VR Force Feedback Gloves Restricting Side to Side Finger Movement Proposal

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1. Introduction

1.1. Problem

Force Feedback gloves may be an important part of the future of VR given the increased sense of immersion they can provide. However, current commercial force feedback VR gloves like HaptiX [3] or Sense Glove [4] are too expensive for regular consumers and are only targeted towards industry and research. On the other hand, open source force feedback VR gloves like Lucid Gloves [5] are economically accessible to regular consumers as long as they're willing to spend the effort and time learning and putting them together. However, they are bulky and don't restrict the finger's side to side movement. The latter would be desired for a greater sense of immersion when for example grabbing an object between the sides of your fingers, or when the friction of an object you're grabbing should prevent you from sliding your fingers.

1.2. Solution

We propose a new design for force feedback VR gloves that are still economically accessible to the regular consumer and that restrict the finger's side to side movement as well as back and forward movement. The result would be that if a user tried to grab an object in VR with the sides of their fingers, this movement would be reflected in VR, and the movement of the fingers would be restricted when they collide with the object in VR. The same would be the case for trying to grab an object with the fingers' back and forwards movement.

Our design would use two actuators and potentiometers on each finger. One pair of actuator and potentiometer to sense and restrict side to side movement and the other pair for back and forwards movement. It would also have a Dead Man switch to stop the gloves from restricting movement in case of an emergency. The actuators, potentiometers, and Dead Man switch would be connected to a microcontroller(STM32). To share the finger's position and know when to restrict each finger's movement, the microcontroller would communicate over USB with a computer running the VR application. The power for the glove would also be provided by the USB.

1.3. Visual Aid

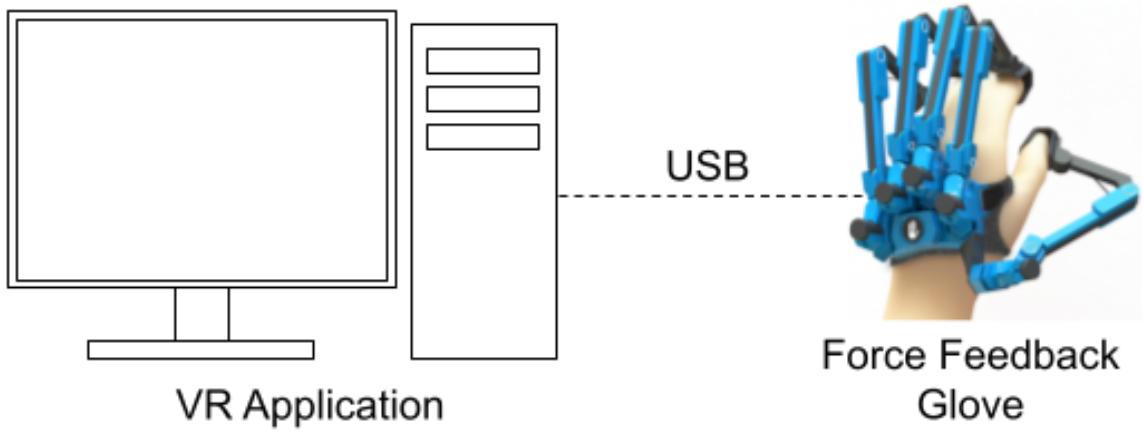

Figure 1. Depicts how the user will interact with the product

1.4. High-Level Requirements

The gloves are able to:

- Accurately track and recreate each finger tip's position within 5% error
- Restrict the finger's side to side movement with 0.22-0.45 Nm of torque and back and forwards movement with 0.7-1.4 Nm of torque
- Restrict the finger's movement when they are in contact with a VR object such that the finger's restriction point is within 5% error of the object's boundary

