Extended Reality in Industry4.0

Lecture 14: Haptic Technology in XR

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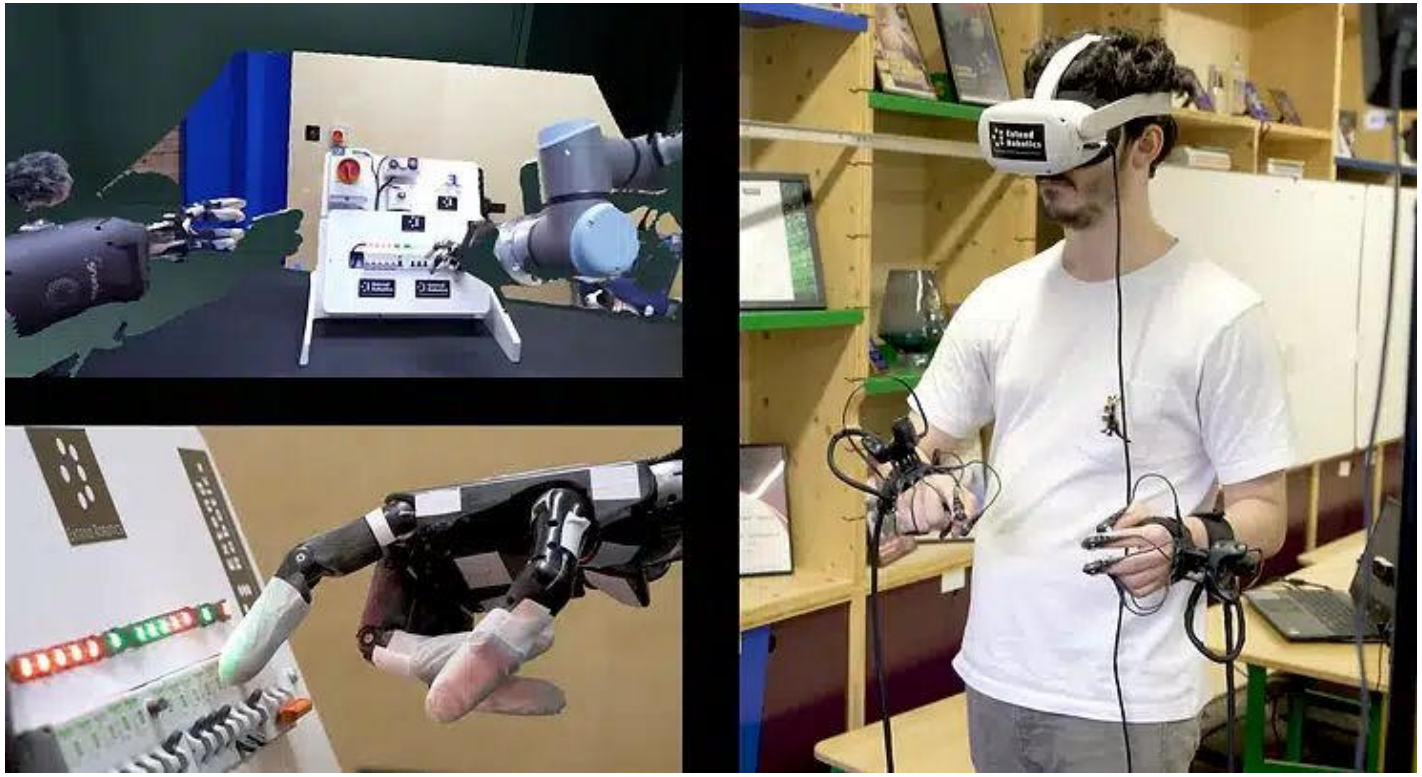
Introduction

- Haptics is the technology of adding the sensation of touch and feeling to computers.
- When virtual objects are touched, they seem real and tangible.
- It can be used to create virtual objects, manipulate virtual objects and enhance remote operation of machines and devices.



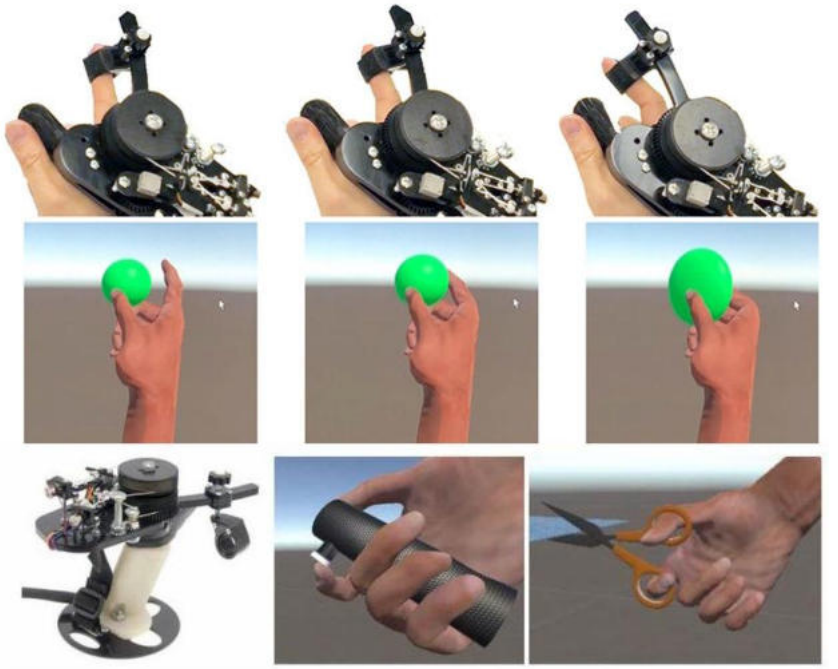
Haptics

- Derived from greek word ‘haptikos’ meaning “ABLE TO COME INTO CONTACT WITH”
- Haptics = Touch = Connection
- Touch is at the core of personal experience.
- Of the five senses, touch is the most proficient, the only one capable of simultaneous input and output

Haptics

- Haptic technology is an integral part of XR, which adds the sensation of touch by applying forces, vibration and motion to make the XR environment realistic and more immersive by enabling users to touch or grab the digital information.
- The integration of visual effects and haptic feedback, called **visuo-haptic**, can enable users to see and touch digital information in a simulated environment

