Haptic Feedback Glove

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CONCEPT OF OPERATIONS

REVISION – 1
19 September 2020

CONCEPT OF OPERATIONS
FOR
Haptic Feedback Glove

TEAM 64

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Change Record

Rev.	Date	Originator	Approvals	Description
-	9/6/2020	Nicholas Minton	BT IG NM	Initial ConOps
1	9/19/2020	Nicholas Minton		Revision based on feedback

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1. Executive Summary

Recent advancements in virtual reality are tightening the gap between virtual and physical perception. One area with the potential to strengthen this connection is haptic feedback technology. To capitalize on the improvements of graphics, there is a need for more immersive ways to interact with the virtual environment. Haptic feedback technology aims to mimic forces felt when interacting with physical objects. The goal of this project is to give the hand realistic feedback by allowing for greater depth while interacting with the virtual space.

2. Introduction

2.1. Background

The origins of haptic feedback are rooted in the goal of allowing remote operation and handling of objects. This is accomplished by using the sense of touch as a way to transmit information. This is also known as kinesthetic feedback. Remote operation had an early application in the handling of radioactive materials while keeping humans at a safe distance during the aftermath of WWII [1]. Kinesthetic feedback is most commonly found in controllers. One example is a vibration in a video game controller indicating a player has crashed into a wall in a driving game. A more practical example is the joystick of aircraft controls vibrating to inform the pilot his engine is about to stall [2].

Currently, haptic feedback for virtual reality is still in its infancy. While some great advancements have been made, most devices are either bulky and unwieldy, or only apply feedback on only a few joints, which heavily reduces effectiveness. For instance, current industry leaders in haptic technology use hydraulic force to provide tactile and force feedback. While the feedback provided is immersive, the hydraulic pads only cover a small part of the hand, and to provide feedback to the entire hand would make the glove heavier and bulkier. So, the goal of this project is to solve these two problems: to reduce size and weight of the glove, as well as maximizing the amount of feedback the hand receives.

Aside from being bulky, many modern solutions require complex mechanical systems that drive up the price of the overall glove. The solution proposed will have a much lower overhead cost, allowing for more attractive prices for industries and consumers. This will lead the way to further development of VR technologies as increased accessibility will provide more exposure to haptic feedback solutions.

2.2. Overview

This project is a continuation of a previous project focusing on the design of a haptic glove. The project aims to provide research in flexibility, precision, and feedback while completing the proof of concept started by last year’s senior design team. There are three fundamental goal areas for this project:

1. Maintain dexterity of hand
2. Track the 6 degrees of freedom in the hand

3. Generate a resistive force feedback to each finger

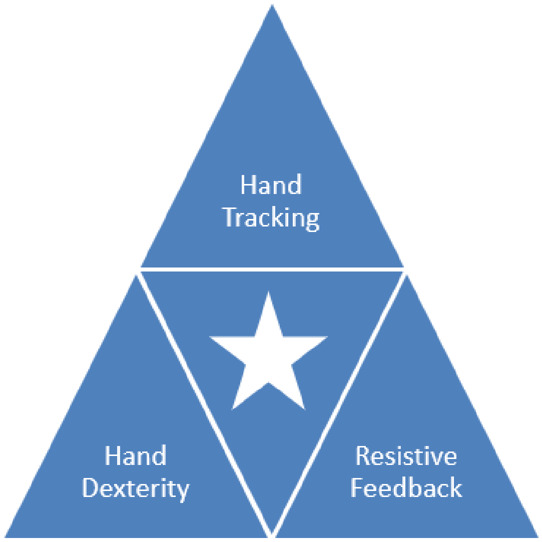

Figure 1: Triangle of Optimal Results

The kinesthetic reaction subsystem in the previous design is inspired by research performed at the Advanced Interactive Technologies Lab at ETH Zurich [3]. Though only a proof of concept, their design boasts a light, form-fitting solution to the force feedback problem using electrostatic brake technology.

Our project and haptic glove solution will focus on reusing and building on the subsystems created by our predecessors. This will allow us the best chance to have a usable product by the end of the year. As detailed below, our work will focus on improving glove structure, sensor placement, electrostatic brake design, and the user interface.

2.3. Referenced Documents and Standards

[1] R. J. Stone, “Haptic feedback: A Potted History, from Telepresence to Virtual Reality,” in Workshop on Haptic Human-Computer Interaction,ser. LNCS, S. Brewster and R. Murray-Smith, Eds., vol. 2058. Glas-gow, UK: Springer-Verlag Berlin Heidelberg, 2000, pp. 1–7

[2] *HAPTICS TECH*, 5 Dec. 2016, hapticstech.wordpress.com/.

