KAIST

Heating & Vibrating 3D Printed Objects for Varying Texture Perception in Virtual Reality

Group Name: Fresh

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1. Background

In the previous research on VR material & texture perception,
there have been less attempts for **perceiving multimodal haptic feedback with bare hands.**

- **Immersiveness**
  Accurate material and texture perception has been studied to enhance realism in VR

- **Natural Interaction**
  Bare hands interaction (without controllers) allows users to interact with the VR environment in a more natural and intuitive way, increasing accessibility and ease of use

- **Multimodality**
  Previous researches focused on enhancing material perception by evaluating single mode of feedback at a time. Previous research in multimodal haptic feedback for material perception is limited.

2. Related Works

In the previous research on **VR material & texture perception**,
there have been less attempts for **perceiving multimodal haptic feedback with bare hands.**

Table 1. Related Works on Temperature with Texture Perception

Year	Researchers	Work Content
2016	Bhattacharjee et al.	Used **wearable devices** with **temperature sensors** to **identify contacts with people and objects.**
2006	Ho and Jones	The established thermal model **predicts temperature and heat transfer** when **fingertips touch objects**.
2007	Childs and Henson	Studied **relationship between perceived texture and surface properties** like roughness and friction.
2008	Liu et al.	Measured the role of **fingertip compliance** in determining **perceived surface smoothness.**

Problems:

- Did not provide **unified bare-hand solutions**, having **bulky mechanical devices** attached to the hand.
- **Lacked multimodal haptic feedback**.
- **Temperature feedback was missing**.
- The **combination of thermal and vibrotactile modalities** was yet to be explored for interactive material perception.

2. Research Purpose and RQ

Purpose

Developing a single device providing thermal and vibrotactile feedback for the sensation of different textures.

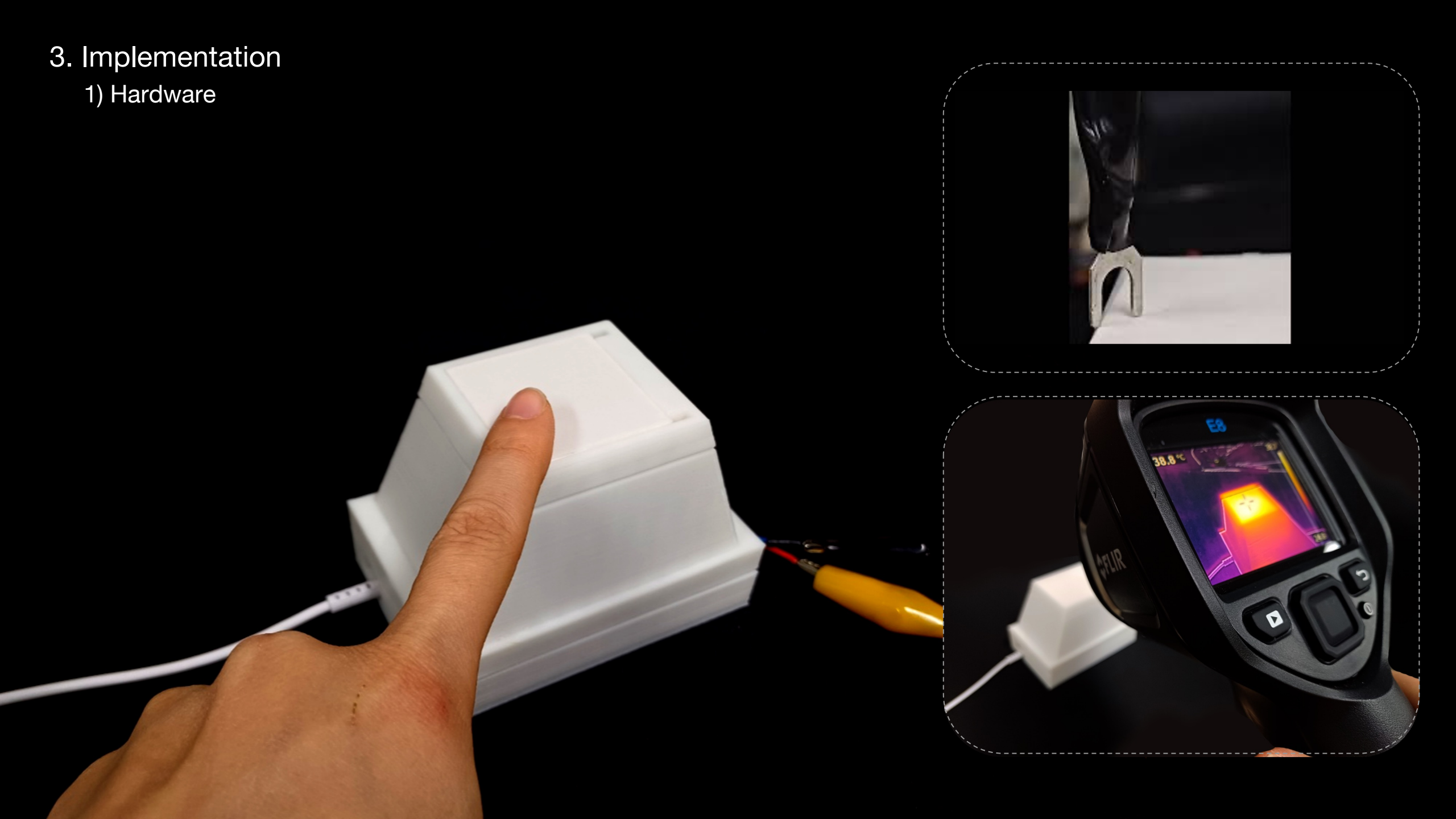
2. Research Purpose and RQ

RQ 1 In the condition of providing **same thermal** but **different vibrotactile** feedbacks, can people distinguish the material?

RQ 2 In the condition of providing **vibrotactile and thermal feedbacks** at the same time which are **different from materials**, can people distinguish the materials?