A haptic VR controller



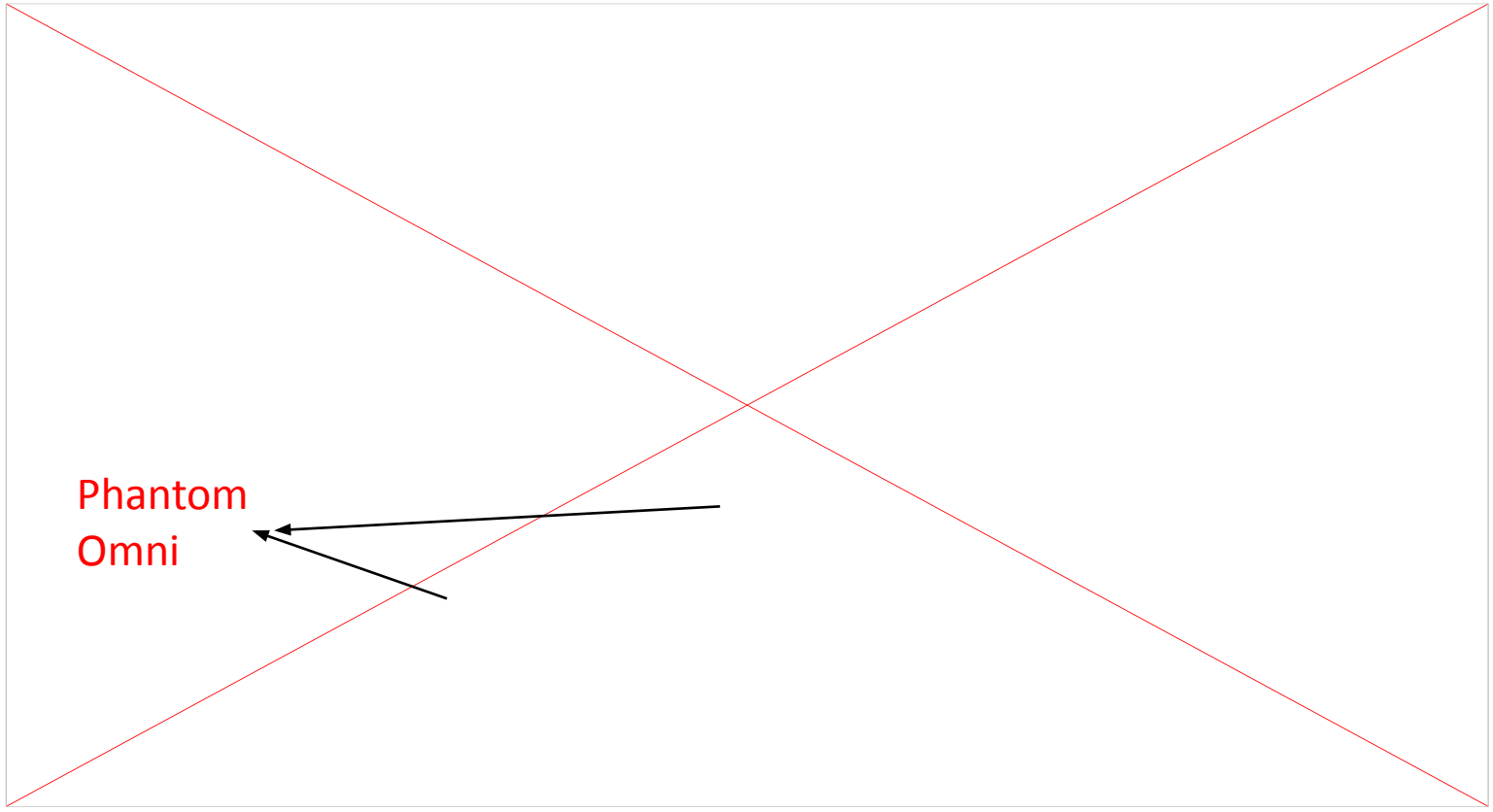
Haptic Information

Combination Of :

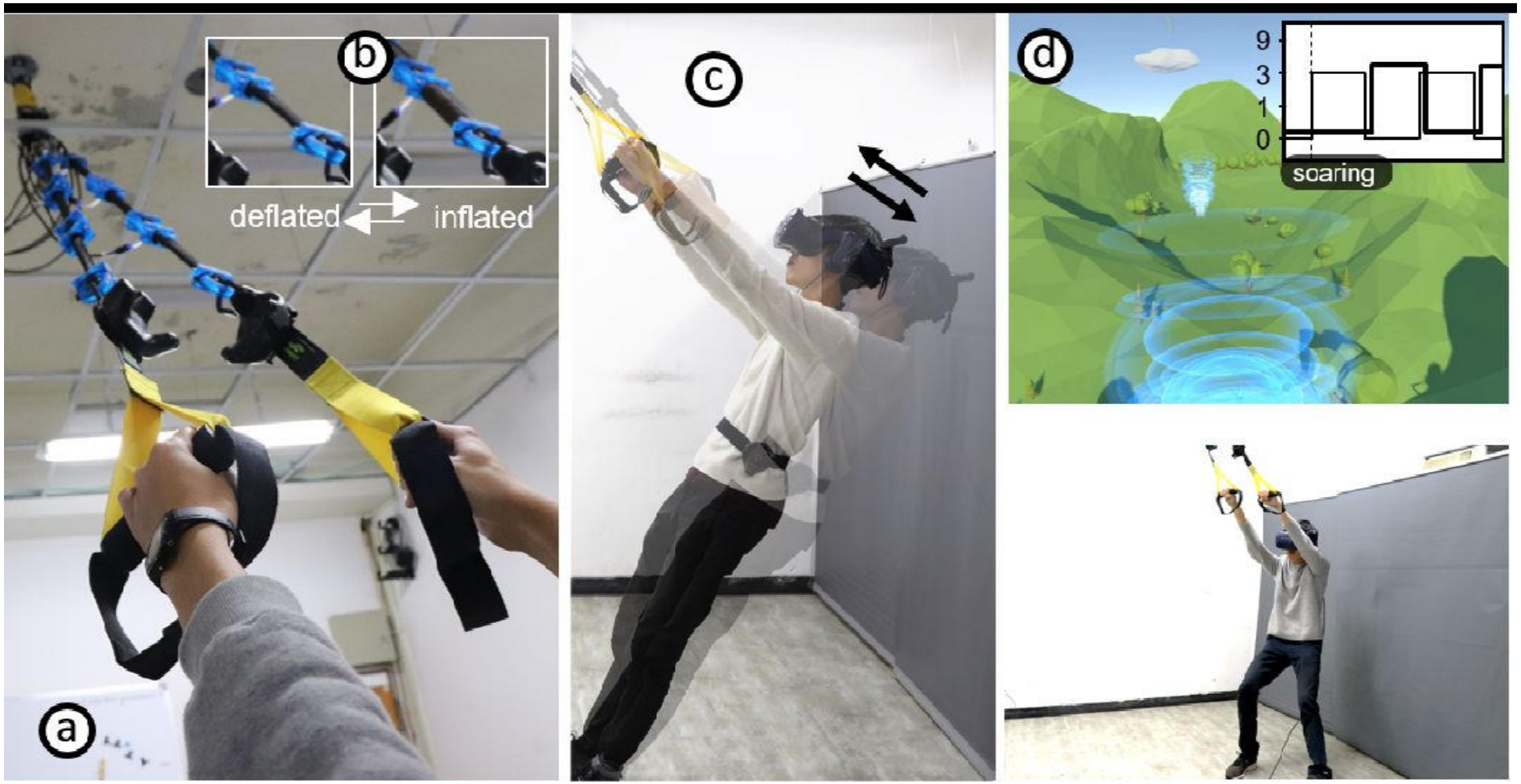
- Tactile Information
  - Refers to the information acquired by the sensors connected to the skin that describe physical qualities of objects through sensations like pressure, vibration, texture and temperature.
- Kinesthetic Information
  - Refers to the information acquired by the sensors in the joints that describe the physical quantities of objects such as weight, stiffness, hardness.