[3] R. Hinchet et al. “DextrES: Wearable Haptic Feedback for Grasping in VR via a Thin Form-Factor Electrostatic Brake”. In: UIST 2018. 2018.

3. Operating Concept

3.1. Scope

The deliverables of this project shall follow the original requirements of the project set by the previous team, which are as follows,

- A glove that accurately and precisely tracks finger and wrist movement.
- To design a modular feedback system that is capable of applying a moderate amount of force to 10 individual joints of the fingers.
- A microcontroller unit to process glove sensor data and transmit to a host computer.
- A microcontroller unit to process virtual interaction data received from a host computer and independently control 10 force feedback outputs.
- A power supply capable of independently and dynamically supplying sufficient voltage to all 10 feedback modules based on a control input.

- A 3D environment that visualizes hand tracking data, calculates feedback forces, and transmits information about interactions in the virtual environment to the microcontroller unit.

3.2. Operational Description and Constraints

The goal of this project is to be used alongside modern virtual reality programs to allow the user to interact with the virtual environment in an immersive way that feels natural to use. The user will use our haptic glove design, with its sensors and electrostatic brakes, to simulate the sense of touch in the virtual environment, by simulating the passive, reactive force of a real world object when touching a virtual object, allowing the user to use their sense of touch to navigate around the virtual environment. Our glove will work similarly to other virtual input devices used today, however our glove will send information of virtual interaction to the microcontroller, which will then process the information and supply the voltage needed for that interaction from the power supply to each haptic module.

The constraints of this system include:

- Budget for Tracking Accuracy:

  Though there are more accurate position trackers available to track something like the tip of each finger, our budget prevents us from going that route. An alternative which fits in this constraint is a single 3D position tracker placed on the wrist paired with sensors to find relative locations of fingers.

- Cables:

  Due to the amount of electrostatic brakes needed and precision of voltage needed to allow for precision feedback, cables connecting to each module will be needed to supply the needed voltages. This is a constraint because the need to give force feedback contradicts the goal of retaining user dexterity and virtual reality immersion.

3.3. System Description

MCU and Hand Tracking Assembly:

The movement of the fingers, hand, and wrist will be tracked by strategically placed flex sensors. This data will be sent to the MCU where it will be processed. The necessary voltage requirements to be applied by the Power Supply Assembly will be determined by the MCU based on the user's hand position relative to a virtual object in the User Interface. This data will be sent by the MCU to the Power Supply Assembly to communicate the necessary voltages to be applied to the electrostatic brakes in order to achieve a desired force feedback.

Power Supply and Distribution Assembly:

This subsystem will interface with a standard 120 VAC RMS wall outlet. The AC supply will be multiplied and rectified into a DC voltage within the required operating level for each module (0-1300 VDC). The MCU and Hand Tracking Assemblies will communicate how much voltage for the required force and when that voltage must be applied.

Graphical User Interface:

The User Interface consists primarily of the virtual environment that the user will be interacting with. This environment will include a virtual model of the user's hand that will replicate the positioning of the user's physical hand based on information received from the Glove Assembly. By providing the user with visual feedback the effectiveness of the haptics implemented in the glove will be reinforced, thus improving the user experience. The virtual environment will also include any virtual models that the user will be interacting with. The User Interface will use its tracking and models with the MCU Assembly to determine when a user should experience haptic feedback and the level of feedback necessary.

Glove Assembly:

The glove assembly is critical for achieving the desired outcome of a functional and usable system. One limitation of the existing, partially completed glove, is a structure not sturdy enough to withstand the force between the electrostatic brakes and the fingers. The glove will provide a structure to withstand the force over repeated use. The glove will impose minimal restrictions on the user's motion. The glove will hold pairs of conducting metal strips attached at each force point of the fingers and near the wrist for the electrostatic brakes. These metallic strips will be separated by a dielectric insulator. When the hand in the virtual environment interacts with an object a voltage will be applied across the strips to provide a stopping force calculated by the microcontroller. At a high level, this design is a primarily mechanical component. However, integration with the hand tracking sensors, electrostatic brakes, and its proximity to the end user makes it one of the most complex problems.

3.4. Modes of Operations

- Tracking without Interaction

  The Haptic feedback glove will function as a controller for the virtual environment. Position of the hand and fingers will be mirrored and displayed in the virtual space without applying any force feedback.

