Haptics

CS 6334 Virtual Reality

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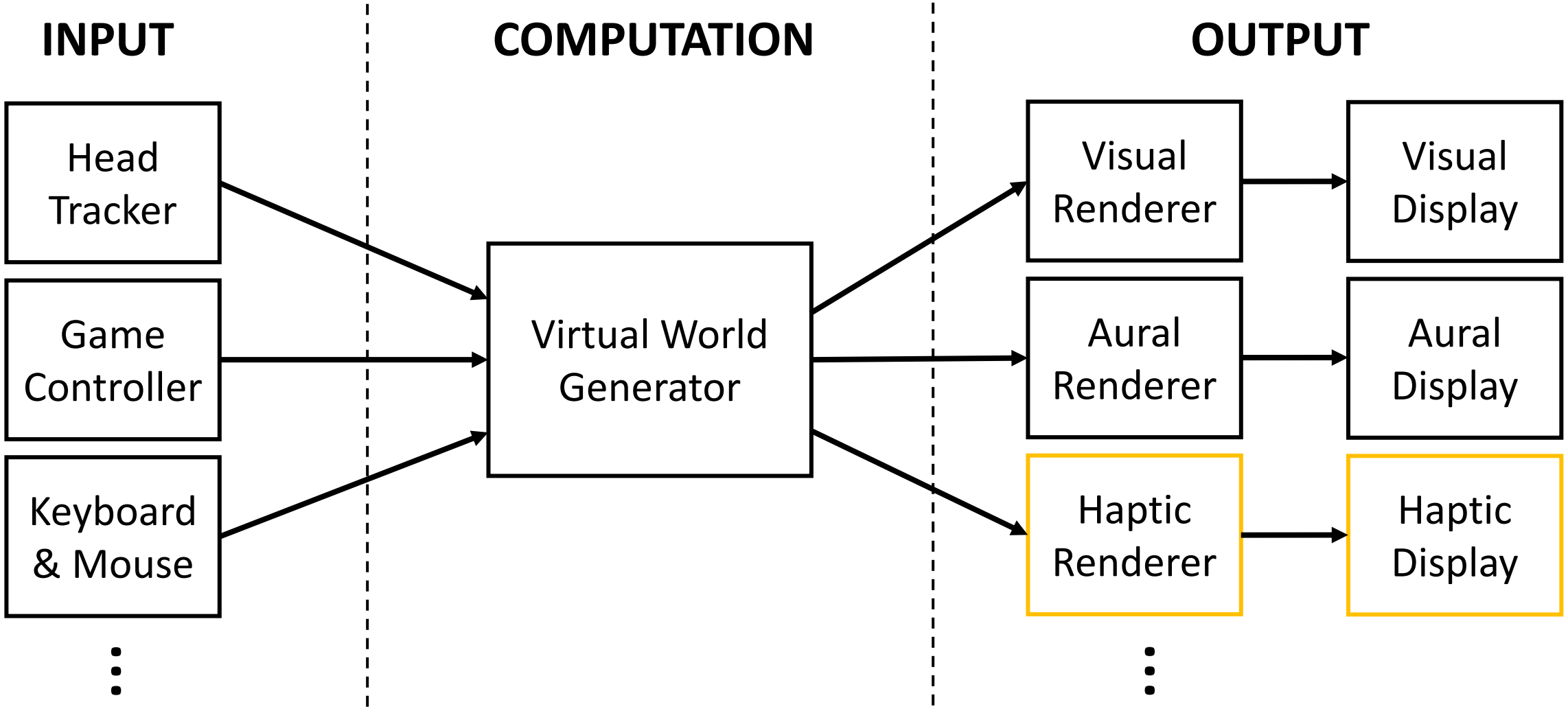
The University of Texas at Dallas