Kinesthetic feedback

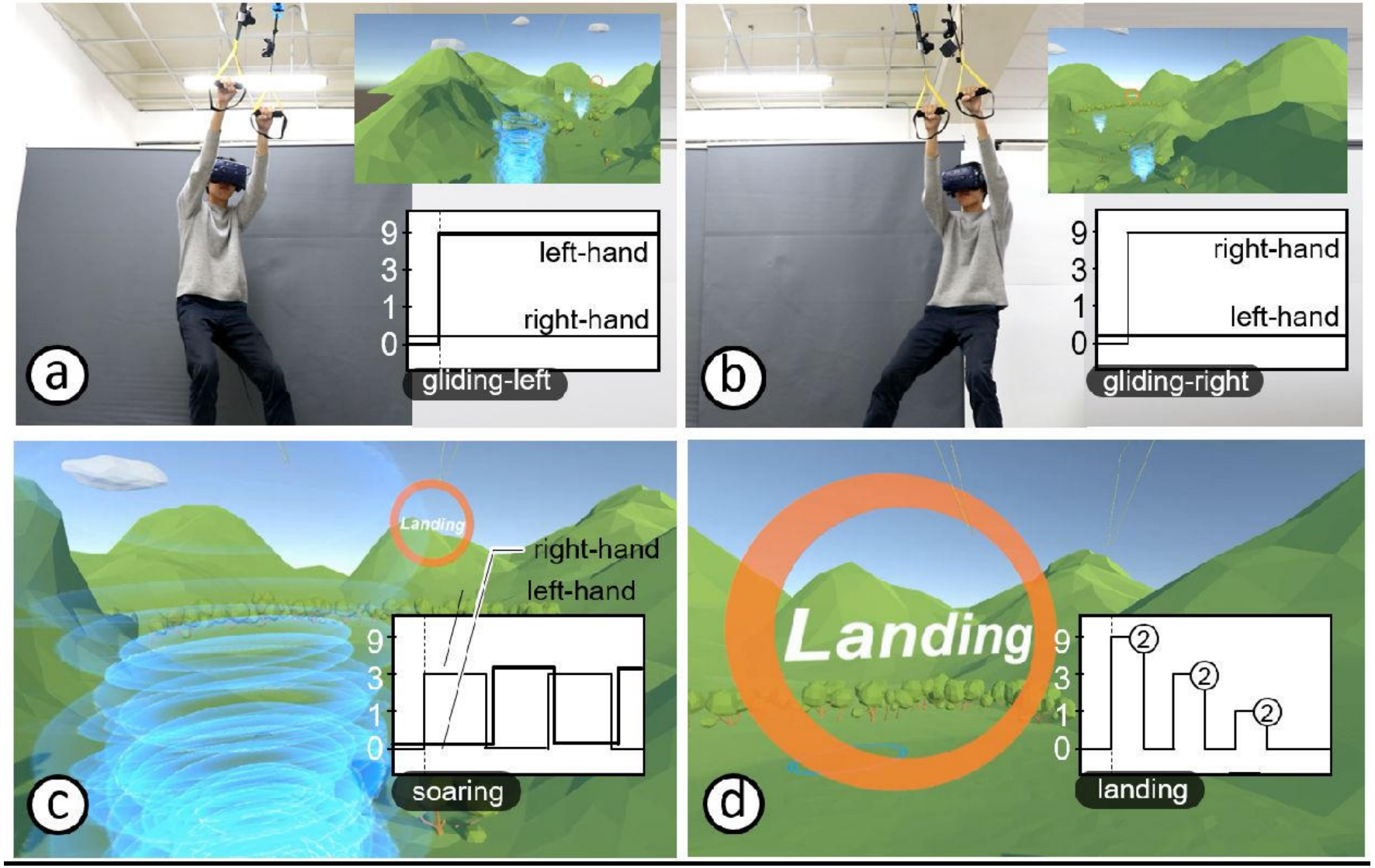
Kinesthetic feedback enables the user to perceive the size and density of an object through physical sensation.



Kinesthetic feedback

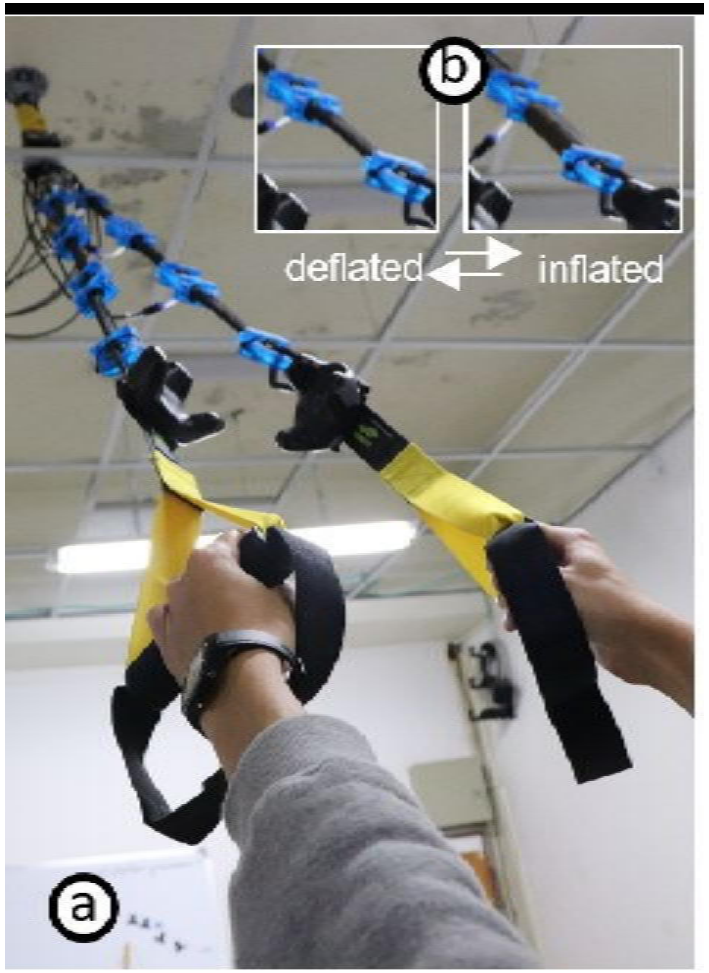


Kinesthetic feedback



Kinesthetic feedback

- Suspension kits contain two-handled straps hooked up to the ceiling. The straps have been replaced with air muscles.
- Air Muscles produce linear motion created by retraction or extension of an inner pneumatic tube, operated by pressurized air filling the tube.
- To allow for sufficient distances that produce stronger kinesthetic forces, three air muscles have been linked up for each strap, which added to 15 cm displacement in total.
- Between the muscle group's up-hook and ceiling hook, a load sensor (ZLBM-102) has been attached to measure the weight of the user's exerted force on each hand and in total.
- The scale of force is such that it can act the user's body to move to create a bodily-kinesthetic sensation.
- The strap can sustain no greater than 20 kg.



Tactile feedback

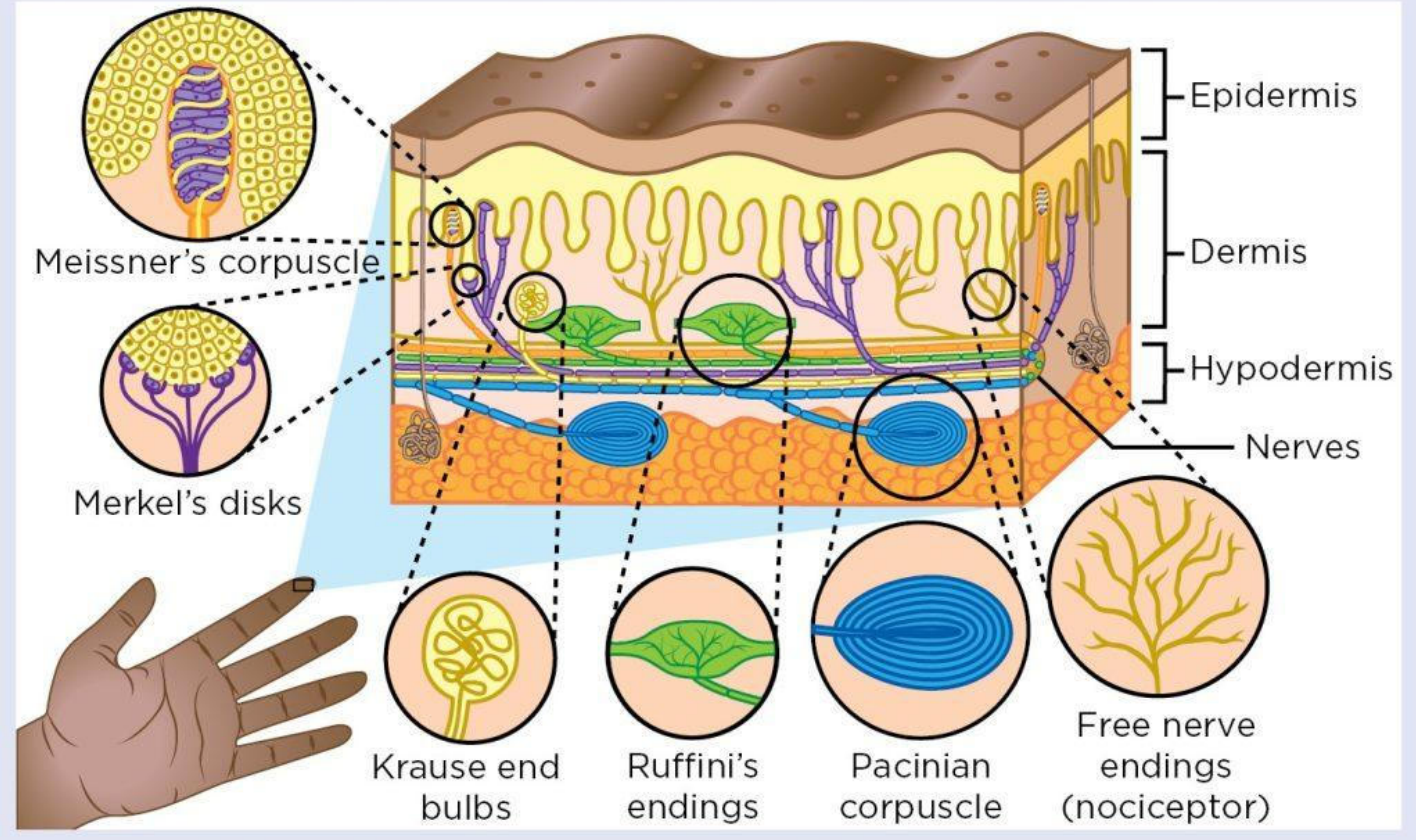
Tactile feedback typically refers to the sense of touch or the physical contact between a user and a device to transmit information and communicate with the user, such as a mobile phone vibration. Tactile feedback can include vibrations, textures, temperature changes, and pressure sensations.

