HAPTIC GLOVES

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INTRODUCTION

“Haptic” refers to the sense of touch. “Haptics” does not only describe pure mechanical interaction, but also includes thermal and pain(nociception) perception. The receptors that give the sense of touch also give the sense of Pain - nociceptors and Thermal interaction.

The sense of touch makes it possible for humans and other living beings to perceive the “borders of their physical being”, i.e. to identify where their own body begins and where it ends.

This concept is now applied here on the functioning of a human palm. The palm along with the fingers forms the most important structural unit of the human body in probing the space around it and knowing the boundaries.
The palm is efficient in that, aided by the mobility of the arm, it has a large reach
The fingers have 27 DOF providing an opportunity for a nuanced interaction with the surroundings

The tips of the fingers are embedded with thermoreceptors, merkel cells that on stimulus, produce a perception of the corresponding sense. A Haptic Glove aims to do the same by incorporating extrasensory perception.

The hand moves in a configured virtual environment and receives stimulation from the glove that make the person feel as though their hand was traversing in the virtual world.

The major advantage of the haptic glove is that it is an embedded decoupled system than can just be worn on the hand and enjoy the experience. But traditional haptic gloves have been bogged down on utility due to the heavy wiring equipment surrounding.
The gloves essentially act as a live in experience transmitters.

The project aims to make the system portable by reducing the wiring connections. Attempts at kinesthetic feedback have been made by using simpler mechanisms to regulate finger movement. Cutaneous feedback is also incorporated by means of tactile electrodes.

It breaks a new frontier in the VIRTUAL REALITY experience as we know it, with ***touch.***

The major deliverables being

- the ability to integrate virtual interaction into real world physical devices such as extracting output from Unity3D
- tune outputs based on virtual world interactions and impose them on real life objects like haptic feedback on palms.
- diversify the feedback systems - tactile, thermal, kinesthetic, etc

LITERATURE

CURRENT TECHNOLOGY

The most popular Haptic suits/gloves available in the market are

- Tesla Suit
  - For Haptic feedback, Tesla Suit uses electrical stimulation channels [13],[14].
- Haptx [15].

OUR APPROACH in BUILDING A MODEL FROM SCRATCH

The foundational work blocs in starting the project were

1. **Design a Virtual environment.**
   1.1. A 3D environment similar to a setting of "*Randomly placed solid blocks on a flat table*" was created.[1]
   1.2. The solid blocks created are Cubes and all objects are prefabs of the original Cube.
   1.3. The Cube is also equipped with a box collider. With the mesh, larger than its size. [2]
   1.4. Physics is activated for a life-like experience.

2. **Provide a proxy for real world hand movement in the virtual environment created.**

   2.1. The movement of the hand needs to be monitored, tracked and the data shall be used to derive conclusive outputs desirable to our operation.

   2.2. Hand tracking can be done using several methods
   2.2.1. Wearable Inertial motion sensors[3]
   Inertial and magnetic sensors are placed on single finger segments. These sensors transmit kinematic data such as velocity and acceleration of

the object on which the sensor is placed. Efforts have been made to place the sensors tactically at different joint locations and accounting for mobility[4].

The major problem with this method is that the sensors are prone to a lot of errors, especially because they can be influenced by magnetic presence.

The sensors are also computationally expensive. A simple feedback, even after calibration would require a) acquiring the data b) use filters to reduce errors c) Integrate Velocity data to get the coordinates.

All these computations create a lag and a general hand motion cannot feel immersed with a feedback of this delay.

2.2.2. RFID - Reflective Marker based methods

This is the method the majority of the Movie Industry relies on while producing animated pictures. The series of steps involved are Calibration seed capture, Calibration, Marker placement, Data extraction and computation[5].

The caveats being that it requires **several cameras** placed all around the environment. It is very accurate at the macro level. For smaller sizes, the markers need to be very distinct to be discernible. The cameras make it expensive to use.