Review of VR Systems

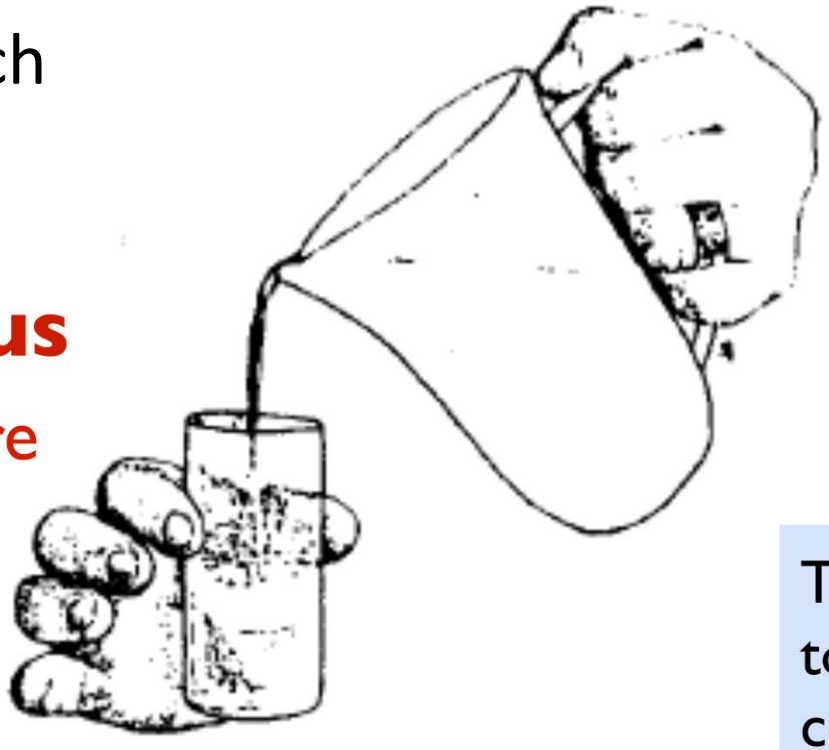


Haptics

- The sense of touch

Cutaneous

Temperature
Texture
Slip
Vibration
Force



Johansson and Westling

Kinesthesia

Location/configuration
Motion
Force
Compliance

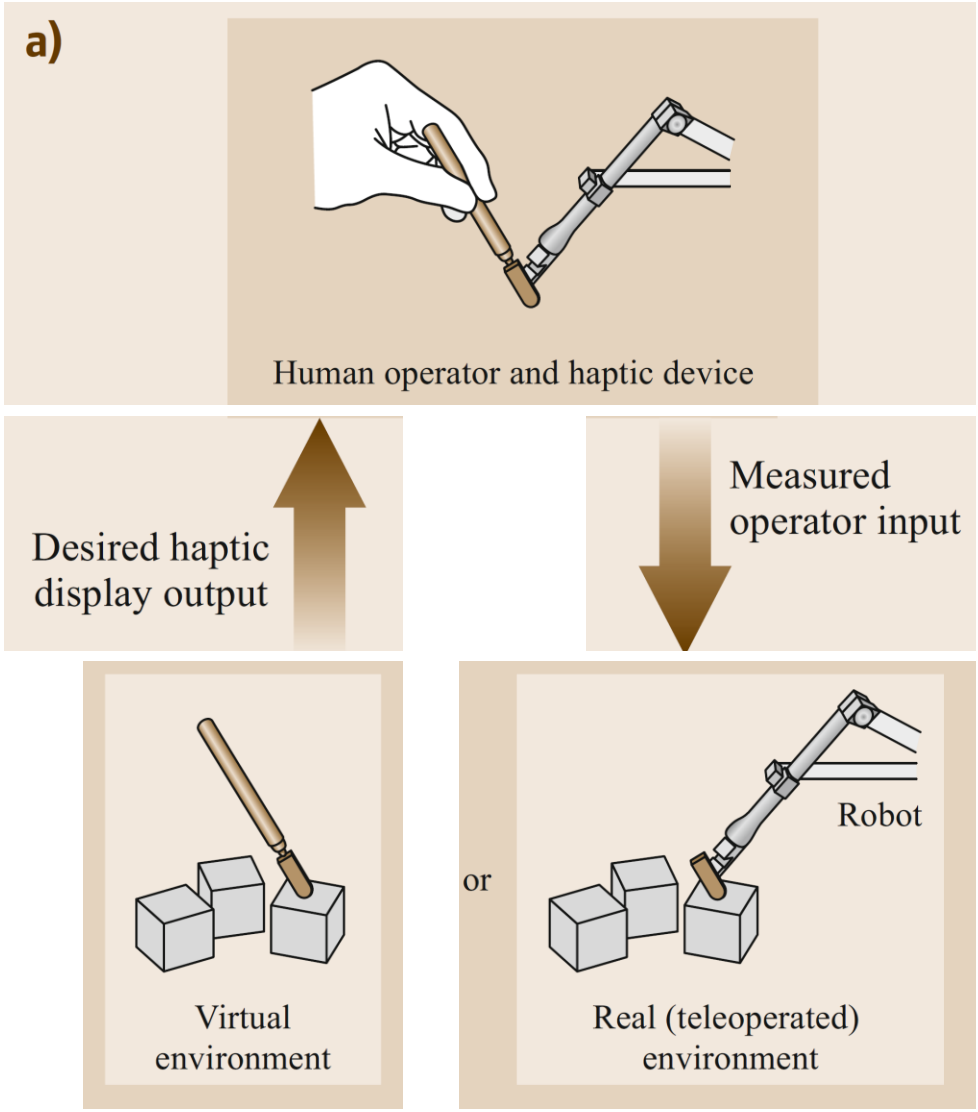
The haptic senses work together with the motor control system to:

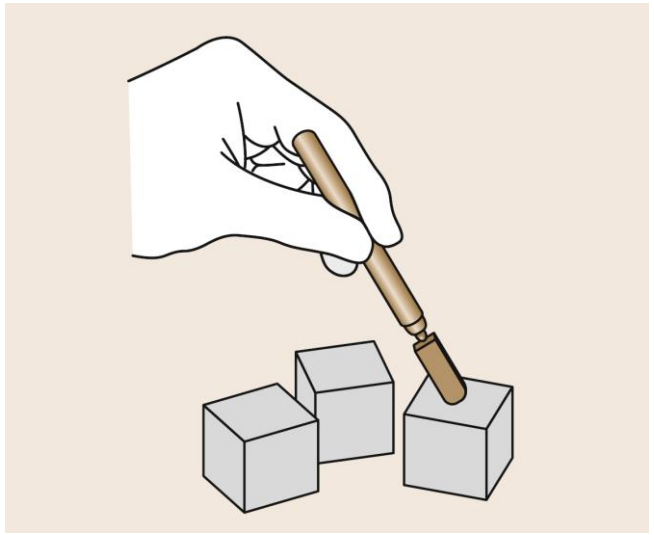
- Coordinate movement
- Enable perception

J. Edward Colgate

Haptic Interfaces

The *haptic loop* of a generic haptic interface

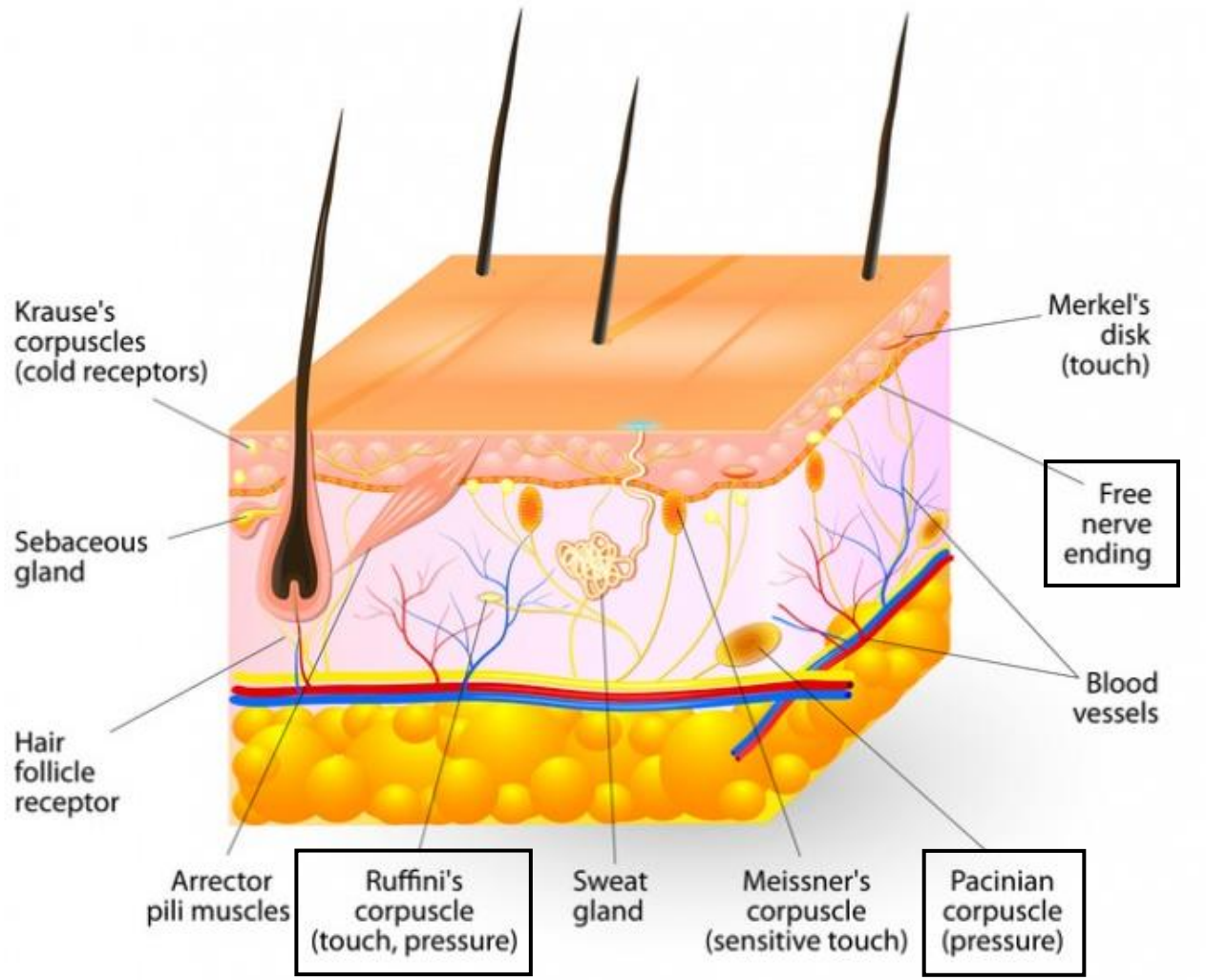




Human Haptics

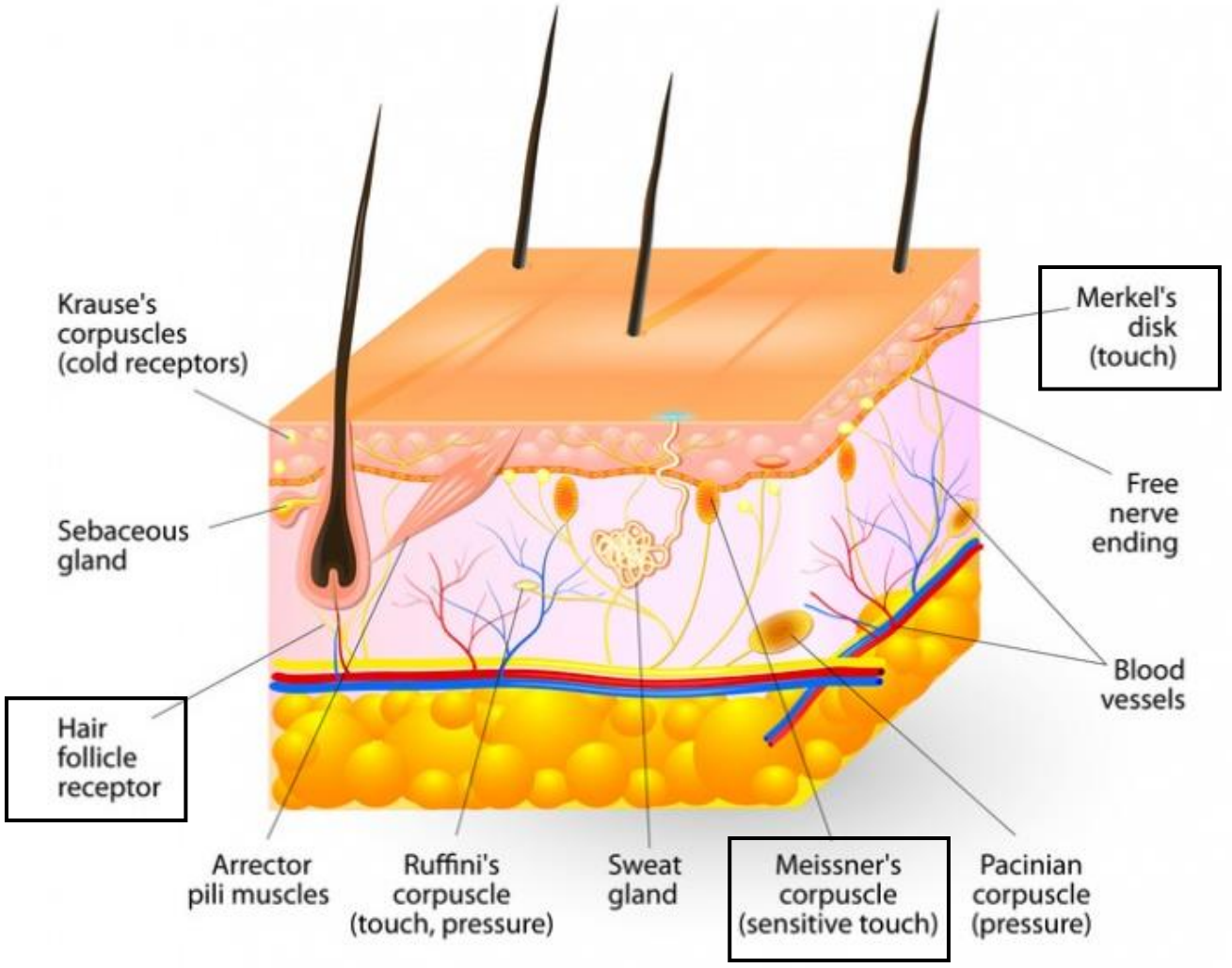
- Kinesthesia
  - The internal sensing of forces and displacements inside muscles, tendons, and joints (velocities, accelerations, and forces)
  - Also referred as proprioception, the sense of self-movement and body position (usually refer to positions)
- Tactile sensing
  - The sensation of deformations of the skin