Mechanoreceptor in finger tissue

Sensory nerve endings in the fingers include

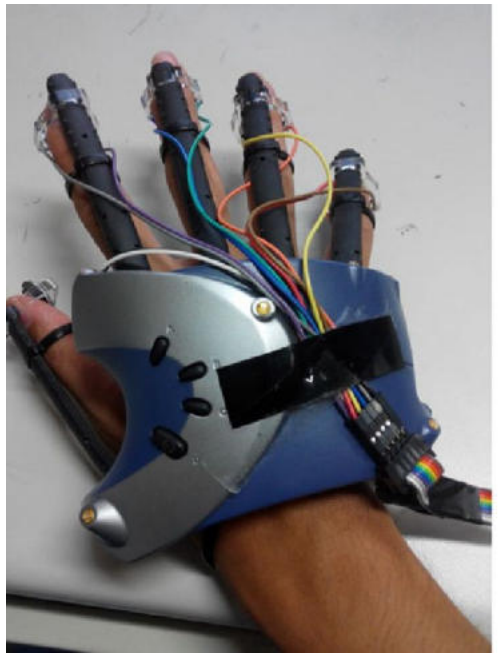
- **Meisnner's corpuscles** (light touch, low frequency vibrations)
- **Pacinian corpuscles** (large receptive fields, detecting fine surface textures, high frequency),
- **free nerve endings** (temperature and pain),
- **Merkel discs** (light touch discrimination of objects and texture, prolonged pressure, object's weight)
- **Ruffini endings** (skin stretching, movement and finger position).

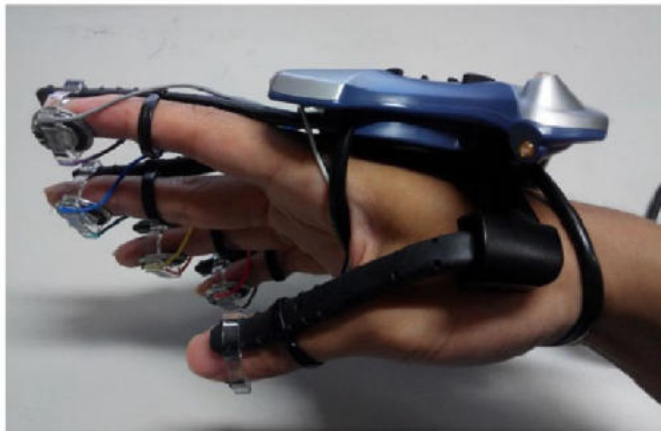
Combined, these receptors allow for the sense of touch and discrimination of shapes, textures, and objects, are responsible for the sensations of heat and pain, and give information on where the hand and fingers are in relation to the body




Subject interacts with virtual object

Tactile feedback





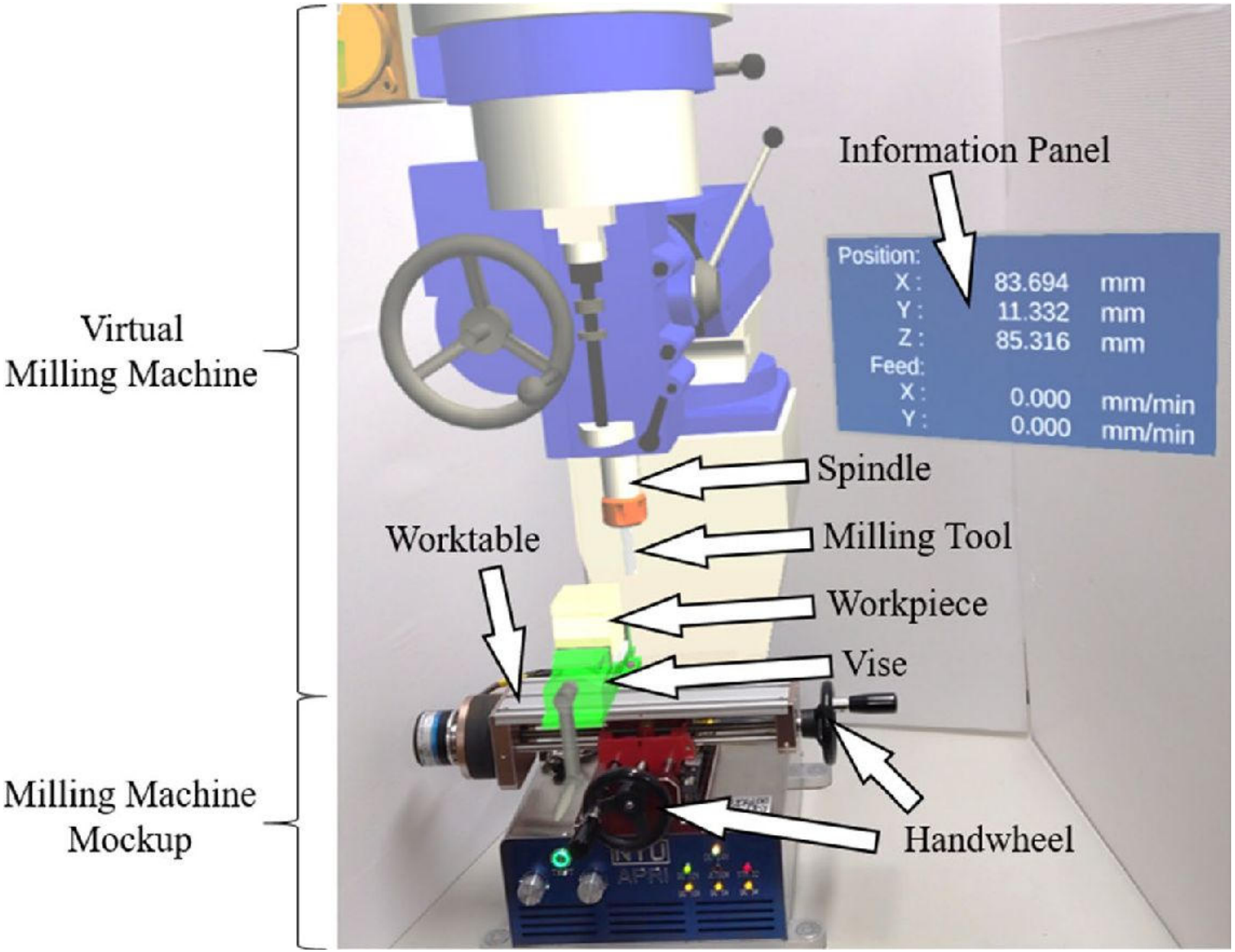
Types of Haptic Devices

Telerobotics-based devices and force feedback-based devices

- Exoskeletons devices
- Gloves and wearable devices
- Specific task devices
- Locomotion interfaces
- Force feedback devices
- Tactile display devices