2.2.3. Image Recognition - Optical Motion Capture

This captures the hand movement without markers. **LeapMotion and Kinect V2** are leading in this field. The devices made handle all the computations. The devices are affordable and use image recognition and computer vision methods to detect and render the hand. They are also very compatible with UNITY 3D.

Thus LEAP MOTION was our device of choice

2.3. LEAP MOTION[6]

2.3.1. Hardware

2.3.1.1. The heart of the device consists of 2 cameras and 3 infrared LEDs. These track infrared light with a wavelength of 850 nanometers, which is outside the visible light spectrum.

2.3.1.2. The detection range is 60 cm above the device location and is a conical frustum

2.3.1.3. Objects illuminated the LeapMotion are only visible and images are extracted from that.

2.3.2. Software

2.3.2.1. The Leap Motion Controller doesn't generate a depth map – instead it applies advanced algorithms to the raw sensor data.

2.3.2.2. This later when integrated with Unity 3D, has certain packages that create rendered model in the virtual world.

2.3.3. Operation

2.3.3.1. Hands can be rendered as skeletal or full objects palms.

2.3.3.2. The Hands can be made rigid bodies and they can interact with the environment

2.3.3.3. Physics i.e Making the objects dynamics, is also an option for a better user experience.

2.3.3.4. Preliminary training to place the hand in a way traceable by the leap motion device properly.

3. Derive conclusions from the interactions of the Virtual hand with the Virtual world.[7]

3.1. A code was written to derive the coordinates of finger tips based on their relative positioning of hand with the LEAP MOTION device.[SCRIPT ATTACHED]

3.2. Distance between the tip of the index finger and obstacles is calculated.

3.3. The trigger is activated when the distance reaches a threshold.

4. Extract conclusions from the UNITY 3D setting to external devices.[**SCRIPT ATTACHED**]

4.1. Unity was connected to arduino that reacts based on the information received. [12]

5. Use of haptic feedback systems on the organ in the real world such as

5.1. Tactile:

5.1.1. Using ECG electrodes made of Stainless steel + Silver/Silver chloride coated electrode.[9]

5.1.2. The electrodes are available as discrete units and can be embedded in a circuit easily without much disturbance to the setup.

5.1.3. PiezoVibe from Murata is another example. [10]

5.2. Thermal:

5.2.1. Similar to tactile, peltier modules are used for giving thermal feedback.

5.2.2. Peltier effect:

Heat is given out or absorbed when an electric current passes across a junction between two materials[11].

5.3. Kinesthetic:

5.3.1. Use of physical systems to constrain the hand movement.

5.3.2. Methods such as electrostatic, electromagnetic brakes are efficient. But they need very high voltages and are not feasible in an educational setting[7],[8].

5.3.3. Simple mechanical systems are used to mechanically constrain fingers like string and a motor.

5.3.4. Using complicated mechanisms such as ones using skeletal linkages or mechanisms not only increase the load but also complexity of manufacturing and operation of that system.

5.3.5. Immersive nature of the mechanism is the important factor to consider.

PROBLEM DEFINITION:

“ Creating a wearable glove embedded with mechanical systems, which can make the hand feel a sense of touch, thermal state - hot/cold - and a kinesthetic finger feedback when it touches an obstacle in the virtual world ”

METHODS USED

- Components:
  - Computer
  - Leap Motion device
  - Arduino compatible Port Cable
  - Arduino Uno
  - Circuit board and connecting wires
  - Relay Switch
  - ECG electrodes
  - Peltier Module : 30 x 30 x 3.86
  - Power Supply
  - Linear Pulse width modulation
  - Servo Motors
  - Fasteners