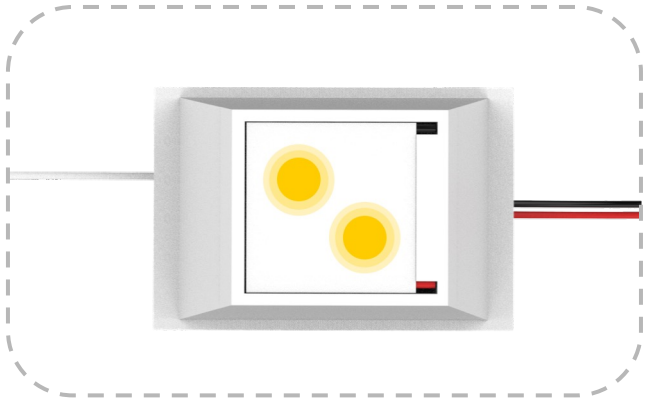
3. Implementation

1) Hardware



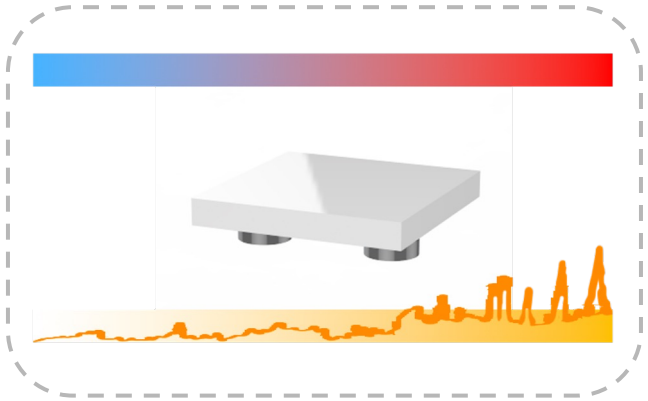
3. Implementation

1) Hardware : Specification



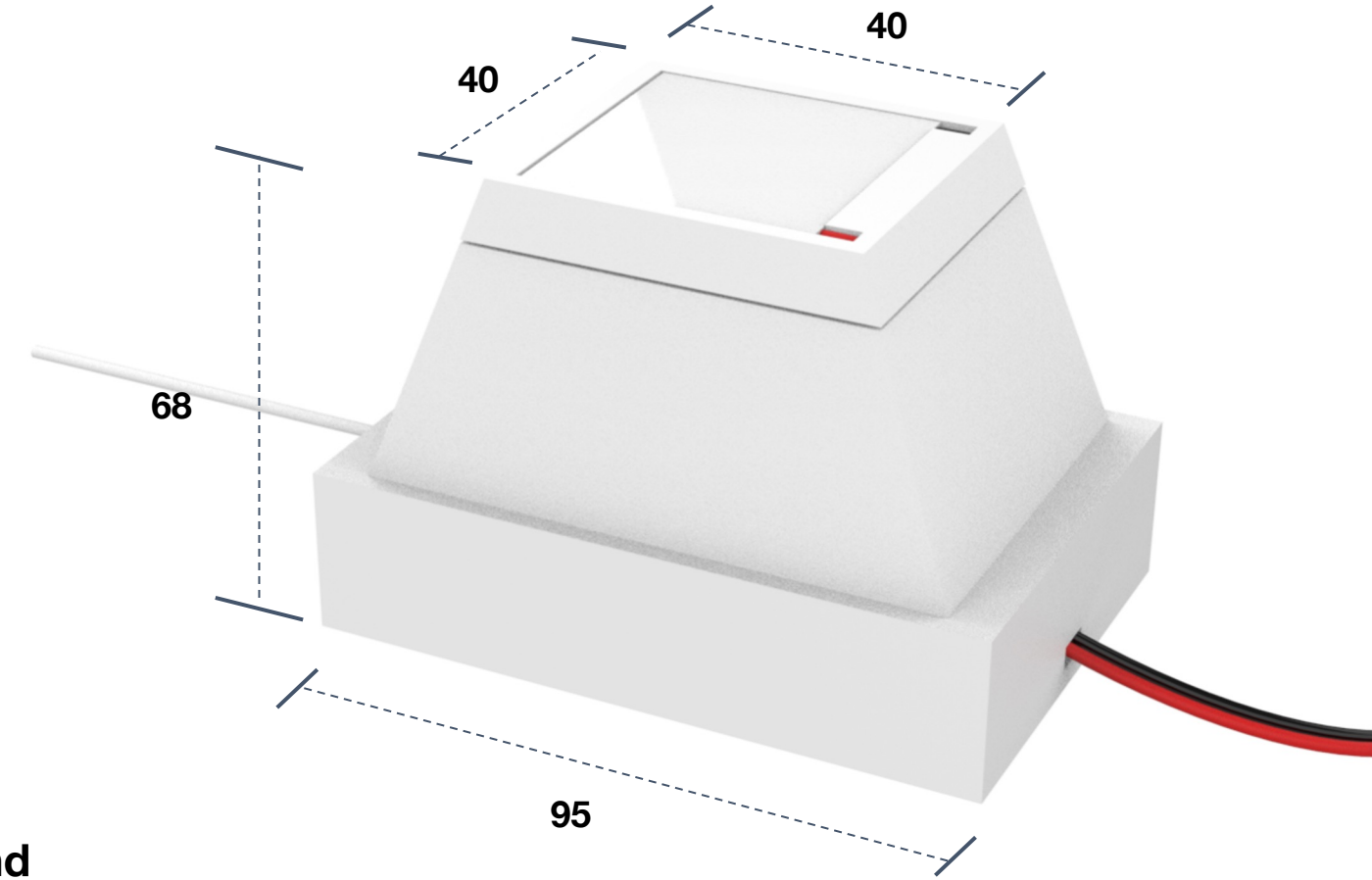
Vibrate Spot