Exoskeleton device

Specific task device



Specific task device

Magnetic force and thermal feedback

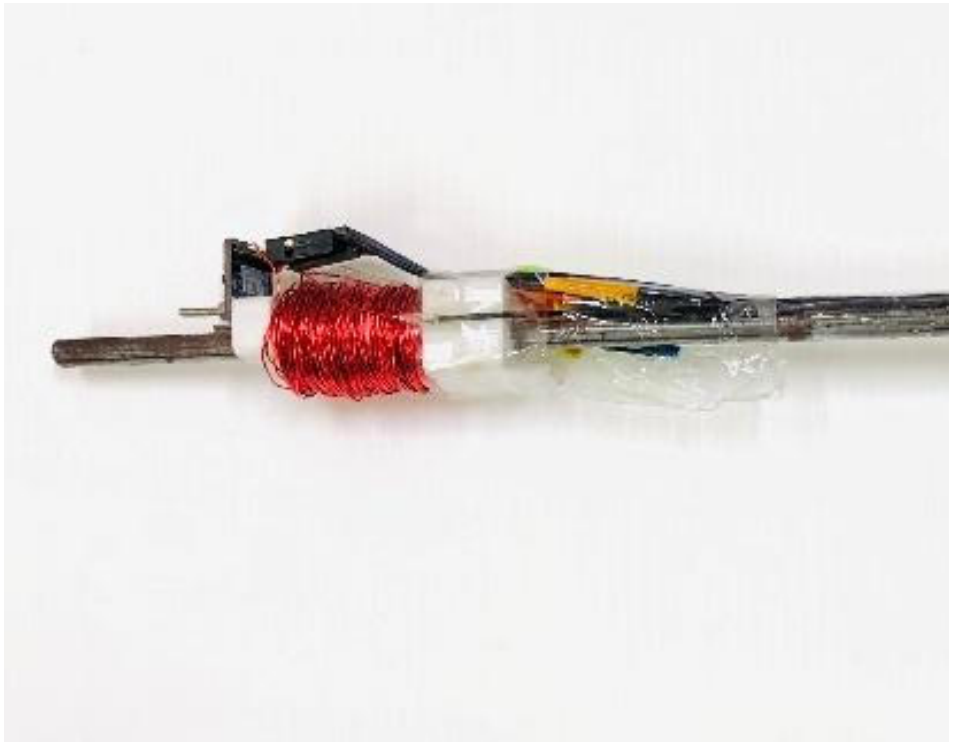


Fig. Simulated magnetic force by forming electromagnet

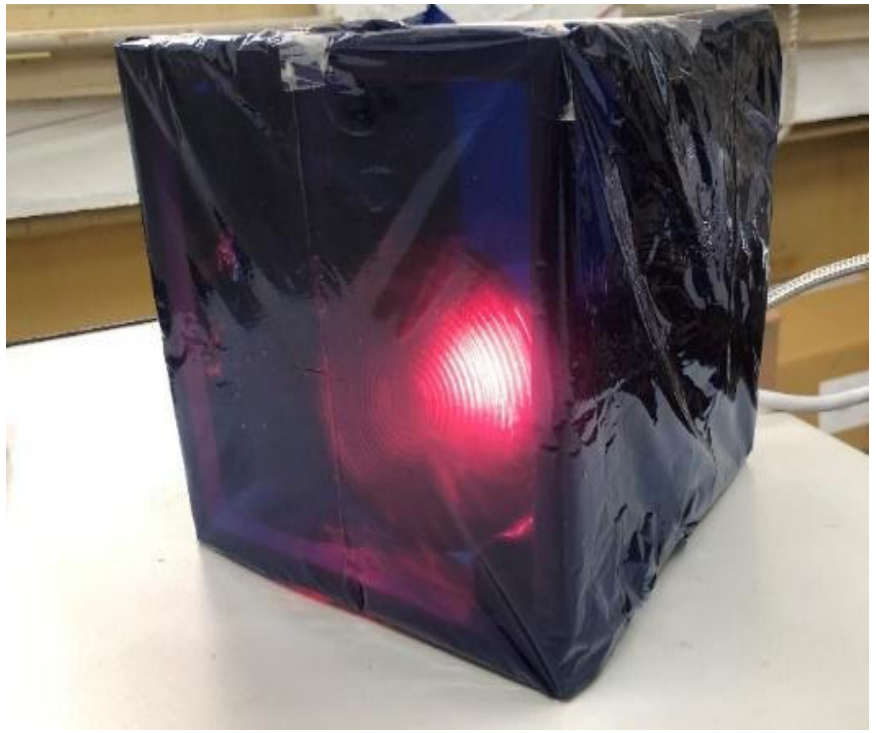


Fig. Infrared heat lamp inside a box made of translucent plastic foil.

Method

According to Ampere's law, the magnetic field can be obtained as follows.

$$B = \mu_0 \left(\frac{N}{L} \right) I$$

The current flowing through the coil is evaluated by using Ohm's law.

$$V = IR$$

The amount of current is increased by increasing the voltage capacity of batteries by using three batteries joined in series.

The magnetic force on the tip of the electrode rod is evaluated as follows.

$$F = \frac{\pi r^2 B^2}{2\mu_0} \left(\frac{\mu_m}{\mu_0} - 1 \right)$$

Parameters	Values	Unit
Number of turns (N)	610	-
Diameter of wire of coil (d)	0.405	mm
Diameter of electrode (core) rod	6	mm
Voltage of battery (V)	3.7	V
Number of batteries (i)	3	-
Permeability of free space (μ_0)	$4\pi \times 10^{-7}$	N/A^2
Permeability of electrode rod material (μ_m)	1.26×10^{-4}	N/A^2
Resistivity of copper wire (ρ)	1.68×10^{-8}	$\Omega \cdot m$
Length of coil (L)	30	mm

Method

Calculated results	Values	Unit
Current in coil (I)	3.233	A
Magnetic field (B)	0.0825	Tesla
Magnetic force (F)	7.6	N

Magnetic force induced during real welding process = 22.3 N

Table. Three different welding conditions.