2. Design

2.1. Block Diagram

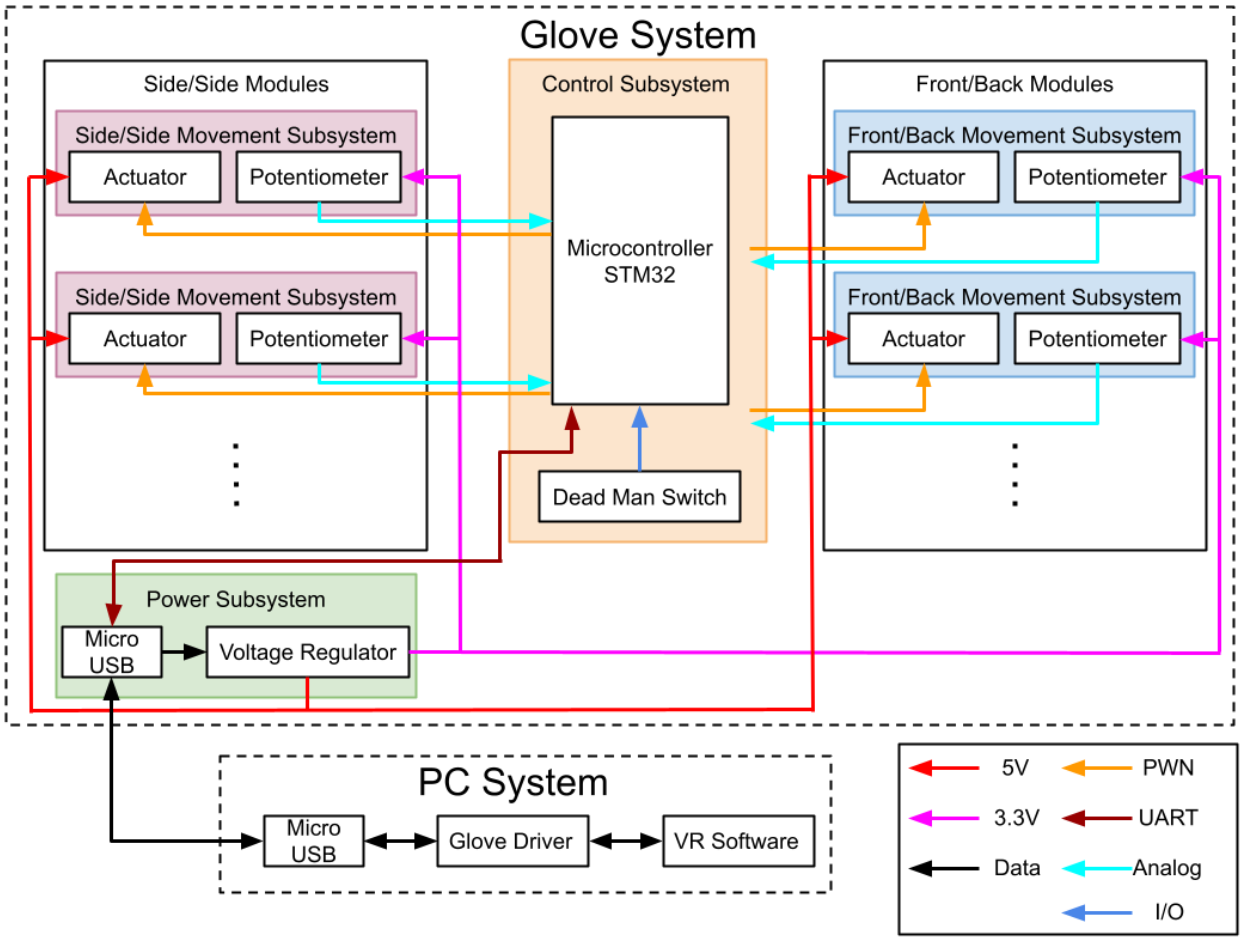

Figure 2. Show all the different subsystems and how they interact with each other

2.2. Subsystems Overview/Requirements

2.2.1. Control Subsystem

The purpose of this subsystem is to control the movement of the actuators, read sensor values, and communicate with the computer running the VR application. A microcontroller will handle all of this data processing.

Microcontroller

The microcontroller reads the potentiometer values, controls the actuators, and reads the dead man's switch. It also communicated with the computer with UART over a micro USB cable.

- *Requirement 1: Must be able to communicate with the computer over UART at a rate of at least 8 Kb/sec*
- *Requirement 2: Must sample each potentiometer at least 30 times per second*
- *Requirement 3: Must sample the dead man's switch at least 2 times per second*
- *Requirement 4: Must be able to adjust the pwm signal at least 5 times per second*
- *Requirement 5: ADCs must have 12-bit precision*

2.2.2. Power Subsystem

The purpose of this subsystem is to regulate the voltage received from the micro USB to the necessary levels.

Voltage Regulator

The voltage regulator will receive a 5V signal from the micro USB and will need to regulate it to the necessary voltages.