Touch Receptors



- Free nerve endings
  - Axons extend up into the outer skin
  - Sensing temperature extremes (hot and cold), pain from tissue damage
- Ruffini's endings or corpuscles
  - Signal the amount of stretching at any moment
- Pacinian corpuscles
  - Small bodies filled with fluid, respond to pressure
  - Sense vibrations of up to 250 to 350 Hz

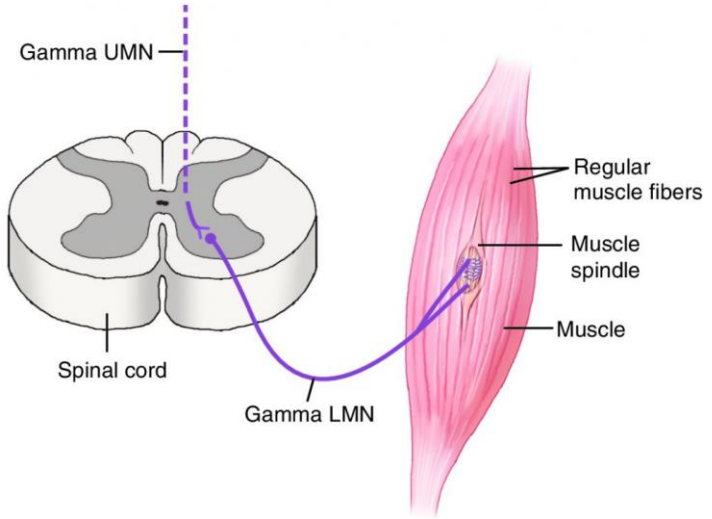
Touch Receptors

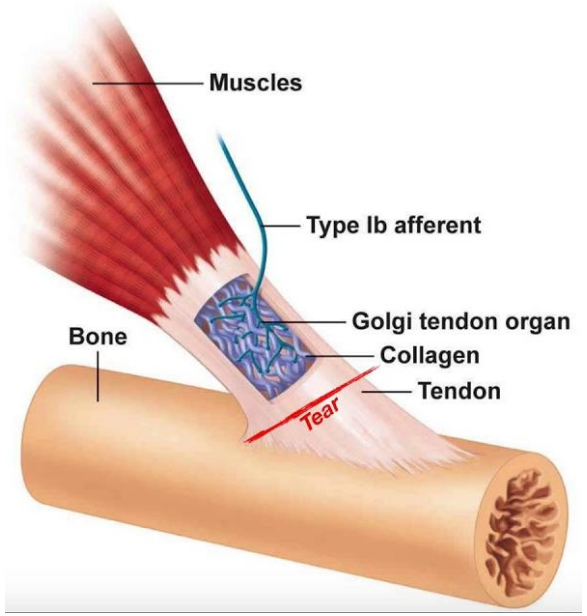


- Merkel's disks
  - Response to static pressure
  - Slow temporal response
- Meissner's corpuscles
  - Response to lighter touch
  - Sense vibration up to 30 to 50 Hz
- Hair follicle receptors
  - Light touch sensation
  - Pain if the hair is removed