Vibration transmitted along the Peltier



Both Thermal and Vibrotactile Feedback

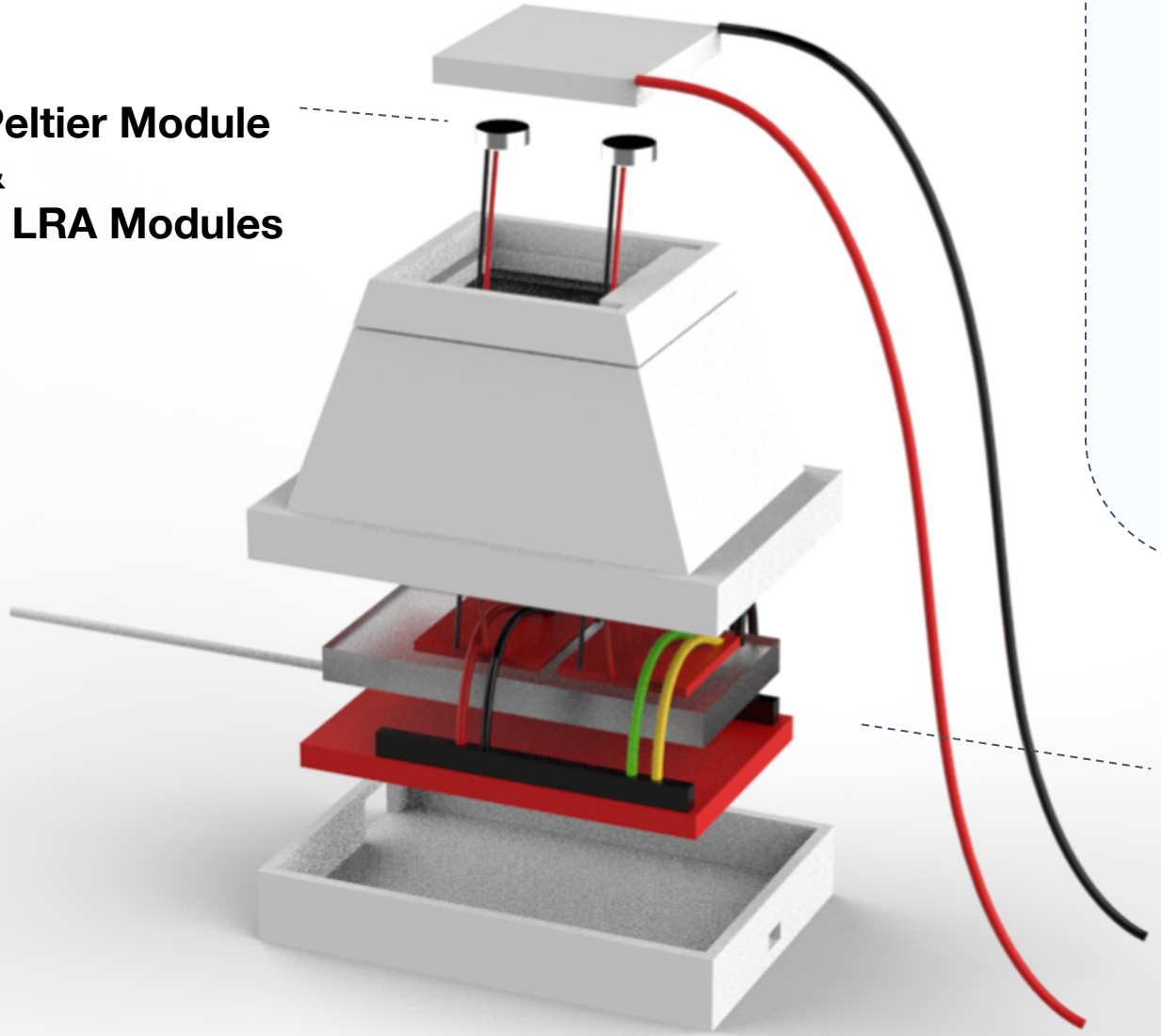
Immediate vibrotactile feedback, 30 secs delay to reach the ultimate temperature (~40°C)