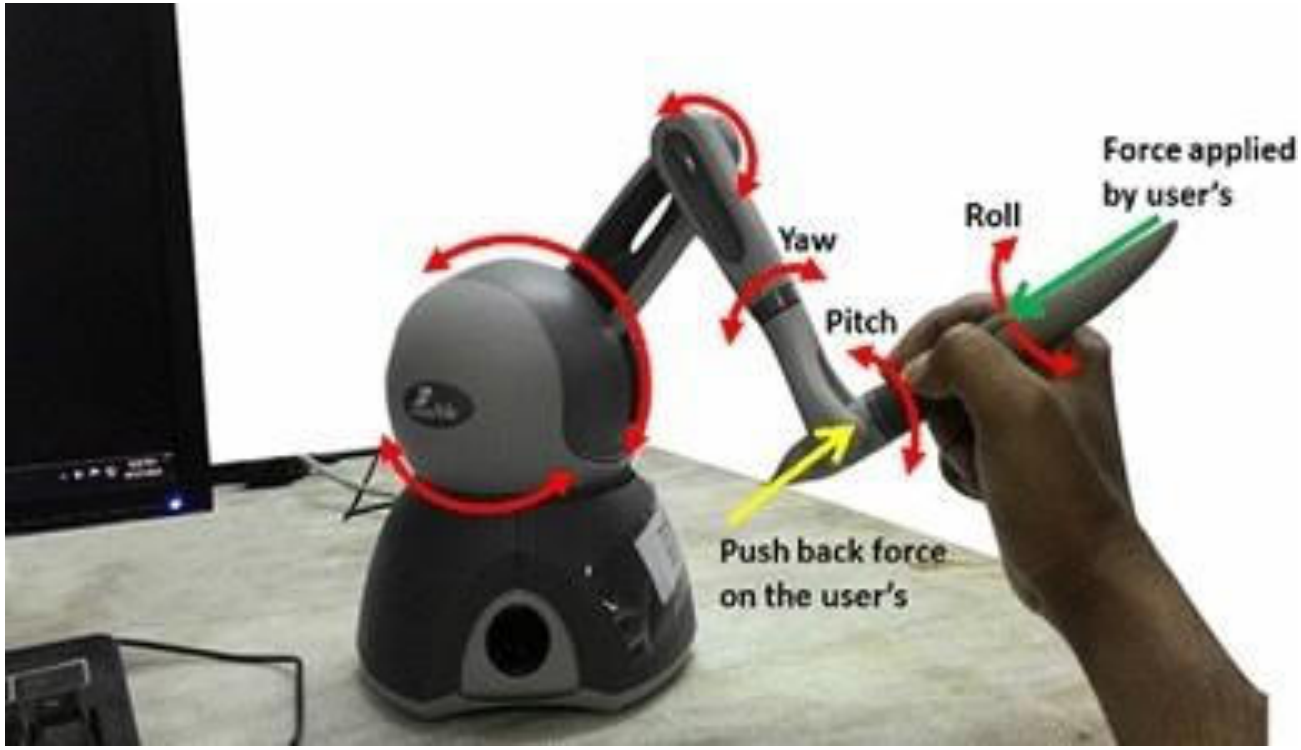
	Case I (Arc length < 2 mm)	Case II (2 mm ≤ Arc length ≤ 8 mm)	Case III (Arc length > 8 mm)
Magnetic force feedback	Enabled	Disabled	Disabled
Thermal feedback	Disabled	Enabled	Disabled
Virtual arc generation	No	Yes	No
Auditory feedback	Disabled	Enabled	Disabled
Speed indicator	Stop	Move	Stop