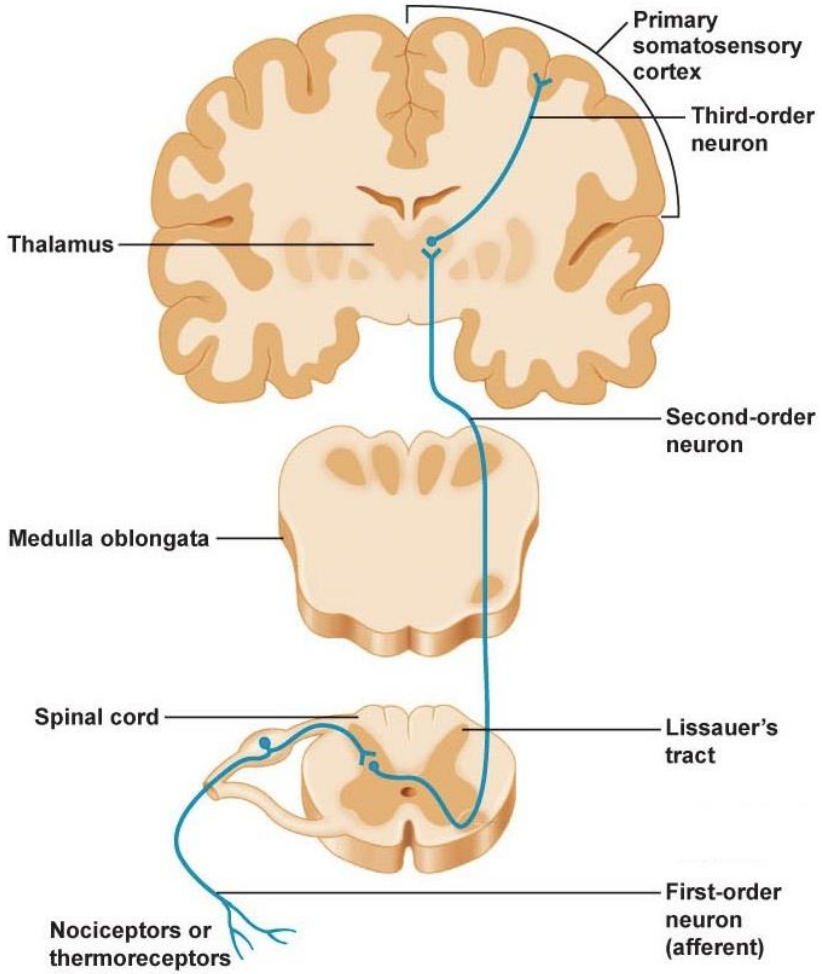
Kinesthesis Receptors

- Muscle spindles
  - Embedded inside of each muscle
  - Report change of length
- Golgi tendon organs
  - Report changes in muscle tension
- Joint receptors
  - Lie at the joints between bones
  - Report relative bone positions





Somatosensory Neural Pathway



Long before the thalamus, some of the signals are also routed through the spinal cord to motor neurons that control muscles