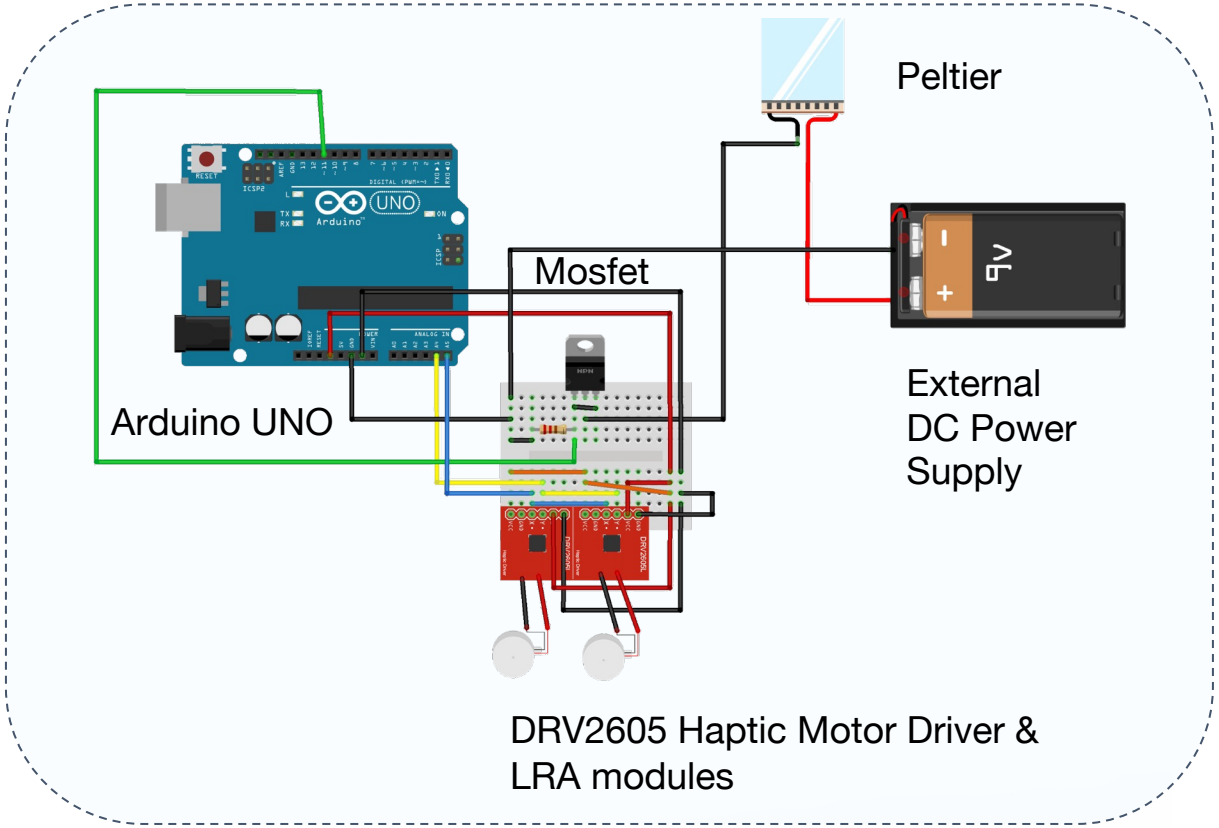


3. Implementation

1) Hardware : Structure

Peltier Module
&
2 LRA Modules





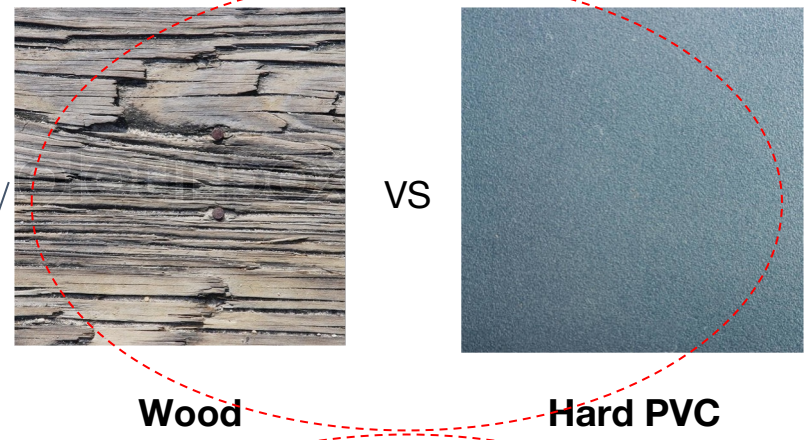
Controller

3. Implementation

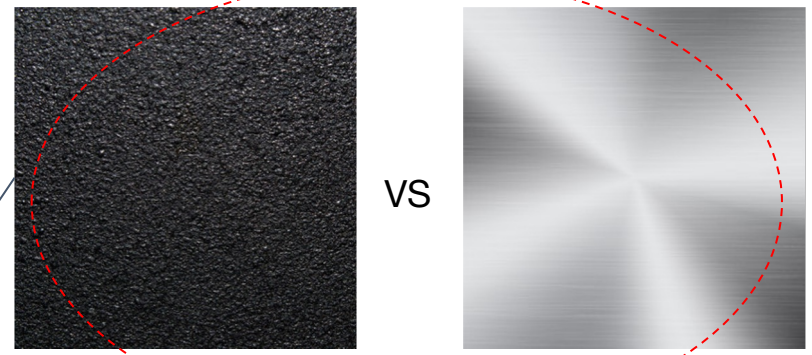
2) Selecting Texture - **RQ 1**

: Compare between the textures that has
similar thermal conductivity, but different roughness

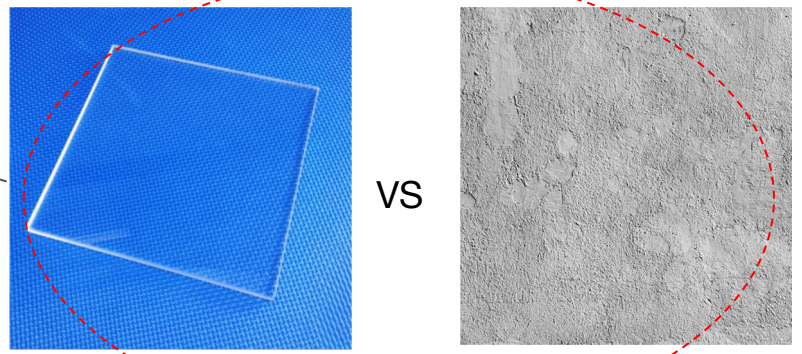
Groups	MATERIALS	Thermal Conductivity [W/(m·K)]	Roughness (10^-3 m)	Density (g/cm³)	Heat Capacity J/(g°C)
1	Hard PVC	0.17	0.0015-0.007	1.45	0.9
	Wood	0.14-0.17	5	0.6	2.4
	Cardboard	0.14	0.015-0.025	0.69	1.3
	Glass	0.52	0.00015-0.00035	2.23	0.84
	Leathers	0.18-0.19	0.02-0.05	1.4	2.5
2	Cast Iron	55	0.25-0.8	7.75	0.46
	Polished Steel	34-55	0.0001-0.0008	7.85	0.5
3	Porcelain	1.05	0.0005-0.002	2.3	0.85
	Quartz Glass	1.46	0.00015-0.00035	2.25	0.84
	Concrete	1.28	0.1-0.5	2.3	0.84



Wood VS Hard PVC



Cast Iron VS Polished Steel



Porcelain VS Concrete

Compare within groups

3. Implementation

2) Selecting Texture - **RQ 2**

: Compare all the textures that has
different thermal conductivity and different roughness

Groups	MATERIALS	Thermal Conductivity [W/(m·K)]	Roughness (10^-3 m)	Density (g/cm³)	Heat Capacity J/(g°C)
1	Hard PVC	0.17	0.0015-0.007	1.45	0.9
	Wood	0.14-0.17	5	0.6	2.4
	Cardboard	0.14	0.015-0.025	0.69	1.3
	Glass	0.52	0.00015-0.00035	2.23	0.84
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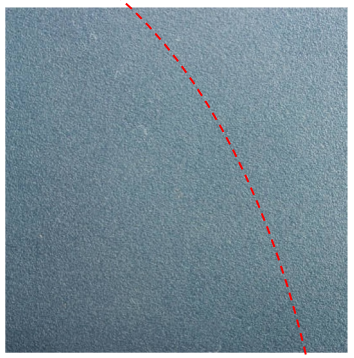
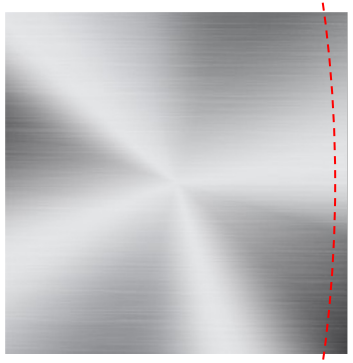
	Quartz Glass	1.46	0.00015-0.00035	2.25	0.84
	Concrete	1.28	0.1-0.5	2.3	0.84

