Carnegie Mellon University

Embedded Systems Design

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TeleTouch

Cristian Vallejo, Chelsea Kwong, Elizabeth Yan, Rohan Jadvani

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1 Project Description

Haptic technology recreates the sense of touch by applying, forces, vibrations, or motions to the user. Users are able to interact with the environment through remote applications, but these actions don't feel real without the sense of touch. TeleTouch is a remote communication device that mimics the touch on a model hand to the glove on a user's hand.

Using sensor laden gloves, we hope to capture the feel of what it is to hold a hand and effectively relay that feeling to a second party. Precisely, our project consists of two physical parts. There is a model hand that the user can touch any area of, and a haptic-feedback glove, that reflects the touch that was performed on the model hand. This product is supposed to be used between two users, who each owns a set of model hand and glove, such that they can communicate with the essence of touching hands, wirelessly across any distance.

Our goal in doing so is to not only allow the sense of touch to transcend the need for physical interaction but also to explore the most effective and believable methods of providing tactile feedback. Our project aims to deliver the most real feeling interaction with a non-human such that you feel as if some one may actually be holding your hand.

2 Design Requirements

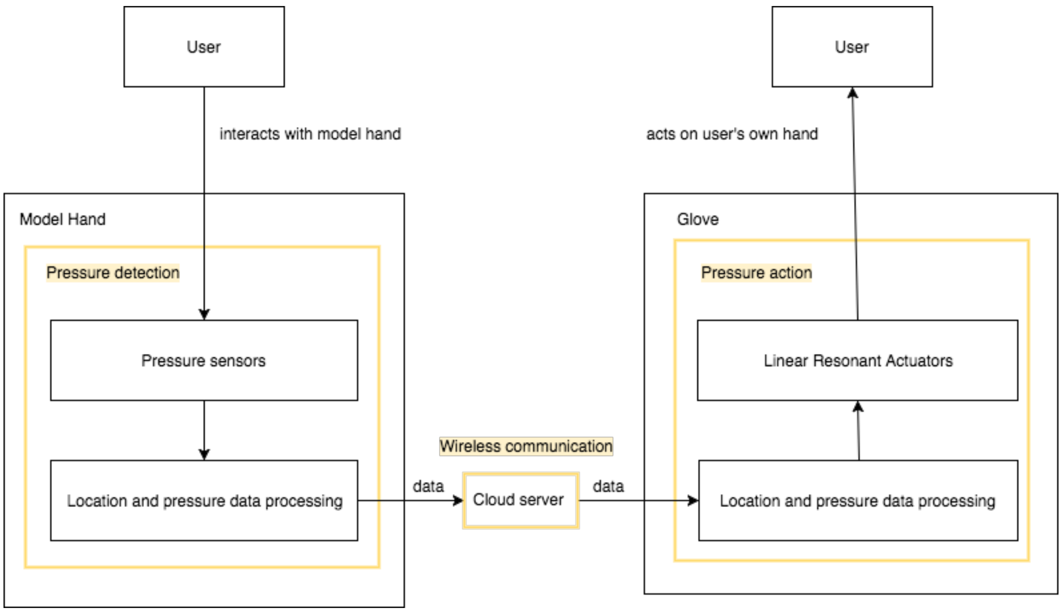
2.1 Functional Requirements

Enacting touch	Collect data about where the user has touched the model hand using pressure sensors.
Receiving touch	Use Linear Resonant Actuators to send haptic feedback to the corresponding areas on glove where the model hand was touched.
Pressure	Accurately reflect the amount of pressure enforced on the model hand to the user's glove.
Communication	The interaction should be able to take place no matter the distance in-between as long as both the hand and glove are connected to Wi-Fi.
Power	Both the glove and the model hand should be rechargeable via USB cable.