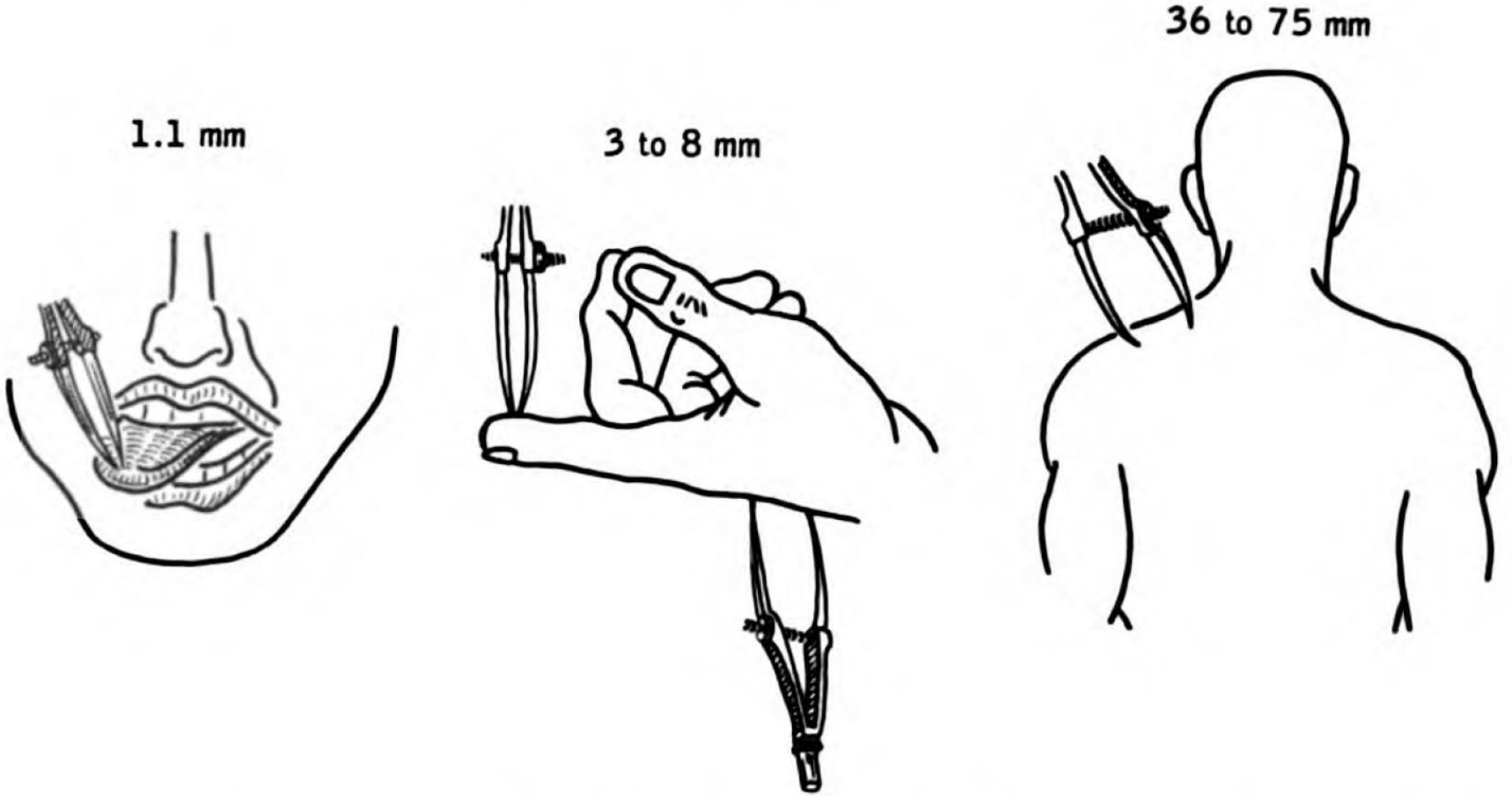
- Knee-jerk reflex

Touch Resolution

- Spatial resolution
  - The density or receptors per square area
  - Density high at fingertips, low on the back

- Temporal resolution
  - Pacinian corpuscles allow vibrations up to a few hundred Hertz to be distinguished from a static pressure

Two-point Acuity



From wikipedia

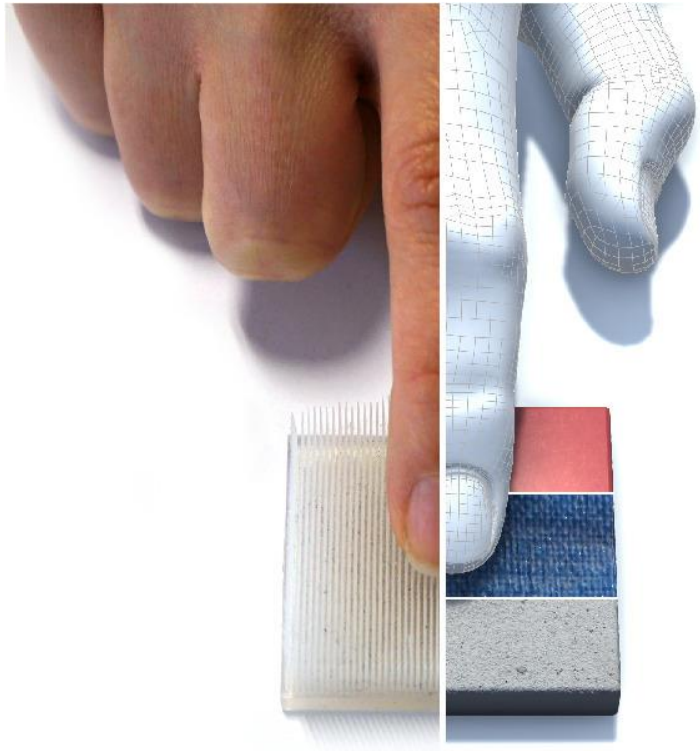
Neurons that correspond to the back have much larger fields (in terms of skin area) than those of the fingertip.