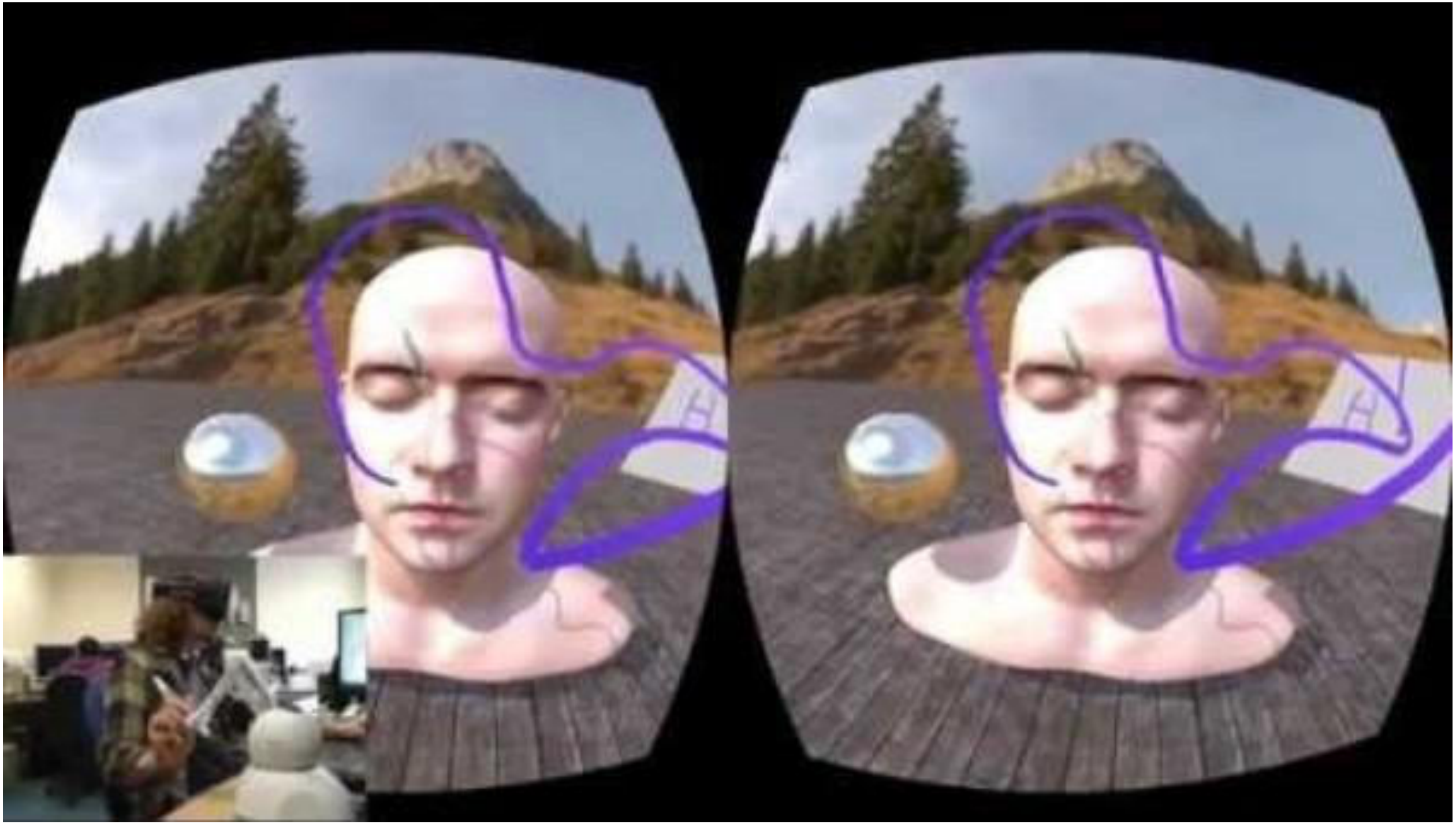
Locomotive device

Commonly used Haptic Devices

1. PHANTOM Omni

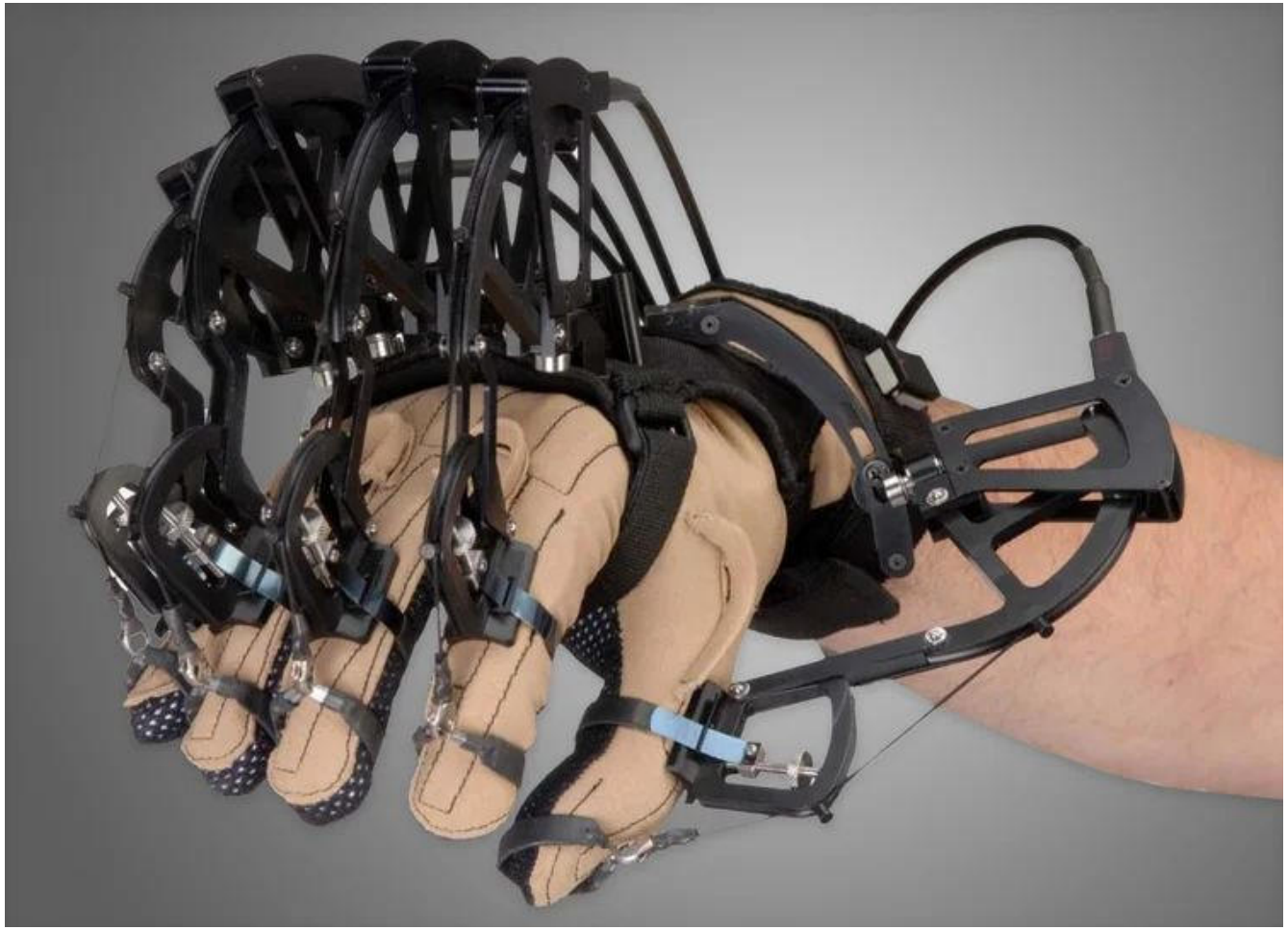
- providing a 3D touch to the virtual objects
- provides 6 d.o.f
- when the user move the end effector of Phantom device, he/she could really feel the shape and size of the virtual 3D object that has been already programmed





2. CYBER GRASP

- The CyberGrasp system fits over the user's entire hand like an exoskeleton and adds resistive force feedback to each finger
- Allows 4 DOF for each finger
- Adapted to different size of the fingers
- Located on the back of the hand



Applications of Haptics

Medical Applications

- Sense of touch is crucial for medical training
- various haptic interfaces for medical simulation may prove especially useful for training.

Military Applications

- For certain applications, for example where terrain or texture information needs to be conveyed, haptics may be the most efficient communication channel.

Assistive Technology for the Blind and Visually Impaired

- feel maps that are displayed on the internet and also learn mathematics by tracing touchable mathematical course

Museum display

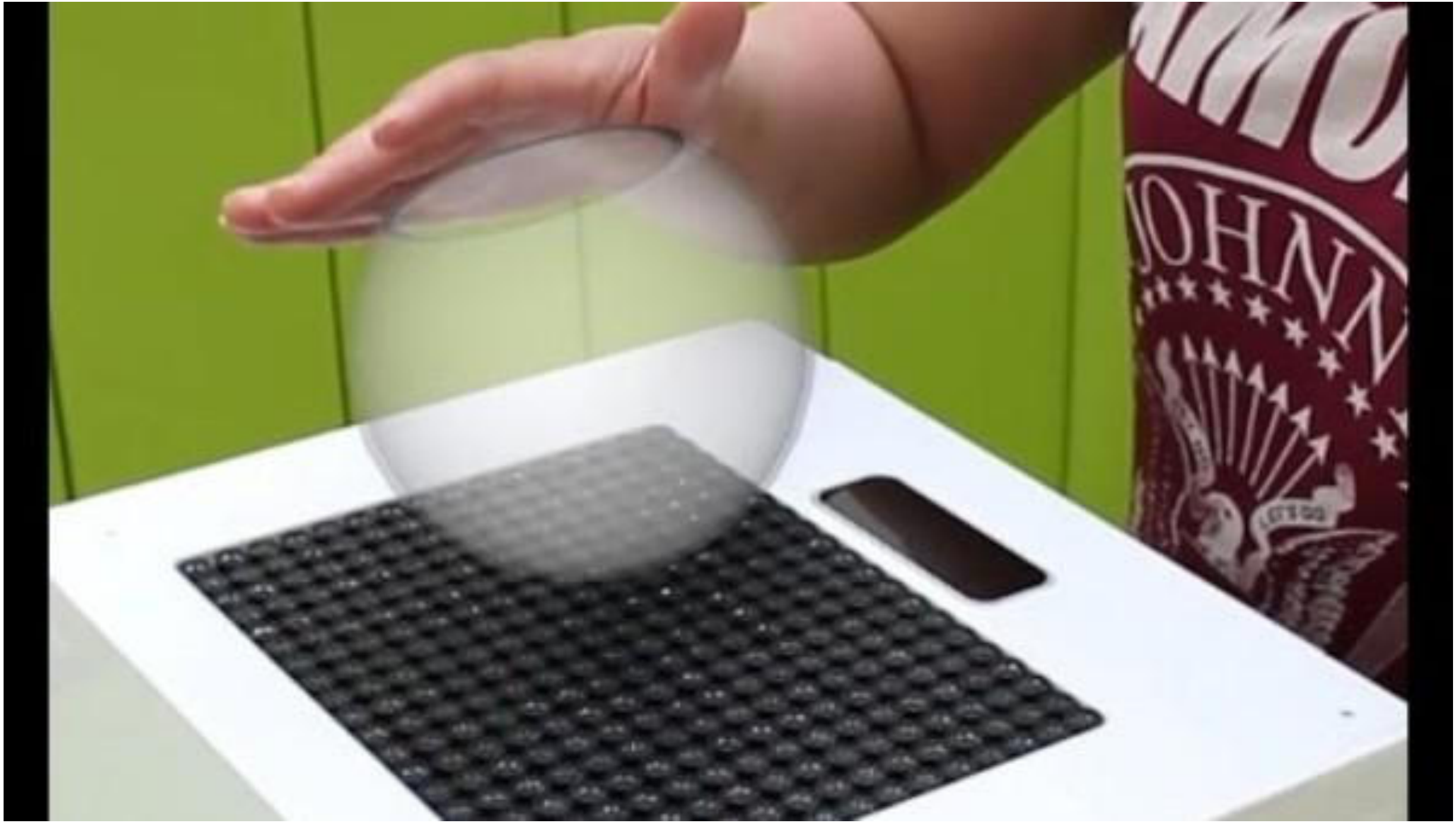
- for 3D digitization of priceless artifacts and objects from their sculpture and decorative arts collections

Entertainment

- Haptics is used to enhance gaming experience
- software also allows you to program force feedback sensations to your game controller button press
- 7D movies

Holographic Interaction

- The feedback allows the user to interact with a hologram and receive tactile response as if the holographic object were real
- Ultrasound waves to create a phenomenon called *acoustic radiation pressure* which provides tactile feedback as users interact with the holographic object.



Technical overview of haptics

Haptic technology is similar to a mechatronic system that is an integration of electrical and electronic devices in the mechanical system.

Elements of haptic systems:

1. Electrical system
2. Mechanical system
3. Computer system
4. Sensors and actuators

Microcontroller

- It is the integration of a **microprocessor** with memory and **input/output interfaces** on a single chip. Example, Arduino Uno, Arduino Nano
- Microcontrollers are desired to perform specific tasks where the relationship of input and output is defined.
- It reads inputs from sensors and turn it into output to activate an actuator.

