Figure 11: Workspace of Fingers Y-axis Direction

This photo shows the range of motion of a finger in the virtual environment after connecting the Unity engine and the glove to link the virtual environment to reality. Because the glove tracks the overall movement of the finger, rather than tracking each individual joint, the finger joints move at the same angle in the virtual environment.

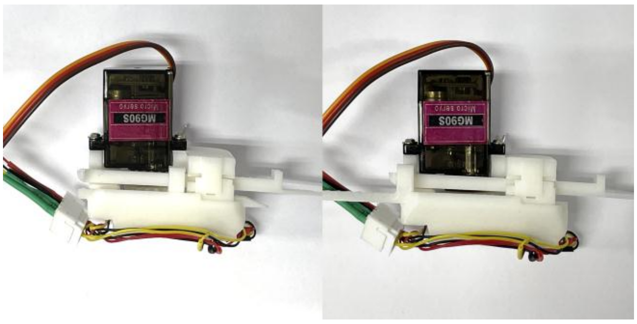

Figure 12: Differences with and without Force Feedback

In the virtual environment, when a virtual object touches the simulated hand, the servo motors in the haptic glove are triggered, causing the ServoRack to pull back, preventing the FingerRack from pulling forward.

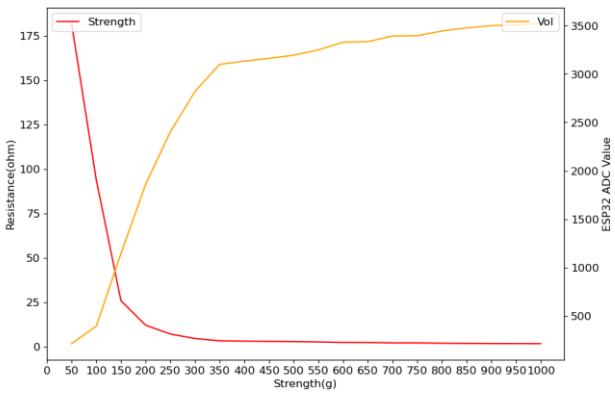

Figure 13: Resistance and ADC values according to Strength

Graph showing the resistance value of the FSR sensor in 50g increments and the conversion value via the ADC in the MCU.

CONCLUSION

Recently, the resurgence of metaverse and MR due to Apple Vision Pro has increased interest in haptics. However, due to the requirement of tracking the user's behavior with a camera, there are limitations in space and reaction speed.

Therefore, this study proposes a haptic glove that supports force feedback and force measurement for improved accessibility and usability. It supports force feedback applied by virtual objects and enables finger tracking.

Finger tracking was measurable in increments of 0.09mm, and force applied to the hand was measurable in increments of 5g, starting as low as 20g.

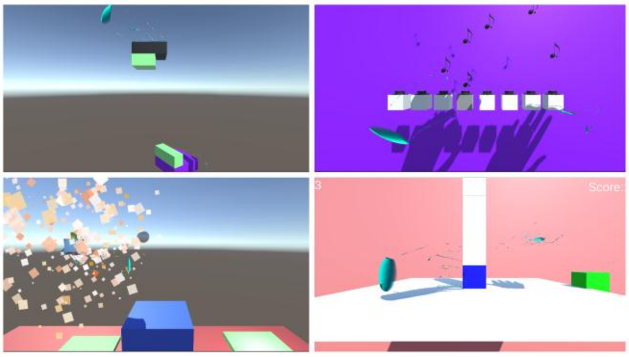

Figure 14: Examples of cognitive improvement games

Further use of the metaverse will increase the utility of this research in bridging the gap between reality and virtual reality, and further research will be conducted to demonstrate the effectiveness of haptic differences in learning and rehabilitation.

Acknowledgement

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