Wireless Embedded System on a Glove for Hand Motion Capture and Tactile Feedback in 3D Environments

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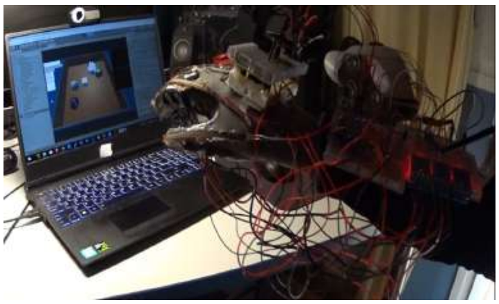
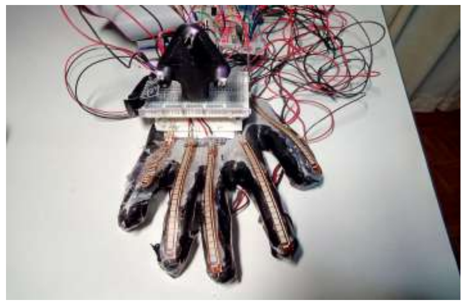
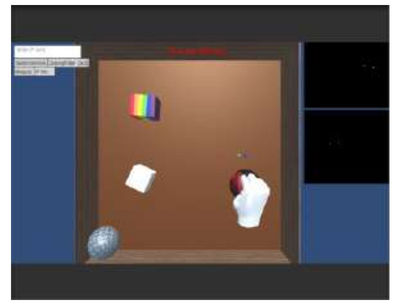


(a) Glove side view



(b) Glove front view



(c) Game application

ABSTRACT

Wearable haptics, compatible with Virtual Reality applications for remote interaction, are still heavily reliant on cumbersome wired systems, restricting user movement. We present an innovative, component-based, wireless embedded system on a glove with hand motion capture providing tactile feedback, operating without the need for a finger tracking device such as the Leap Motion. The user's hand is tracked by an infrared filter pass camera which detects three infrared LEDs attached on the 3D printed base on the glove. The system is built using inexpensive parts making it ideal for prototyping and customization, therefore resulting to a scalable and upgradable system.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; • **Computing methodologies** → **Virtual reality**.

KEYWORDS

Infrared Tracking, Embedded Systems, 3D Environments, Haptics

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1 INTRODUCTION

Haptics stimulate the senses of touch and motion, employed in Virtual Reality [Koulieris et al. 2019],[Drakopoulos et al. 2020], but also applicable in the fields of teleoperations, robotics and cellular devices (Android and Apple smartphones). Current state of the art wearable haptic systems for the fingertip do not often provide a wireless haptic experience with 3D hand tracking capabilities, mostly requiring separate hand tracking devices [Pacchierotti et al. 2017]. A recent solution for wireless haptics involves hand tracking that is handled by a separate Oculus device, which results in a rather expensive system [Bebop 2020]. An alternative to Oculus 3D tracking is Leap Motion which tracks all fingers as they move through open space between the user and the sensor. However, this controller's hand tracking area is relatively small and its reliability detecting finger movement outside a small area, obstructed by embedded systems in gloves, is questionable. Furthermore, previous research showcased an embedded solution for hand tracking in a 3D scene by using a web-camera and a glyph placed on a wrist of a data glove [Sulema et al. 2016]. Its haptic actuators do not have scalable frequency and intensity which would result to a haptic experience of high fidelity.

In this poster, we propose a wireless embedded system on a glove, incorporating 3 infrared LEDs positioned in an equilateral triangle above the wrist tracked by an infrared filter pass camera, for hand tracking in 3D space. Pitch and roll rotation are handled by an accurate gyroscope accelerometer. 5 vibration motors of both customizable frequency and intensity are controlled by a raspberry pi providing a high fidelity haptic experience to the user.

2 IMPLEMENTATION

We propose a wireless embedded system on a glove for hand motion capture and tactile feedback in a 3D environment without the need for using a Leap Motion device. The user's hand is tracked by a infrared filter pass camera which detects three infrared LEDs attached on the 3D printed base on the glove. The Raspberry Pi zero W attached on the glove communicates via wifi with the computer and controls the vibration frequency and intensity of the vibration motors attached on the glove. This allows the user to have a wireless hand tracking experience and, haptically, interact with virtual