2.2 Non-Functional Requirements

Real-time	After a touch is enacted on model hand, the glove must receive the touch within 10 seconds.
Energy-efficient	Both the glove and the model hand should maintain battery life of at least 2 hours.
Intuitive	A poll on the users of the interaction of touching and being touched should result in at least 90 percent users feeling natural while using the product.

3 Functional Architecture



3.1 Pressure Detection

When pressure is detected, the model hand computes and records the location and amount of pressure, and sends this aggregated data to the cloud server in order to drive an action on the glove.

3.2 Pressure Action

Glove enacts haptic feedback on user's hand when it receives location and pressure data from the server, driving corresponding vibration motors to mimic the touch on the model hand.

3.3 Wireless Communication

The interaction is facilitated by a cloud server that receives and forwards the location and pressure data from model hand to glove.

4 Design Trade Studies

4.1 Hand Design

Metric	(1) Fabric Square Sensors	(2) Force-Sensitive Resistor
Price	$24.95/sheet (12inx13in)	$7.00/sensor
Size	Flexible	2.35in x 0.73in
Sensitivity	Resistance changes by distance from pressure or stretch	10 percent variation by sensor: suggested for detecting weight, not accurate in how much
Pressure Range	0.01lb - 220lb	0.04lb - 22lb
Cost	$93.85	$221.99

The choice of which pressure sensors to use was between EeonTex Pressure Sensing Fabric and Round Force-Sensitive Resistors. Comparing the price of 12 sensors cut out from the fabric sheet to the price of 12 force-sensitive resistors, the fabric saves $4.92 per sensor. The fabric is more flexible to fit on the model hand than the solid force-sensitive resistor. The fabric resistance is a function of the pressure applied and is relatively uniform, while the force-sensitive resistor has a 10% variation of resistance by each sensor, and has been recommended for detecting the presence of weight, and not as a load measurer. Since we are modeling human touch, we care more about the lower end of pressure range capabilities. The fabric has a lower threshold of 0.01lb compared to the force-sensitive resistor threshold of 0.04lb. Comparing every characteristic, the EeonTex Pressure Sensing Fabric is the superior choice to the Round Force-Sensitive Resistors to use as our hand sensors.

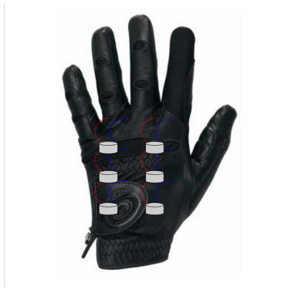
(a) Fabric Square Sensors (b) Pressure Sensors

Figure 1: Hand Design Brainstorming

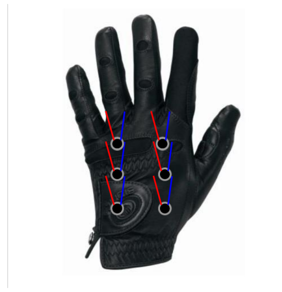
4.2 Glove Design

Metric	(1) Vibration Motors	(2) Linear Resistant Actuators
Price	$4.96/motor	$6.66/actuator
Size	10 mm	8 mm
Latency	Time to turn on and off	7ms
Force Range	One speed: 13 krpm/min	Modifiable frequency and amp.
Cost	$168.83	$218.13

The choice of which glove design to use compared the use of vibration motors or linear resonant actuators. Each vibration motor is $1.70 cheaper compared to one linear resonant actuator. The diameter of a linear resonant actuator is 2mm smaller than a vibration motor. The latency of both the motor and the actuator are both fast enough for our purpose. The most important characteristic was the force range, since we want to be able to simulate sensitive touch sensations. The vibration motor was not intended to have many controllable speeds, while the linear resonant actuator responds to changes in frequency or amplitude changes from the AC input and changes its vibration. So, even though the cost of the linear resonant actuator is considerably more than the vibration motors, we chose to use the actuators because of the range of vibration frequencies.



