Haptic Feedback Glove

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INTERFACE CONTROL DOCUMENT

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Interface Control Document
for
Haptic Feedback Glove

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1. Overview

The following ICD will detail the methods used by each subsystem of the Haptic Feedback Glove and how they meet the criteria provided in the FSR. To ensure that each subsystem will operate properly when applied to the Haptic Feedback Glove detailed descriptions of the physical, electrical, and communication interfaces will be presented. These sections will break apart each subsystem to provide a detailed overview of what is to be accomplished.

2. References and Definitions

2.1. References

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[3] U. Nanda and S. K. Pattnaik. "Universal Asynchronous Receiver and Transmitter (UART)". In: 2016 *3rd International Conference on Advanced Computing and Communication Systems (ICACCS)*. Vol. 01. 2016, pp. 1–5.

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[6] *MPU-6000 and MPU-6050 Register Map and Descriptions Revision 4.0.* InvenSense. 2012.

[7] *Unity Documentation*. https://docs.unity3d.com/Manual/index.html, last accessed on 09/20/20.

2.2. Definitions

MCU	Microcontroller Unit
UI	User Interface
GUI	Graphical User Interface
IMU	Inertial Measurement Unit
ICD	Interface Control Document
MCP	Metacarpophalangeal
DIP	Distal Interphalangeal
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver Transmitter
VR	Virtual Reality
mA	Milliamp
μA	Microamp
mW	Milliwatt
V	Volts
N	Newton
ft	Feet
cm	Centimeter
lbs	Pounds
μm	Micrometer
Hz	Hertz

3. Physical Interface

3.1. Weight

3.1.1. Glove Assembly

For purposes of the physical interface control, the glove assembly system includes the electrostatic brakes, flex sensors, and exoskeleton. The total mass of the glove assembly will be no more than 140 g. The breakdown is seen as follows.

3.1.2. Exoskeleton

The exoskeleton will weigh no more than 80 g. The exoskeleton will be 3D printed and attached at multiple points of the hand and fingers. Each finger will have two mounting locations: one at the tip of the finger and the second at the base of the finger.

3.1.3. Hand Tracking Sensors

The hand tracking system is composed of 19 flex sensors and 1 IMU. The combined weight of all the sensors, wires shall not exceed 28 g (24 g for sensors and wires, 4 g for IMU).

3.1.4. Electrostatic Brakes

The electrostatic braking system will be composed of 30 stainless steel electrode strips. There will be two brakes per finger. Each brake Each brake consists of three stainless steel strips. The total mass of these steel electrodes will be no more than 50 g. The calculation is as follows:

$$Area_{sheet} = 127\ cm * 15.24\ cm$$
$$Weight_{sheet} = 226.796\ g$$
$$Area_{strips} = 10 * (18\ cm * 1\ cm) + 20 * (9\ cm * 1\ cm) = 360\ cm^2$$
$$Weight_{strips} = \frac{360\ cm^2 * 226.796\ g}{1935.48\ cm^2} = 42.2\ g$$

An extra 21 g will account for mass of the dielectric film.

3.1.5. Power Supply

The power supply will be an off-glove solution, sending the output voltages to the electrostatic brakes via insulated cabling. It will be created out of very small passive components as well as transistors, therefore the weight of the power supply will be no more than 1.5 kg, excluding cabling.

3.1.6. Hand Tracking MCU

The hand tracking system will connect to an MCU and PCB; although it will not be placed on the glove, the weight of the MCU is 29 g and the weight of the PCB is 41 g.

3.2. Dimensions

3.2.1. Dimension of Glove Assembly

The base glove to be used will measure approximately 22 x 15 cm. The dimensions of the stainless-steel electrodes will be 18 x 1 x 0.0127 cm for the middle plate and 9 x 1 x 0.0127 cm for the 2 outer plates. The dielectric that will be placed on the outside plates will cover the entire length of both sides of each electrode and will be 25.4 µm thick. Each flex sensor measures 5 x 0.8 x 0.22 cm. The IMU measures 2.38 x 2.38 x 0.1 cm.

3.2.2. Dimension of Power Supply

The power supply circuitry will be placed in a 3D printed enclosure that measures 30 x 20 x 10 cm.

3.2.3. Dimension of Sensor MCU

The MCU and peripheral PCB for the Glove Assembly sensors will measure 9.5 x 5.7 x 2.54 cm and 8.2 x 5.7 x 1.31 cm respectively.

3.3. Mounting Locations

3.3.1. Electrostatic Brakes

The electrostatic brakes shall be mounted at two locations on each finger. The base of each brake will be secured at the wrist. One brake will be fixed on the tip of each finger by a thimble and the second brake will be secured by a mount on the base of the finger. The mount at the base of the finger will hold in

4. Thermal Interface

The Power Supply will be the only source of measurable heat emission. Since the power supply will operate at no more than 3W, the system shall provide no more than 5°C of heat. A fan may be included in the power supply housing to ensure cooling through the device and maintain little temperature deviation.