- Tracking with Hard Interaction

  The hard interaction mode will provide maximum force feedback through the haptic glove based on interactions in the virtual environment. This will occur with hand tracking and the stopping force will only be applied to the joints indicated by the MCU as currently interacting with a hard object.

- Tracking with Soft Interaction

  Soft haptic feedback will provide a suggestive force to the given joint. This intends to simulate a soft object which would not fully stop the finger. This will occur with hand tracking and the resistive force will only be applied to the joints indicated by the MCU as currently interacting with a soft object.

- Standby

  In standby, the system will not receive or transmit information. It is only waiting for the user to change to an operational mode.

3.5. Users

Our haptic glove is targeted to be used in TAMU's virtual reality lab. The resulting product of our project will demonstrate haptic feedback to users of any experience level in virtual reality. While we plan to only make one glove, the design will be replicable for use in other labs or applications.

3.6. Support

Each glove will be accompanied by a manual which describes how to set up the device and enumerates common problems with their solutions. While the user is in the virtual space, we hope the user will require little to no instructions as we aim to mimic real life interactions.

4. Scenarios

4.1. Space Exploration

Potential use for the space industry in training and sustaining operations. Virtual environments can allow for increased training exercises, since the user can better experience a space-like environment. With our haptic glove, these exercises will increase the user's spatial awareness of the objects around them. There are existing sites such as the Sonny Carter Training facility that simulate many situations in zero gravity. Sites such as Sonny Carter require a large investment of capital and are restrained in areas that they may be built. With further development of VR technologies like the Haptic Glove, the space industry is closer to having the ability to simulate space-like situations at a much lower cost and in many locations.

4.2. Medical

Giving doctors a virtual space to interact with patients has potential to benefit both parties. The use of a realistic, virtual space for training could give medical students experience before they even work with a real patient for the first time.

Recent improvements in speed and reductions to latency (e.g. 5G networks) have made performing surgeries in real time from a remote location a possibility. Accurate physical feedback given to a surgeon's hands paired with the improvements in network speed could make this possibility a reality. Other medical applications could be in supplying virtual environments for physical therapy or immersive sensory environments for the blind.

4.3. Design

Computational models and software are popularly used in design processes because of their ability to accurately simulate physical properties. Often the user interfaces paired with these models are not intuitive to use. They also lack in giving users a hands-on experience.

Pairing current design software with virtual reality and haptic feedback to the hands could give realistic hands on design experience to users. Bridging the gap between difficult design interfaces and computer simulations would also allow users to focus on learning in their subject rather than wasting time learning how to operate software. This technology would also eliminate time spent acquiring physical parts for design and eliminate the cost associated with new designs.

5. Analysis

5.1. Summary of Proposed Improvements

- The glove will utilize a low-footprint exoskeleton that will provide support for the electrostatic braking plates.

- The movement sensors will be placed in specific locations on the exoskeleton to allow for precise tracking of the hand and finger locations.

- The electrostatic plates will be thin and flexible allowing for a more immersive experience for the user.
- The design, particularly the shape and size, of the electrostatic plates will allow for forces of up to 15.5 N to be emulated.
- End caps will be placed on the tip of each finger and mounted on the exoskeleton to provide more strategic leverage for the electrostatic plates.

5.2. Disadvantages and Limitations

The electrostatic braking concept requires that the haptic feedback glove provides voltages of up to 1200 V. This places several restrictions upon the implementation of the design, particularly in the power supply system. To produce an adequate voltage the glove must draw power from a standard outlet and then the AC voltage must be stepped up to the required level via a separate voltage multiplier circuit. The braking systems will also need to operate at very low currents in order to remain safe to the user at high voltages. The need to use standard AC wall power also limits the user's mobility as the gloves will be tethered to the power supply and will only be able to travel as far as the power cable permits. The voltage multiplier circuit needed to provide the high voltages necessary will consume a lot of space and weight on the glove due to the large capacitance requirement.

5.3. Alternatives

The most common alternative to our haptic feedback design is a hydraulically powered glove. While hydraulics allows for greater force to be achieved, it is heavier and bulkier than the electrostatic brake concept. Other competitors in haptic feedback gloves provide vibration or an array of several small touch points. These are better at providing the sense of touch across your skin. However, when used alone, they do not provide much resistance to the movement on fingers, so they are less effective at providing the sensation of gripping or supplying stopping force.

Another alternative would be to utilize a motor-pulley system. This would involve having wires connected to the exoskeleton of the glove at the fingertips and joints. The other end of the wires would be connected to small motors that would wind or unwind the wire to simulate the desired force. The motors would need to be mounted on the glove around the wrist and the wires would extend to their contact points.