Haptic Response Gloves for XR

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Abstract — anyone who has ever experienced a Virtual Reality (VR) environment has dreamed of being able to touch the virtual objects and manipulate them with his or her bare hands. Sadly, that requires much more than just a fast graphic board and an immersive visual display. For multi-finger interaction, this requires some kind of wearable force-feedback device, a so-called 'haptic glove'. The recent growth of the Virtual Reality market resulted in an intensification of development efforts in this technology. These days many teams and start-ups around the world are announcing imminent releases of commercial haptic gloves. Indeed, in the last year there has been one new product announcement almost every month. It is clear that not all new ideas will actually make it to the market, and that not all haptic gloves are addressing the same range of applications. In this paper, the main technical constraints which are faced when designing a haptic glove are addressed with a special focus of the actuation technology. Then, a review of existing devices, past and present projects, comparing their characteristics and performance is provided. Lastly, insights on future developments are sketched.

Introduction

The Haptic Glove is a wearable device that simulates tactile sensations of virtual objects!

We created a glove that provides tactile feedback of virtual objects. When activated, it provides real feedback about the tactile sensation of holding a virtual object. Feedback includes temperature, weight, the size (diameter) of the object, and visual feedback will be provided using a Matlab interface. While this is just a demo, potential applications for a haptic glove includes use in virtual reality, gaming (like playing tennis the Wii, but you actually get to feel the ball hits that sweet spot!), online shopping, and physical therapy!

I. Literature Review

This kind of technology can be an important complementary solution to vision and voice recognition as well; hence, a considerable amount of the controlling tasks could be realized. Moreover, subtle, emotional, and detailed interaction between human and human and human and machine could be realized with the aid of gestures and hand motions. More specifically, there are several important parameters required to capture the comprehensive information from hand and deliver it to the controllable objects.

1. A Pneumatic-Driven Haptic Glove with Force and Tactile Feedback - To produce force feedback, two inlet ports of a double acting pneumatic cylinder are opened and closed via solenoid DC valves through Pulse-width modulation (PWM) technique. For tactile feedback, an air bladder is actuated using a diaphragm pump via PWM operated solenoid valve. Experiments on a single finger prototype validated that the glove can provide force and tactile feedback with sufficient moving range of the finger joints. The maximum continuous force is 9 Newton and the response time is less than 400ms
2. Haptic Glove Using Tendon-Driven Soft Robotic Mechanism - a haptic interface that renders kinesthetic feedback and cutaneous feedback using a tendon-driven compliant mechanism that can render the normal contact force between the fingertip and a virtual/remote object. The interface was designed based on the human hand skeletal model, where the index finger consists of three phalangeal joints (DIP, MCP, PIP), and thumb consists of two phalangeal joints (DIP, MCP). In our system kinesthetic feedback is rendered on PIP and MCP joints of an index finger, and DIP of a thumb. Also, cutaneous feedback is imparted on distal phalanx of both index finger and thumb. Both kinesthetic and cutaneous feedback are imparted, and extend the finger by applying the force on finger joints and a fingertip.
3. Exo-tendon motion capture glove device with haptic grip response (Patent. US10137362B2) - A glove portion to be worn on top of a user's hand, the glove having finger portions for the fingers and thumb of the user; a plurality of anchoring finger caps circumscribed around the extremities of the finger portions; a plurality of anchor points configured to generate sensor data identifying a flexion/extension and an abduction/adduction of the finger portions; a plurality of tendon-like cables configured to transmit the flexion/extension and the abduction/adduction data to a plurality of measuring devices for processing; a plurality of return force providers to ensure flexion and tension in the tendon-like cable elements; and a housing structure residing on the forearm and

connected to the glove portion via the plurality of tendon-like cables.

II. METHODOLOGY

For the ease of understanding we have divided the device into two parts; hardware and software. Let's see it in more details:

1. Software Design

There are several software technologies deployed in this project out of which most of them are open source. **Unity** is the base software in which the mobile application for android phone is developed. Unity uses **ARFoundation** as a base for all its AR/VR projects, it provides support from application to the mobile functionality. **MediaPipe** is used for supporting the AR platform on various devices. The main haptic pattern generator software used is the **InterHaptics,** haptics feedback software deployable on different devices.

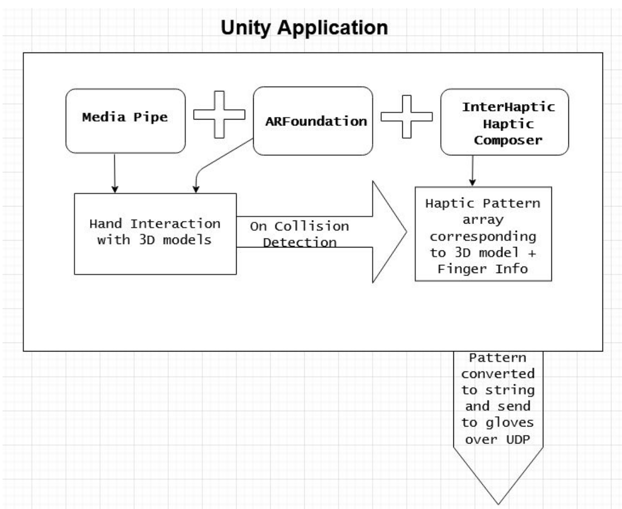

Figure 1. Software Block Diagram

You can clearly understand from the figure 1. That how different software components contribute and the final output is a string which is sent to the gloves.