Wood

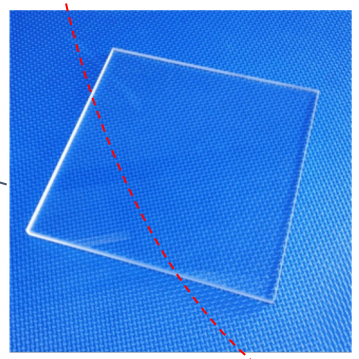


Hard PVC

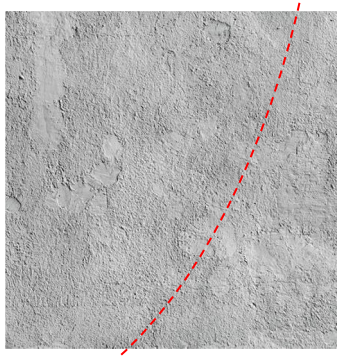
Cast Iron



Polished Steel



Quartz Glass



Concrete

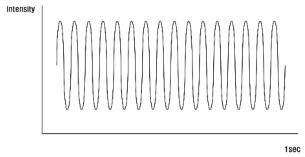
Compare among those 6 materials

3. Implementation

3) Software
: Temperature & Vibrotactile Amplitude, Frequency Settings

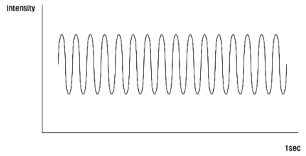
Wood

: 25.16°C



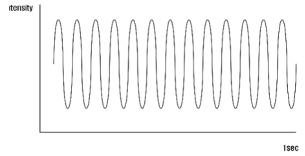
Hard PVC

: 26.99°C



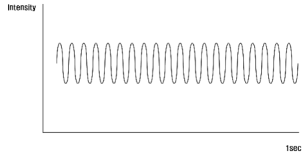
Cast Iron

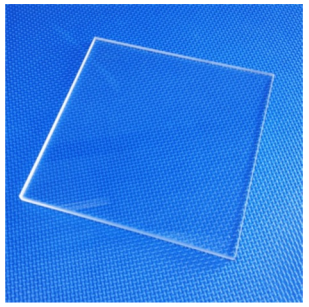
: 40.00°C



Polished Steel

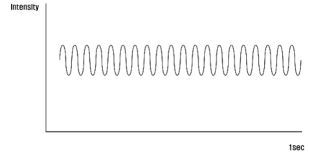
: 41.80°C





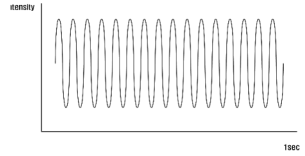
Quartz Glass

: 37.05°C



Concrete

: 35.04°C



The temperature for each objects

when the objects are heated at **40°C** directly for **60 sec.**

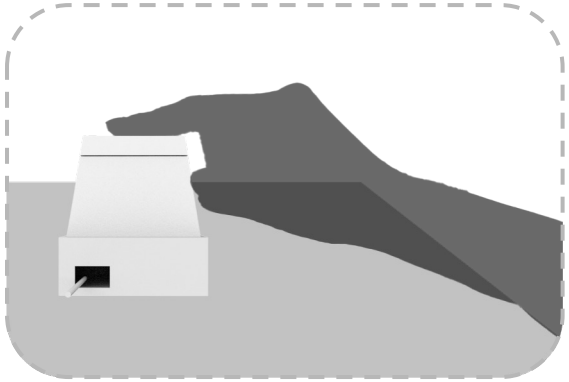
(All the objects are 4cm * 4cm * 1cm, Original temperature = 25°C)