- *Requirement 1: Must be able to output 3.3V +/-1% from a 5V source*
- *Requirement 2: Must be able to output 5V +/-1% from a 5V source*

2.2.3. Side/Side Subsystem

The purpose of this subsystem is to send the angle of the finger to the microcontroller and receive the actuator control signal from the microcontroller.

Actuator

The actuator receives a PWM control signal from the microcontroller.

- *Requirement 1: Must have a step size of at most 1 degree*
- *Requirement 2: Must have a stall torque in between 0.2 and 0.45 Nm*

Potentiometer

A potentiometer will be located near each knuckle and will measure the angle of each finger. It will send its value to an analog port on the microcontroller.

- *Requirement 1: Must measure the finger's angle within +/- 0.5 degrees*

2.2.4. Front/Back Subsystem

The purpose of this subsystem is to send the position of the fingertip to the microcontroller and receive the actuator control signal from the microcontroller.

Actuator

The actuator receives a PWM control signal from the microcontroller.

- *Requirement 1: Must have a step size of at most 1 degree*
- *Requirement 2: Must have a stall torque in between 0.7 and 1.4 Nm*

Potentiometer

A potentiometer will measure the finger's flexion and extension. It will send its value to an analog port on the microcontroller.

- *Requirement 1: Must measure the fingertip's position within 5% error*

2.3. Tolerance Analysis

Since these are force feedback gloves they will have to be able to resist a comfortable amount of torque from the fingers. If the actuators are unable to resist the torque from the fingers then when attempting to grab a virtual object your fingers will go through the object and you'll lose your sense of immersion. However, we don't want to pull with too much torque on the fingers as this could hurt the user. Therefore to guarantee this operation we must find the normal torque a finger can apply and also the maximum torque a finger can apply.

After testing our finger strength we have found that our fingers can comfortably produce 0.2 Nm of torque with side to side movements and 0.7 Nm of torque with back to front movements. When exerting our fingers more we can produce 0.45 Nm of torque with side to side movements and 1.4 Nm of torque with back to front movements.

Therefore we'll need actuators that can produce a torque in between 0.2 and 0.45 Nm for the side to side movements and between 0.7 and 1.4 Nm for the back to front movements.

3. Ethics and Safety

Our project in all aspects will adhere to the IEEE and ACM Code of Ethics in the following ways:

ACM CoE 1.1 [1] states that products should be broadly accessible. Our design is built on the idea that technology should be accessible to all consumers at a cheap cost and for all interested individuals to take their ideas and build upon ours for the advancement of our society. To follow through with these ideas we'll make the project open source and choose components that fulfill our requirements but aren't unnecessarily expensive.

In addition to our project's accessibility, we also wanted to emphasize that the VR glove's design prioritizes the safety of its users and its features make sure the device doesn't inflict damage to the user's hand. This follows ACM CoE 2.9 [1] which clearly mentions that we should make sure our design works as it's supposed to and that our safety features are intuitive. To accomplish this we will test our design,

especially the actuators to make sure they can't hurt the user, and we'll design the dead man's switch to be easily accessible in case of an emergency.

Lastly, following IEEE CoE I.5, as engineers, not only is it our responsibility to advance technology and safety implementations but also to have the ability to acknowledge our shortcomings of technical work and to honestly correct these in a professional manner. Our group will focus on creating the best product that is needed for the public, and when we're done implementing our design we will evaluate our design and communicate its strengths and weaknesses.

All of our members in this group are well-versed in these claims and will strive to make this product following these ethical guidelines.

4. References

[1] "The code affirms an obligation of computing professionals to use their skills for the benefit of society.," *Code of Ethics*. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 15-Sep-2022].

[2] "IEEE code of Ethics," *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 15-Sep-2022].

[3] "Haptic gloves for virtual reality and robotics | HaptX" HaptX https://haptx.com/. [Accessed: 15-Sep-2022].

[4] "VR & Haptic Technology Gloves | SenseGlove | Feel the virtual like it's real" SenseGlove https://www.senseglove.com/. [Accessed: 15-Sep-2022].

[5] "Arduino/ESP32 based DIY VR Haptic gloves. Compatible with SteamVR via OpenGloves" Lucid Gloves https://github.com/LucidVR/lucidgloves. [Accessed: 15-Sep-2022].