Figure 2. Hand detected with 21 Point skeleton

1. Hardware Design

NodeMCU which employs the Esp8266p IC is a low cost open source system on chip internet of things (IOT) micro-controller development board. It have 30 pins and work on 5 to 12 volts. Esp8266p works on 3.3V which is provided by on board AM1117 regulator. The MCU controls the 6 **LRAs** that is linear resonant actuators. These work on 2.5-6 Volts at 175-235 Hz. A coil produces magnetic field which moves the mass against the spring and with movement of mass to and fro on Y-axis vibrations are produced which is our haptic feedback. The intensity and time can be controlled to generate different patterns. A **BC337** transistor and a diode is used with each LRA, so that we can manage the voltage change between LRA and MCU as well as provide external power supply to the switching circuitry. An **In4007** Diode as a freewheeling diode is connected across an inductor (LRAs) used to remove flyback, which is the sudden volt spike observed across an inductive load when its supply current is suddenly changed.

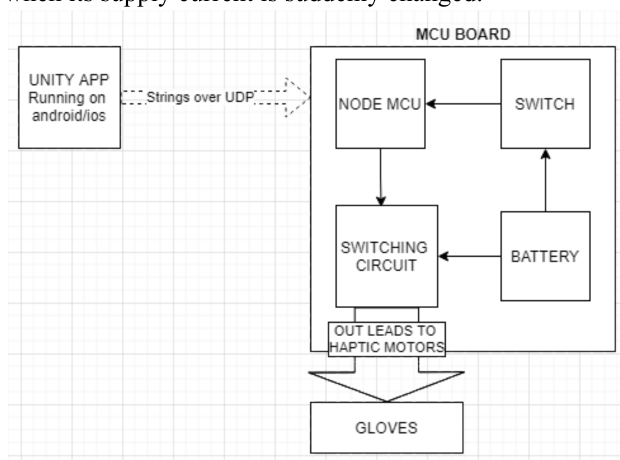

Figure 3. Hardware Block Diagram

The above figure 3 shows the block diagram of the hardware system. A switch is used to ON-OFF the system, when the system is powered on the NodeMCU receives 9V from the battery and the inbuilt regulator keeps it down to 3.3V. The NodeMCU powers up and starts searching for the WIFI device to connect. Once the device is connected you can start interacting with the XR world with a mobile device and glove on the other hand. The mobile device sends strings over UDP. These strings are read and sampled in a range that can be read and mapped for the process ahead. Then the control signal is sent to each LRAs switch and from that the LRA actuates and gives haptic feedback to the person wearing the glove. This feedback has different patterns with respect to the different objects with which the person interacts.

1. System Working

Figure 4. Complete Hardware Setup

The above figure 4 shows the complete hardware setup. The prototype glove has 6 LRA actuators. As you can see the NodeMCU is powered with the 9V battery. For demonstration purposes it is also connected to a laptop with the I^2C USB cable.

The setup is quite simple, the LRAs are placed on key points on the hand. These points are near the tip of the thumb, index, middle, ring, pinky finger and one in the groove of the palm. When the person interacts with objects in the AR world wearing this glove, the person will feel the haptic feedback when the respective finger interacts with the object. The haptic feedback may vary from finger to finger or will be the same for all the key touch points. The current consumption of all the LRAs is less than 400mA maximum. The battery can power the system independently for 30 minutes which is what we have tested, this can be easily scaled upwards to 120 minutes.

III. Results and Discussions

1. The amplitude Control Range of the LRA actuators is from 0-1023.
2. Accuracy of 21 point hand tracking in MediaPipe is an average precision of 95.7% in palm detection.
3. The gloves give haptic feedback with a 1 milli second delay between each amplitude value.

Usability

Due to constraints of the glove (tight-fitting, stiff), we had to choose a glove that could only fit the hand of one of the group members. We chose Suheb as the model, and since he has bigger hands, Narode and others who have small hands will not be able to use this glove, at least not to its full abilities.

IV. Limitations

Current technology suffers from a number of limitations, which go beyond the higher price of haptic interfaces. These technical drawbacks include the limited workspace of desktop interfaces, the lack of force feedback to the body, safety concerns, etc.

V. Future Scope

We rely on touch — or “haptic” — information continuously, in ways we don’t even consciously recognize. Nerves in our skin, joints, muscles and organs tell us how our bodies are positioned, how tightly we’re holding something, what the weather is like, or that a loved one is showing affection through a hug. Around the world, engineers are now working to recreate realistic touch sensations, for video games and more. Engaging touch in human-computer interactions would enhance robotic control, physical rehabilitation, education, navigation, communication and even online shopping.

“In the past, haptic has been good at making things noticeable, with vibration in your phone or the rumble packs in gaming controllers,” says Heather Culbertson, a computer scientist at the University of Southern California. “But now there’s been a shift toward making things that feel more natural, that more mimic the feel of natural materials and natural interactions.”

The future is not just bright, but textured.

VI. Conclusion

This project worked mostly according to our expectations. If we were to do this project again, we would have put more thought into planning out the design of the glove, what kind of glove we need, and where to mount the parts for optimal performance. We would also have been more careful in the design of the project and done more research about our components before we decided to implement them. We would also put more consideration into how to implement the force feedback, which turned out to be a lot more difficult than we had expected. Ideally, if we were to do this again, we would also find ways to make the glove with plug and play to allow easiness of device use.

Acknowledgment

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