(a) Vibration Motors



(b) Linear Resistant Actuators

Figure 2: Hand Design Brainstorming

4.3 WiFi Modules

Metric	(1) SMD Module - CC3000	(2) ESP8266 (TCP/IP)
Price	$26.95 / module	$6.95 / module
Size	16.3 mm x 13.5 mm x 2 mm	16 mm x 24 mm x 3 mm
Throughput	4 Mbps	320 kbps
Cost	$53.90	$13.90

One of the main operations of our system is communicating sensor data wirelessly from the mannequin hand to the glove. The system architecture includes one module on the mannequin and one module on the glove, each of which communicate through a cloud server. Two of the WiFi modules that were considered were the CC3000 and ESP8226. Since the data packets being sent are mostly numbers that translate to operations for each vibration motor, throughput was not a huge factor in deciding between modules. Online research also indicates the ESP8266 is more performant, has better modularity for hardware, and is significantly cheaper.

5 System Description/Depiction

5.1 Fabric Square Sensors

The mannequin hand is covered in 40 1in x 1in EeonTex Pressure Sensing Fabric on the back of the hand, the palm, and fingertips. Each fabric square has a measured resistance that is sent as data to the cloud server.

5.2 Linear Resonant Actuators

Black elastic glove is lined on the inside with 40 linear resonant actuators on back of hand, palm, and fingertips to mirror sensor placements on mannequin hand. Resistance data from each sensor in the cloud server is translated to corresponding force output in linear resonant actuator. Different forces are controlled by modifying actuator amplitude and/or frequency to simulate pressure.