3. Implementation

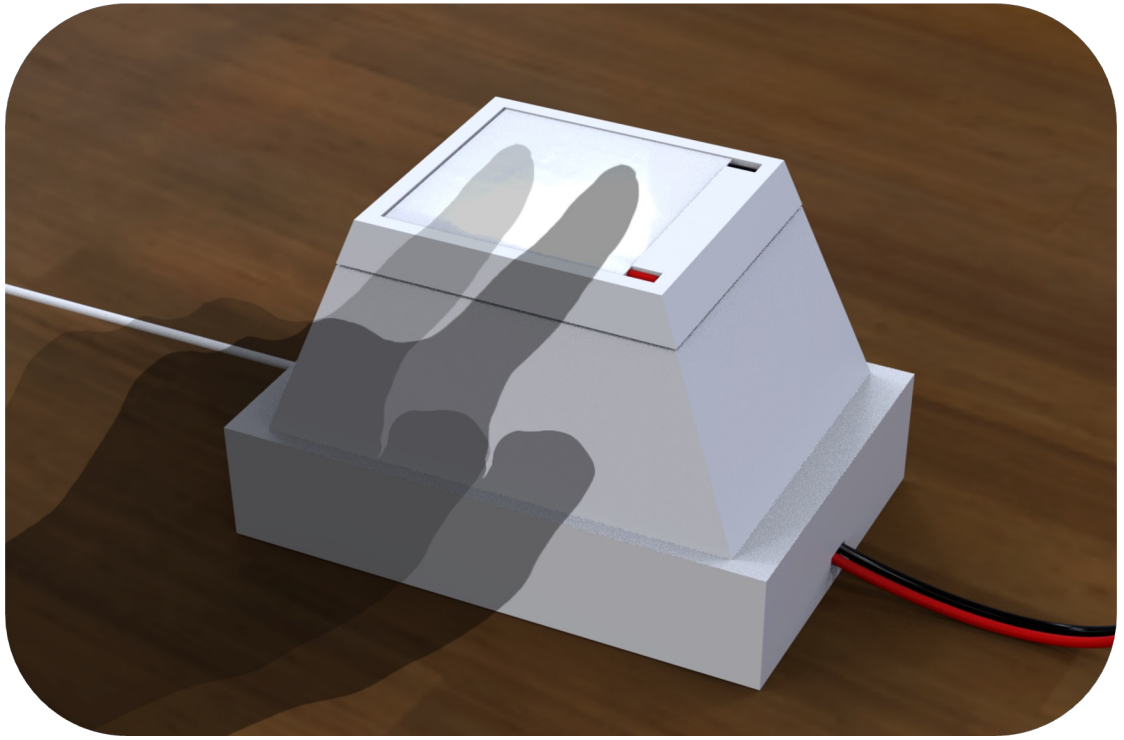
3) Design Interaction

User take on the HMD and enter the Virtual Reality Scene

Device Position matches with virtual object position



Device starts vibrating when user hand touches the display



User can feel multi-modal haptic feedback

by rubbing on the surface of the object with bare hand

3. Implementation

3) Design Interaction

```
if (surface touched) {
        if (finger moves to different position) {
            switch (texture){
                case 1: vibration A  activate;
                    thermal feedback A activate;
                break;
                case 2: vibration B activate;
                                thermal feedback B activate;
                break;
                // … case 6
                default : no activation
                break;
                }
            }
        }
}
```

1.

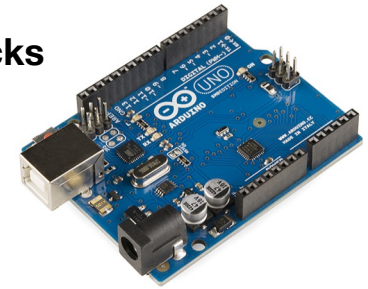
Touch detection by tracking the collision with object when user touches the real object,
by mapping the real objects' position and virtual objects' position via unity 3D collision detection.
Send collision data to arduino.

2.

Hand position detection
by using Oculus Hand Tracking.

3.

Set of **vibration and thermal feedbacks alternation** according to textures
via **Arduino Uno**

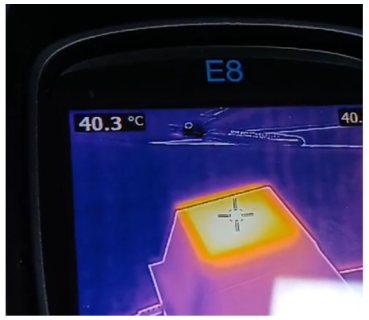


4. Technical Evaluation

1) Temperature

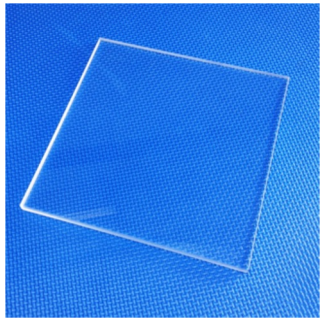
Wood

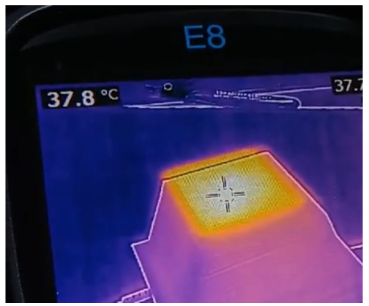
: 26.99°C



Cast Iron

: 40.00°C



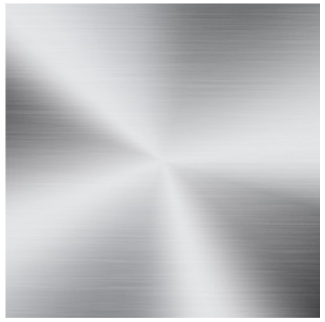


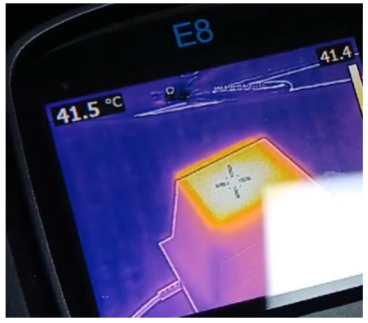
Quartz Glass

: 37.05°C

Hard PVC

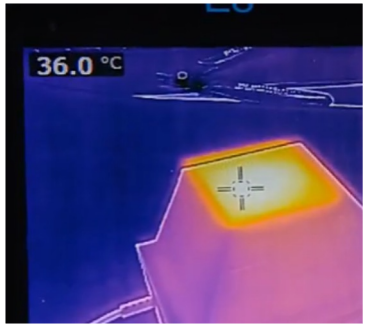
: 25.16°C





Polished Steel

: 41.80°C



Concrete

: 35.04°C

4. Technical Evaluation

2) Vibrotactile

How motor

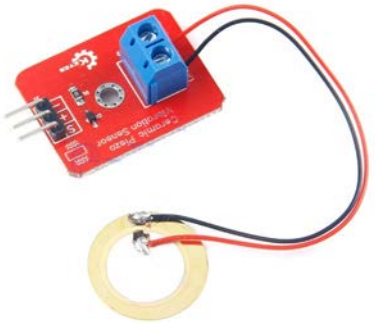
Vibration measurement through Piezoelectric sensor