5. Electrical Interface

5.1. Primary Input Power

All power to be used by the haptic feedback glove will be supplied by a standard Type B electrical outlet providing single-phase 120 V RMS at 60 Hz. This input will be used for peripheral hardware and to supply power to the voltage control and multiplier circuits, which will convert the AC voltage into a high DC voltage. The DC voltage will be used in the electrostatic braking system to generate the simulated forces.

5.2. Signal Interfaces

5.2.1. Analog Flex Sensors

The analog flex sensors will communicate to the MCU by outputting a specific voltage range for each sensor. This voltage range – between 0 V and 5 V – will be linearized and mapped by the MCU to accurately determine the degree of movement of each finger. This information will then be sent out to other subsystems.

5.2.2. Power System MCU

The output signal from the user interface as well as the finger tracking will be sent to the power controller MCU. This data is then parsed into the 10 separate control signals required to individually operate control points across the glove. Each of these signals will translate directly to the duty cycle of the switching transistor, which in turn changes the duty cycle of the output transistor. This will allow the output voltage to be easily controlled and variable, of which shall be applied as variable force feedback across the glove. The formula to calculate the output voltage is the voltage across the high voltage line multiplied by the duty cycle.

$$Vo = Vhv * D$$

5.2.3. Digital IMU Sensor

The digital IMU sensor will communicate to the MCU by the I2C protocol. The sensor will send data from the gyroscope and accelerometer to the MCU. The MCU will interpret and linearize this data and transmit to the host device.

5.2.4. Host Computer

The host computer will connect to the hand tracking MCU and the power controller MCU via a USB cable to transmit and receive information on both ends.

5.3. User Control Interface

5.3.1. Physical Interaction

The physical portion of the user control interface shall be simply wearing and using the glove. By using natural hand movements to adjust an array of variable resistors, the user is effectively controlling the Virtual Environment on the host device. There will be no physical interfacing elements on the glove itself.

5.3.2. Digital Interaction

The digital portion of the user control interface shall be the Virtual Environment on the host device that allows for calibration and setup of the device. This will be performed using simple mouse and keyboard commands. The user will be informed when the glove is active and tracking. Once the glove is active and tracking, the glove itself will become the interfacing element allowing interaction with the digital component of the device. There will be three types of interaction surfaces in the virtual environment: none, soft, and rigid. These three correspond to different feedback percentages, namely 0, 50%, and 100%, respectively.

6. Communications / Device Interface Protocols

6.1. Host Device

The host device will communicate with both the hand tracking and the power controller MCUs on the Haptic Feedback Glove using Universal Asynchronous Receiver-Transmitter (UART) protocol via USB 3.0. This will also provide 5V to the MCUs. Both the hand tracking MCU and the host device will transmit data as soon as it is available. This means that it falls on the receiver to manage their input stream effectively. The receiving device may need to flush the input buffer every time that it reads data so as to have the most recent data available to it. The hand tracking MCU will transmit with a baud rate of 115,200, while the host computer will transmit interaction data to the power controller with a baud rate of 9,600.

6.2. Device Peripheral Interface

The connection between the MCUs and computer will be handled through a serial port using UART. Analog and digital pins on the MCUs will be used to communicate with sensors and power switching circuits. Commands will be sent from the Host Device to the MCU to place the electrostatic brakes in the required mode of operation.

6.3. MCU Communication Protocol

6.3.1. Hand Tracking MCU Communication Protocol

The data being sent from the hand tracking MCU to the host computer will be sent as lines of data each containing 21 comma-separated floating-point numbers. These floating-point values will describe the rotation data being measured by the glove sensors. The first three data points in the communication stream will be reserved for the roll, pitch and yaw values of the hand as measured by the IMU. Data from the flex sensors will be placed in the remaining 19 floating-point numbers, with 4 data points reserved for each individual finger. The four data points will contain the joint rotation data at different angles. In the data stream the values for the fingers will be ordered: Index, Middle, Thumb, Ring, Small. For each finger, the order of data will move from the base of the finger towards the tip, meaning that for a normal finger the data will be in the following order:

ProximalX, ProximalY, MiddleY, DistalY

The data received from the thumb will be ordered in a different manner:

ProximalX, ProximalY, ProximalZ, DistalY

6.3.2. Power Supply MCU Communication Protocol

Data to be sent from the host device to the power supply MCU will be sent as lines of 10 comma-separated values. These values will contain the percent of force required to be applied by each electrostatic braking plate. The data will be sorted by finger in the following order: Thumb, Index, Middle, Ring and Small with two values for each finger. Force data will be divided into two joints based on how the electrostatic brake plates are connected. Each finger will have a data value for the Proximal and the maximum value of the Middle and Distal joints.