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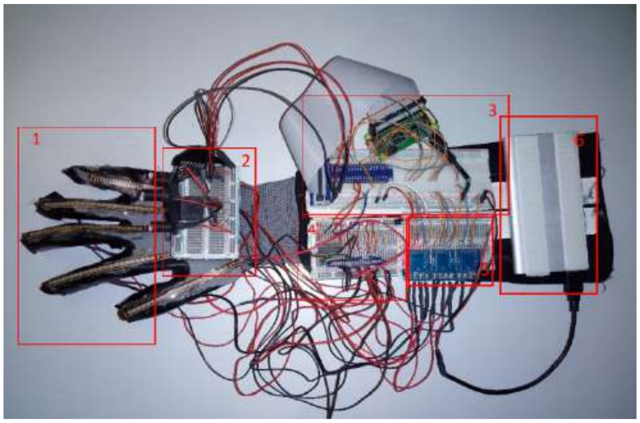

Figure 1: Glove top view with areas of interest marked red

objects in the digital world. The glove comprises of the following elements as shown in Figure 2:

(1) *Five independent points of tactile stimulation.* Five 2-3.6V 10mm shaftless vibration motor 3.4mm button type were added on the glove, on each tip of a finger to provide a sense of touch (Figure 2, red box 1). Those vibration motors are activated whenever the digital representation of the user's hand fingers collides with digital objects.

(2) *Custom vibration capabilities.* By adding driver motors directly connected to a Raspberry Pi, the vibration motors can change both the intensity and the frequency providing a more accurate sense of touch (Figure 2, red box 5). By changing the intensity of the vibrations, the user can sense heavier or lighter objects. All vibrations are independent from each other adding an extra layer of tactile realism.

(3) *Wireless communication.* Wireless systems, when compared to wired systems, provide more autonomy and freedom of movement. By adding wifi communication between the server (the Raspberry Pi zero w) and the client (the computer), wire cluttering is reduced so that the user can feel a truly immersive and realistic tactile experience.

(4) *Hand tracking capabilities.* In order to achieve hand tracking capabilities, a combination of an IR pass filtered camera, IR LEDs and an accelerometer/gyroscope were used (Figure 2, red box 2). The IR LEDs are attached on the top of the glove, tracked by the camera with an infrared pass filter. The computer, then, tracks the 3D position of the glove as well as the pitch and roll rotation based on the input from the accelerometer/gyroscope. Combined with the values gained from the flex sensors attached on each hand, these measurements can, then, be used to create an accurate representation of the hand movements as well as the finger movements.

3 EVALUATION

A 3D game was implemented in order to evaluate our wireless glove prototype. A 3D model of a hand represents the real hand of the user. The system tracks the movement of the hand reflected on the 3D model in real-time. Whenever the digital hand is colliding with another digital object (Figure 1(c)), vibrating motors activate at specific frequencies so as to give the feeling of touch. The user can form a fist which activates the hand's grab mode and the digital hand will attempt to grab nearby spherical and cubical objects. If the user opens any finger, the glove exits grab mode and drops the object. The metal ball activates the strongest vibration on all fingers, the white box activates the weakest vibration, the rainbow sphere has a wave vibration feature which increases and decreases periodically while the rainbow box activates a random vibration percentage and applies it to all motors. We investigated perceived usability of hand tracking interaction in the Unity 3D game as shown in Figure 1(a), asking users to push objects around the box. The goal was for users to freely move their hand and express their views based on the think aloud usability evaluation methodology.

Apparatus & Discussion. 5 graduate engineering students wore our glove and played the game incorporating touch-driven actions: users could interact with objects by touching them with their fingers. The user was required to grab an object and attempt to collide it with another object. Most users were able to successfully grab the objects and collide them with each other. We noted that sometimes the flexing of the fingers was not very accurate due to flex sensors having unstable readings. However, we advised users to strengthen their grip to activate the flex sensors.

4 CONCLUSION AND FUTURE WORK

We propose a wireless embedded system on a glove for hand motion capture and tactile feedback in a 3D environment without the use of a Leap Motion device. In the future, the weight and the size of the model will be reduced by using lighter wires and a printed circuit. The three infrared lights positioned on the 3D printed base which are detected from a single camera will be swapped for a singular infrared light detected by dual cameras, enhancing depth perception of the glove's position. Furthermore, we will add the capability to measure the rotation on the axis of gravity by connecting a magnetometer near the 3D printed base. Finally, a combined thermal and tactile feedback for augmented haptics as well as a spiraling-metasurface will be considered, taking inspiration from [Murakami et al. 2017], [Bilal et al. 2020].

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