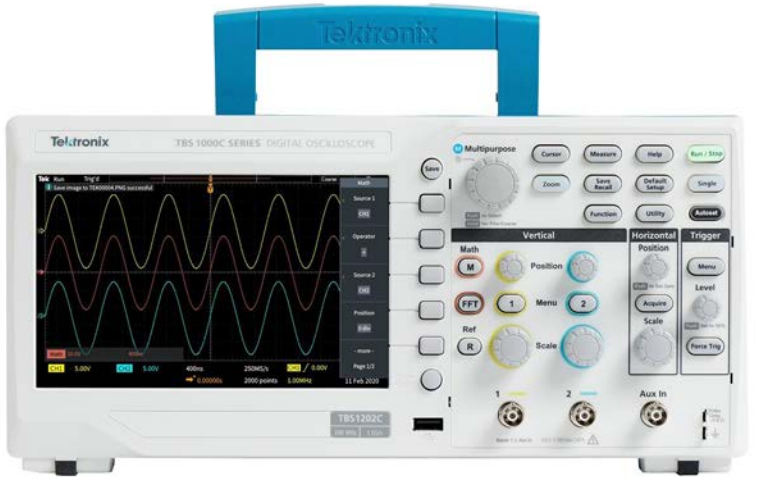
Visualize it through oscilloscope

How user sense it

Vibration measurement through Piezoelectric sensor

Visualize it through oscilloscope



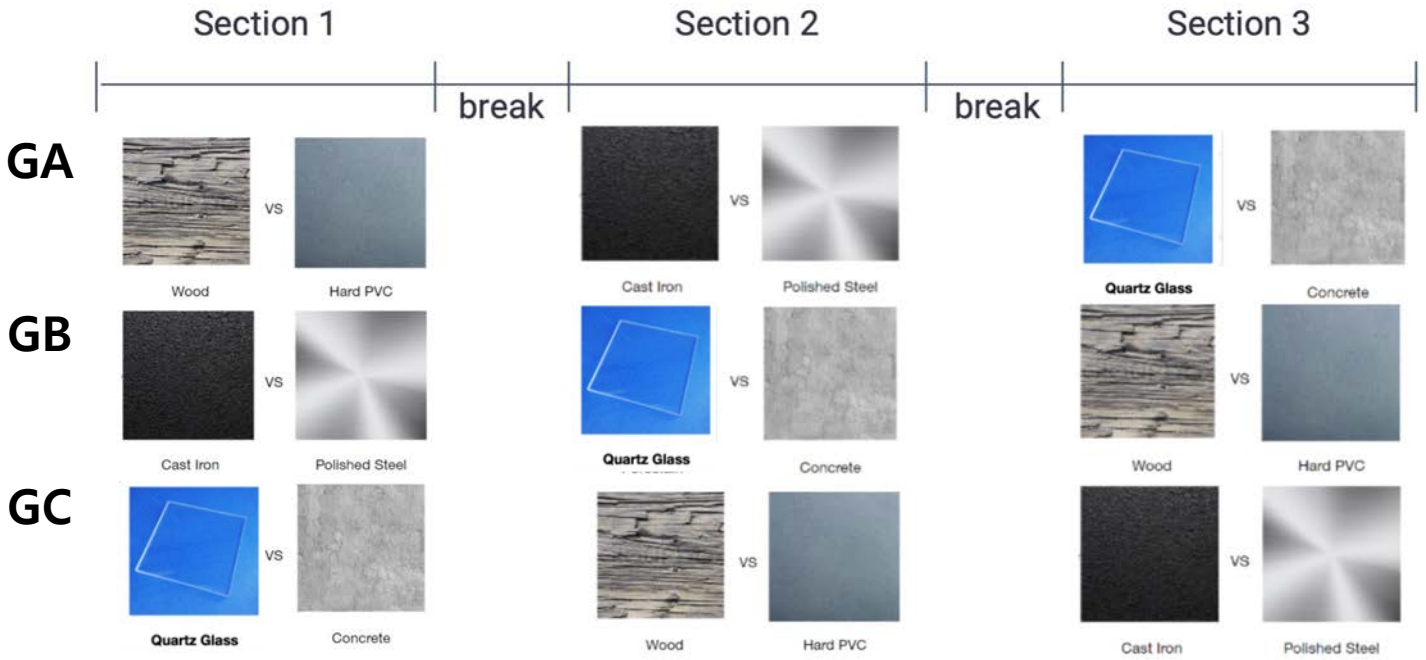


5. User Study

User Study 1

In the condition of providing same thermal but different vibrotactile feedbacks,

1. **Can people distinguish the material?**
2. **Whether the recognition accuracy will be different in material groups in different temperature zones after heating?**



15-20 Participants:

→ **Divided equally into 3 Groups:**

Group A, Group B, Group C;

3 Groups of Materials:

→ **same thermal conductivity, different roughness**

Group 1: Wood, Hard PVC

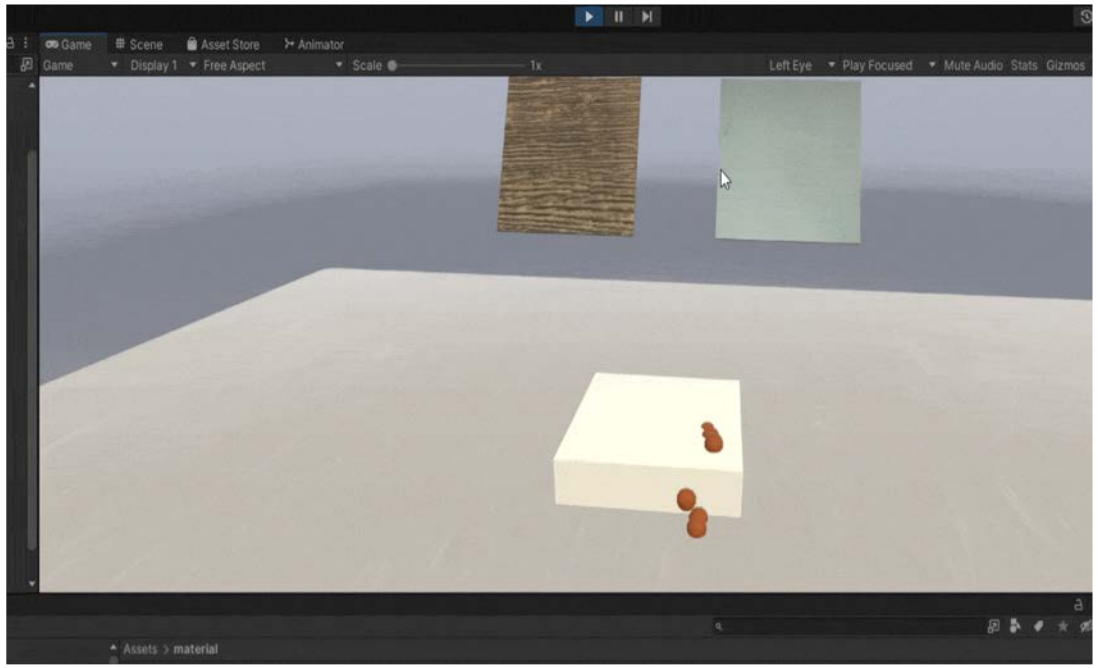
Group 2: Cast Iron, Polished Steel

Group 3: Porcelain, Concrete

5. User Study

Task :

- ➢ Participants will be asked to feel each texture by hand before the experiment.
- ➢ Participants blindly rub on the surface of the virtual object which provides no texture information but multimodal haptic feedbacks.
- ➢ Then choose one of the 2 visual option of each materials group that best matches the haptic feedback.
- ➢ Repeat 3 times in order.