Sensors

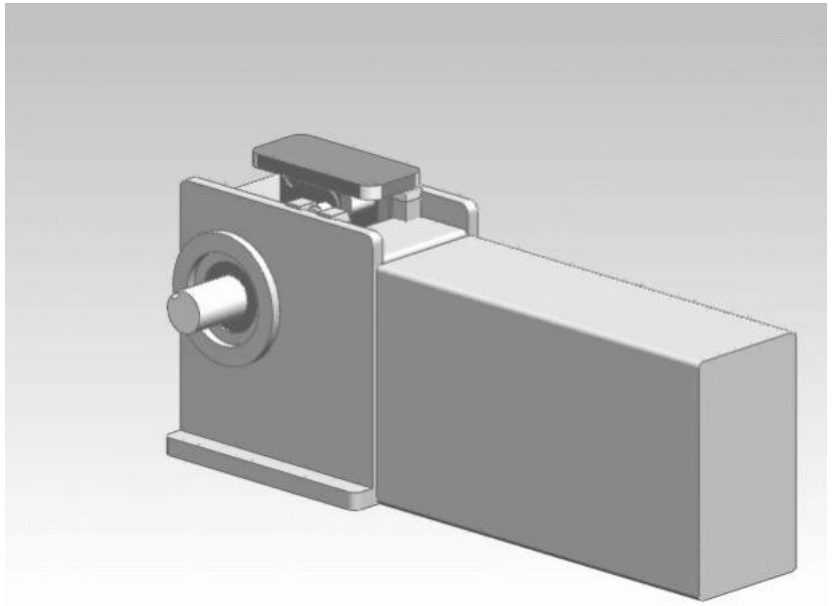
- A device which provides a usable output in response to a specific measure is defined as **sensor**. Hence output is usually an electrical quantity and property which is to be measured.
- **Transducer:** It is defined as an element which, when subjected to a physical change experiences a related change which converts a specified measure into a usable output. (a device that converts the signal from one form to another form.) Example: Speaker, microphone, motors
- When a **transducer** converts a measurable quantity (sound, pressure level, optical intensity etc.) into an electrical voltage or current then it is called a **sensor**. Examples: temperature, pressure, proximity sensor

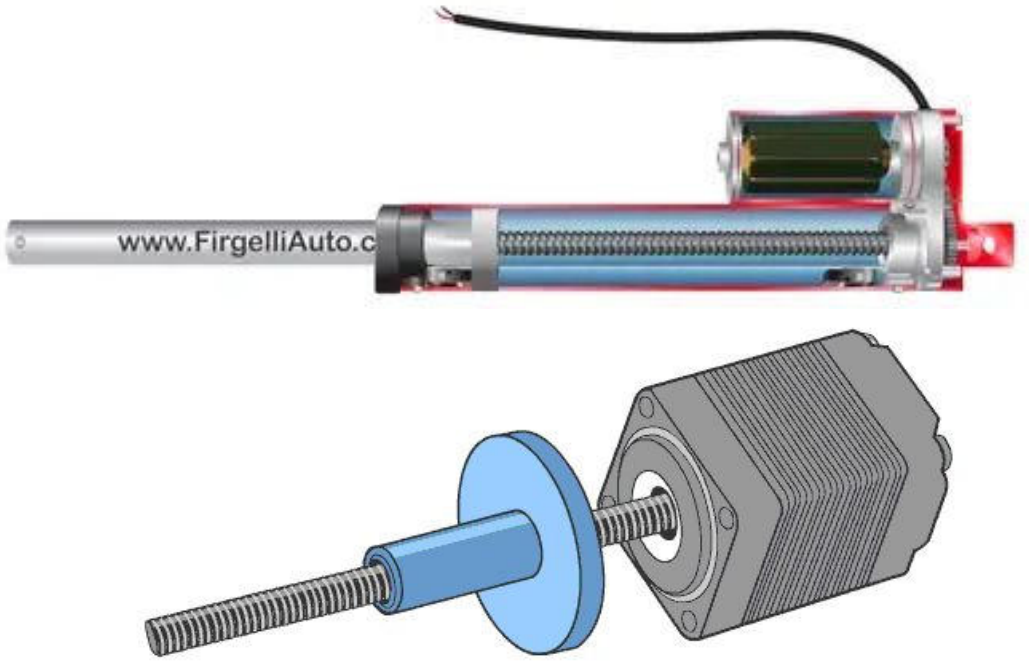
Types of Sensors

1. Velocity and motion sensors
2. Force sensors
3. Fluid pressure sensors
4. Displacement, position and proximity sensor
5. Temperature sensors

Actuators

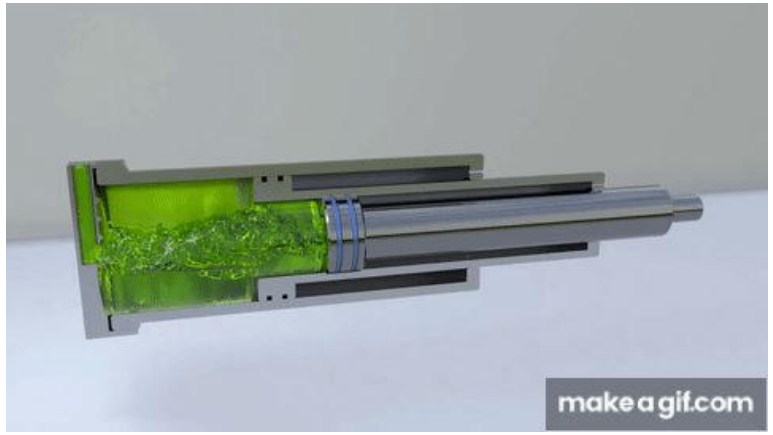
- Actuators produce physical change such as linear and angular displacements.
- There are four types of actuators:
  1. Mechanical: may not be programmed easily but generate large amount of mechanical power

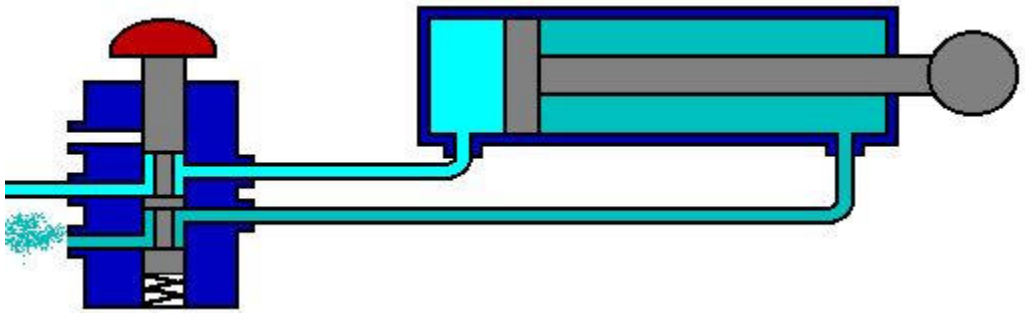


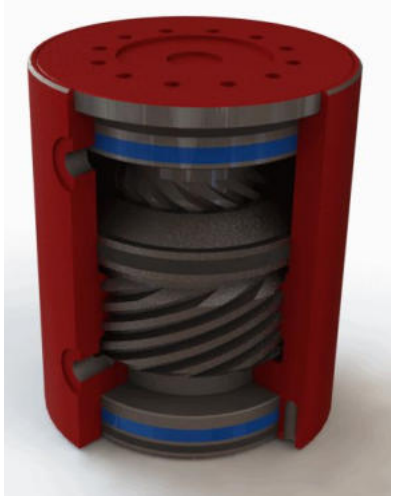


Actuators

- Hydraulic: Used to convert fluid pressure energy into mechanical power.
  a. Linear actuators: For linear force and motion, provide motion in a straight line
  b. Rotary actuator: For rotary actuation







Actuators

3. Pneumatic: These are the devices used for converting pressure energy of compressed air into the mechanical energy to perform useful work.
4. Electrical actuators: Easily programmable, highly precise but provide very low mechanical power.

Limitations of haptic technology

- High cost involved
- Large weight and size of haptic devices (especially wearable ones)
- Haptic interfaces can only exert forces with limited magnitude and not equally well in all directions

Future Vision

1. Medical Application

2. Thermal feedback

3. Taste rendering

4. Smell rendering