5.3 System Depiction Diagram

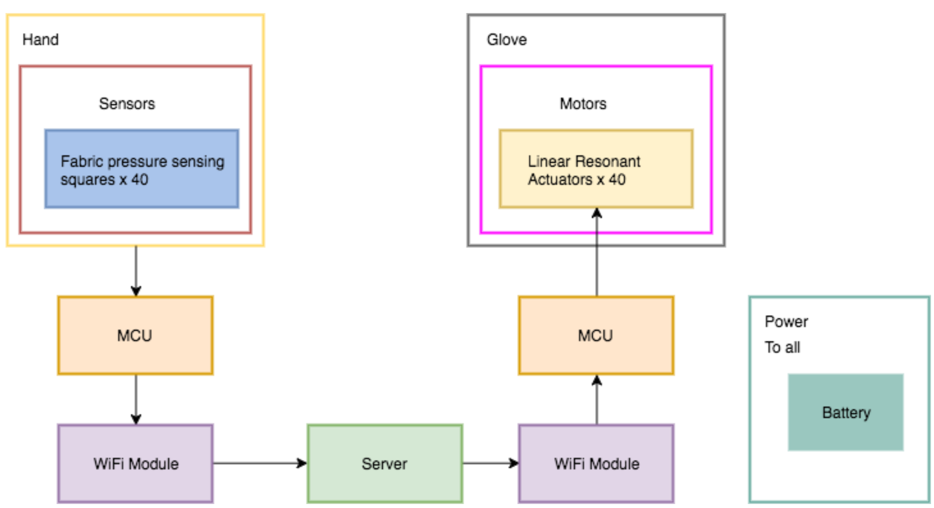


Figure 3: System Diagram

6 Project Management

6.1 Project Schedule

Date	Milestone
2/13	Basic Website Landing Page
2/17	Purchase Components Deadline
2/21	Website Sections Created and Filled
2/21	Setup Pressure Meshing
2/24	Website Check 1
2/24	Design for Pressure Meshing Mappings
2/28	Live Updating of Pressure Meshing
3/6	System Demo 1
3/10	Website Updated System Demo 1 Post Mortem
3/14	Vibration (Tactile) Mesh Design Complete
3/14	Design for Pressure Mesh to Vibration Mesh Mapping
3/20	System Demo 2
3/24	Communication between Mesh Layers
3/24	Website Updated System Demo 2 Post Mortem
4/3	System Demo 3
4/3	Website Updated System Demo 3 Post Mortem
4/7	Website Check 2
4/7	Full Vibration Mesh Control via Wireless Communication
4/10	System Demo 4
4/12	Website Updated System Demo 4 Post Mortem
4/15	Basic Feel via Vibration Mesh from Human Interaction
4/15	Ability to touch a model hand sensor and feel it on glove
4/17	System Demo 5
4/17	Website Updated System Demo 5 Post Mortem
4/24	Refined Feel via Vibration Mesh from Human Interaction
4/24	Ability to touch a model hand anywhere and feel it on glove
4/25	System Demo 6
4/25	Website Updated System Demo 6 Post Mortem

6.2 Team Member Responsibilities

Team Member	Primary	Secondary
Rohan Jadvani	Wireless Communication	PCB designer, Videographer
Chelsea Kwong	Sensor data collection	Website
Lisa Yan	Actuator implementation	Wireless Communication
Cristian Vallejo	Mechanical design	System integration, Website

6.3 Budget

Item	Vendor	Quantity	Price
Model Hand	Amazon	2	$18.99
Linear Resonant Actuators	Precision Microdrives	40	$266.40
Pressure Sensing Fabric	SparkFun	4	$99.80
WiFi Module - ESP8266	SparkFun	2	$13.90
Black Elastic Glove	Cabela's	1	$24.99
Total			$424.08

6.4 Risk Management

6.4.1 Design Risks

1. Sensor are not accurate or do not work as expected
   (a) Utilize our design alternative to change the design to an alternative or use other sensors that will work more closely with our needs
2. Actuators can not deliver sensation in the way expected
   (a) Utilize alternatives identified in our proposition.
3. Communication over certain protocols may not serve the device properly

   (a) Using our research on differing methods for wireless communication we would use an alternative protocol to achieve our design

6.4.2 Resource Risks

1. Availability issues with group member
   (a) Have overlapping responsibilities so that no areas of the project fall behind
   (b) Have excellent communication between team members so that the team is able to keep the project moving
2. Part Failure
   (a) Order multiple of each part so that should one fail there is a back up.

6.4.3 Scheduling Risks

1. Incorrect Estimations for Task Completion Deadlines
   (a) Reevaluate deadlines weekly to ensure people are staying on task
2. Incorrect Analysis on the Importance of Subsystems
   (a) Should it become apparent that an element of a certain subsystem should need to be worked on first the schedule will be altered to better reflect the team's needs

7 Related Work (Competition)

7.1 GloveOne

GloveOne is a haptic glove designed to feel objects in VR. The gloves transfer data using either a low latency USB connection or via Bluetooth. The glove vibrates with varying intensities and frequencies to recreate touch sensations for the user. The glove also uses Leap Motion and Intel RealSense and has a price tag for $200 for each glove. Our team has an edge on this glove in different ways. GloveOne is not able to communicate long distances due to using a USB connection or Bluetooth. Our design, however, is able to communicate over WiFi allowing it to be used anywhere a connection is available. The glove is comparable in price to what it takes to make our proposed project. The actuators for GloveOne and our design are similar since they both "vibrate independently at different frequencies and intensities, reproducing accurate touch sensations". However, their design uses 10 actuators, while the size of ours allows us to use 40.

7.2 Hands Omni

Hands Omni is a haptic glove as well that uses inflatable bladders to simulate pressure on touch. Inflatable bladders may create a more realistic sense of physical pressure on the hand compared to vibrating actuators, but since the device relies on air compressions to drive interactions, the latency of the device is a huge hurdle for real-time interactions.

References

[1] Hayden, Scott. *2 VR Gloves Promising Haptic Feedback, 2 Very Different Approaches.*

[2] Bala, Shantanu. *How It Works: Linear Resonant Actuators.* Somatic Labs. N.p., 4 Apr. 2016. Web. 10 Feb. 2017.