Data Requirements & Analysis

- ➢ Recognition success rate
- ➢ Recognition success time
- ➢ Compare identification accuracy between materials groups in different temperature zone after heating.

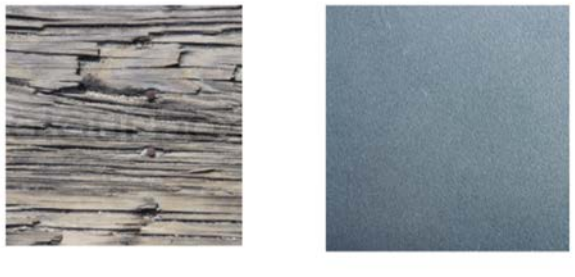
Quantitive Scale：

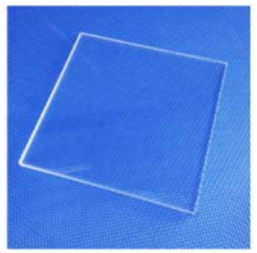
7 Points Likert Scale for the immersion and reality of haptic representation.

5. User Study

User Study 2

In the condition of providing **different vibrotactile and thermal feedbacks**,
can people distinguish the material?





→ all different thermal conductivity, roughness

15-20 Participants

Assess ability to distinguish a wider variety of materials through haptic contact.

1. **Participants will be asked to feel each texture by hand before the experiment.**
2. **Then try to identify those 6 materials with 3 different conditions**

5. User Study

15-20 Participants

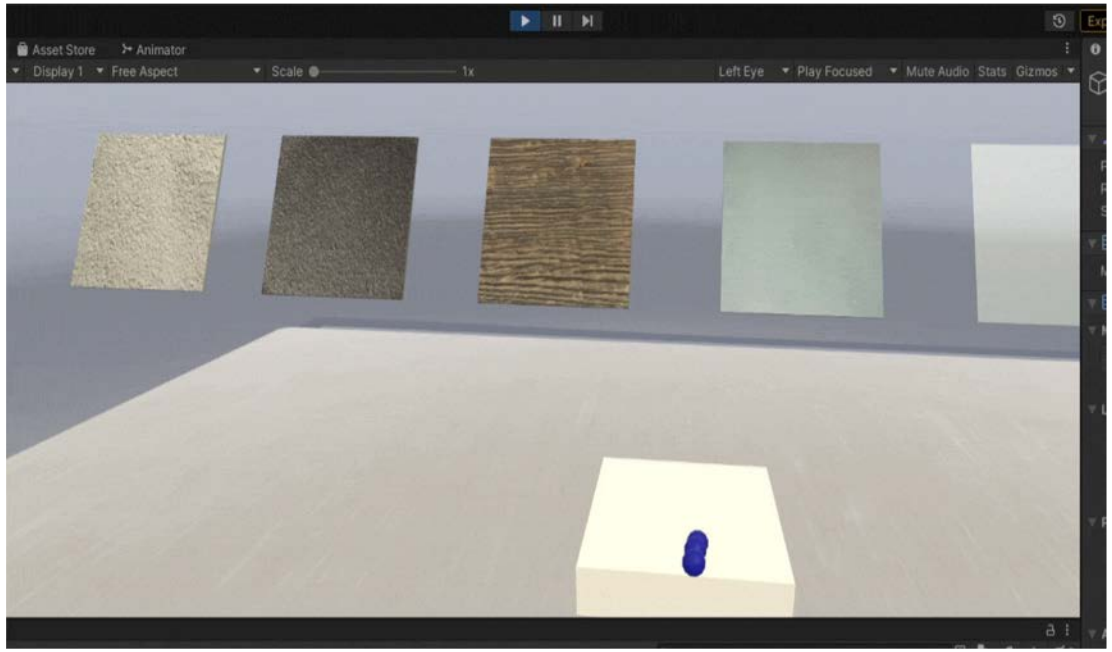
1. There are 3 groups provided different haptic feedback conditions:

➢ **Vibrotactile feedback only**

➢ **Thermal feedback only**

➢ **Both vibrotactile and thermal feedback**

1. Participants will choose the appropriate texture visualizations that matches with haptic feedback.



Data Requirements & Analysis

➢ Recognition success rate

➢ Recognition success time

➢ Compare identification accuracy between materials groups in different conditions.

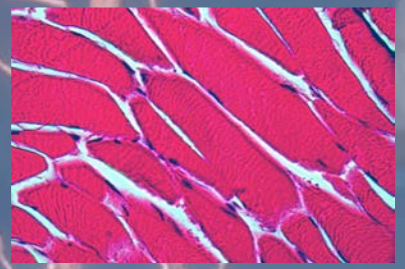
Quantitive Scale：

7 Points Likert Scale for the immersion and reality of haptic representation.

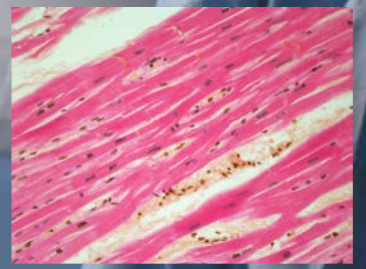
6. Application - Medical field

skin

muscle tissue



organ tissue



6. Application - Accessibility

7. Contribution and novelty

Contribution 1: Addressing a gap by focusing on multimodal haptic feedback, specifically combination of thermal and vibrotactile feedback for perceiving different textures, enabling more immersive and realistic virtual reality experience

Contribution 2: Single device, bare hand solution allows for variety of experiences within a uniform interface

Novelty: Combining thermal and vibrotactile feedback for differentiating texture perception

Q & A