- SOFTWARES used:
  - Unity3D
  - ArduinoUno

- Methods
  - Motion capture
    - Leap Motion device is connected to the computer
    - The device is placed at a location in the vicinity of a hand's range of motion
    - The device is now integrated to Unity 3D software
    - The hand models are made Game Objects and their movements are modeled based on hand movement in the real world.
  - Hand position calibration and dynamic data extraction
    - The hand model is rendered in due consideration of calibration with respect to the leap motion device
    - The device is placed on the table, same as in the real and virtual worlds
    - The virtual world is calibrated with the centre of the device as the location of the frame of the world
    - The coordinates are extracted from the inbuilt hand models
    - The distances between the solid blocks and hand models were calculated
    - If the distance approached close to side length of the object, it means a trigger
    - The trigger sends an output of sorts from the UNITY 3D software
  - Compound Collision - Trigger response
    - The model can be simplified by using collision triggers with a larger mesh around the objects
    - The computational costs go hugely down
    - When both the physical spaces of Index Finger and an Object come in contact, they produce a trigger
  - Arduino serial input based output
    - The output from the computer is fed into Arduino
    - Arduino reads the output and assesses it based on the program it runs on.
    - If there is a collision, the output is ON
    - No collision, the signal red will not initiate any reaction.

- Relay control
    - The arduino outputs are fed into the Relay system
    - The on/off give a open or closed gate in the Relay
    - This can be used as a switch where, the

      Trigger => Arduino On => Switch ON

- Accessory implantable circuit system
    - The relay is placed in the middle of a circuit containing the
        - Tactile feedback
        - Peltier unit
        - Motor
    - The circuits perform only one operation and that they are specifically designed to do.
    - The switch decides if the circuit is active or not.
    - Based on your hand position, these embedded accessories, based on their circuits, will give you feedback.

ALGORITHM IF ANY

- In arduino, we derive the output based on the last input received from the Unity channel
- The algorithms are visualised better in the code scripts attached.

RESULTS & SUMMARY

- The index finger-tip was considered as the trigger initiator.
- Once the finger came in contact with a virtual object, the UNITY 3D software recognises the trigger collide, sends an output via serial port to arduino
- Arduino reads the output and produces a 1 or 0 output.
- Relay closes or opens based on this
- Closed relay produces the corresponding Tactile, Thermal, Motor feedback

FUTURE WORKS

- The glove can be made more portable upon the invention of mobile tactile systems with harmless voltage requirements

- Design of MicroMechanical systems, light enough to not burden the user and also is able to regulate 5 finger motion.

- Calibrate the hand motion using universal cameras to give a better range of motion

VR CONCEPTS USED IN THE PROJECT

- **Position tracking**
  - Hand's position relative to the Leap Motion device
- **Multimodal perception**
  - The movement of your hand in the VR environment is the clearer visual feedback but once your touch the object, the feedback from the tactile systems also makes you feel the touch through - "touch" sensation.
- **Visual immersion**
  - As your hand doesn't know the calibration, you look for cues in the virtual environment and you movement is dictated based on the feedback of your reflexive motions reflection in the virtual environment.
  - One gets immersed in the scene moving their virtual hand without realizing the motion of human hand
- **Sensory perception**
  - Ability to experience the Tactile, thermal, mechanical stimuli once you hit an object.

References:

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8. "A lightweight, low-power electroadhesive clutch and spring for exoskeleton actuation".Stuart Diller, Carmel Majidi, and Steven H. Collins.
9. "Reusable Flexible Concentric Electrodes Coated With a Conductive Graphene Ink for Electrotactile Stimulation".Benjamin Stephens-Fripp, Vitor Sencadas, Rahim Mutlu, and Gursel Alici

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14. Telsasuit.io - official website of Tesla suit
15. https://haptx.com/

Links to Scripts

https://github.com/AbhishekSureddy/VR/blob/master/Sending.cs - Sending the trigger signal from UNITY 3D to external device through serial port.

https://github.com/AbhishekSureddy/VR/blob/master/recieving_unity.ino - Control the relay switch

https://drive.google.com/open?id=1ZA2CO0ufDiIlJrkdCde4ffRqvFYZ6tWi- Motor control for Kinestheitc feedback