Texture Perception

- Running fingers over a surface

- Duplex theory
  - Coarse textures are mainly perceived by spatial cues (pressing the finger against the surface)

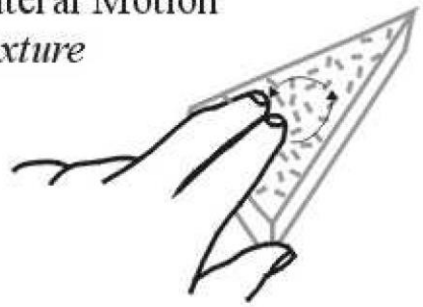
  - Fine textures are perceived by temporal cues (the finger is slid across the surface, resulting in a pressure vibration)



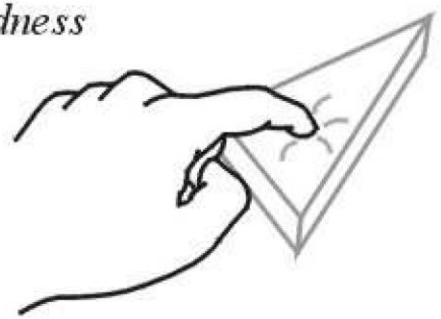
https://dl.acm.org/doi/fullHtml/10.1145/3290605.3300479

Haptic Perception

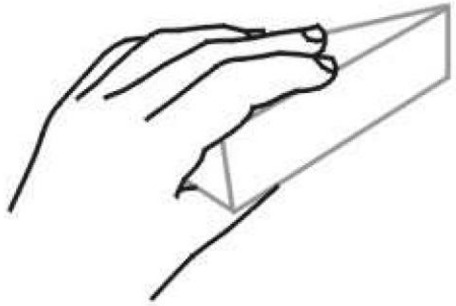
Lateral Motion
Texture



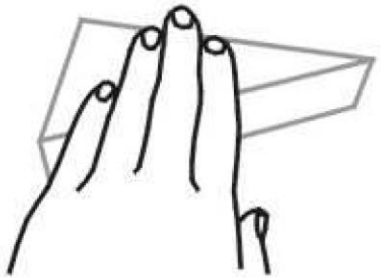
Pressure
Hardness



Enclosure
Global shape/Volume

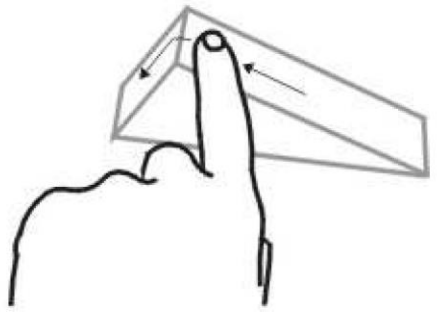


Static Contact
Temperature



Unsupported Holding
Weight

Contour Following
Shape



Haptic exploration (also refer to as *exploratory procedures*)

Somatosensory Illusions

Figure 13.3: The *rubber hand illusion*, in which a person reacts to a fake hand as if it were her own. (Figure from Guterstam, Petkova, and Ehrsson, 2011 [108])

Somatosensory Illusions

https://ri-science.tumblr.com/post/161089570687/proprioception-is-the-sense-of-your-own-body/embed

Examples of Haptic Interfaces

(a)

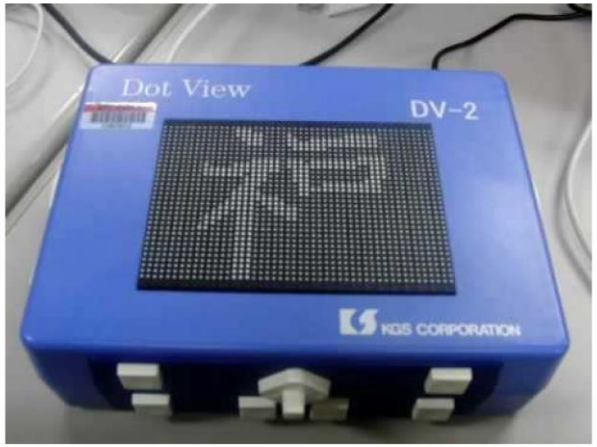
Logitech M325 wireless mouse

(b)

Sega Dreamcast Jump Pack: vibrations

(c)

Haptic Omni: pressure and vibrations



(d)

KGS Dot View Model DV-2: haptic pin array

Examples of Haptic Interfaces

Phantom Premium (3 DOF)

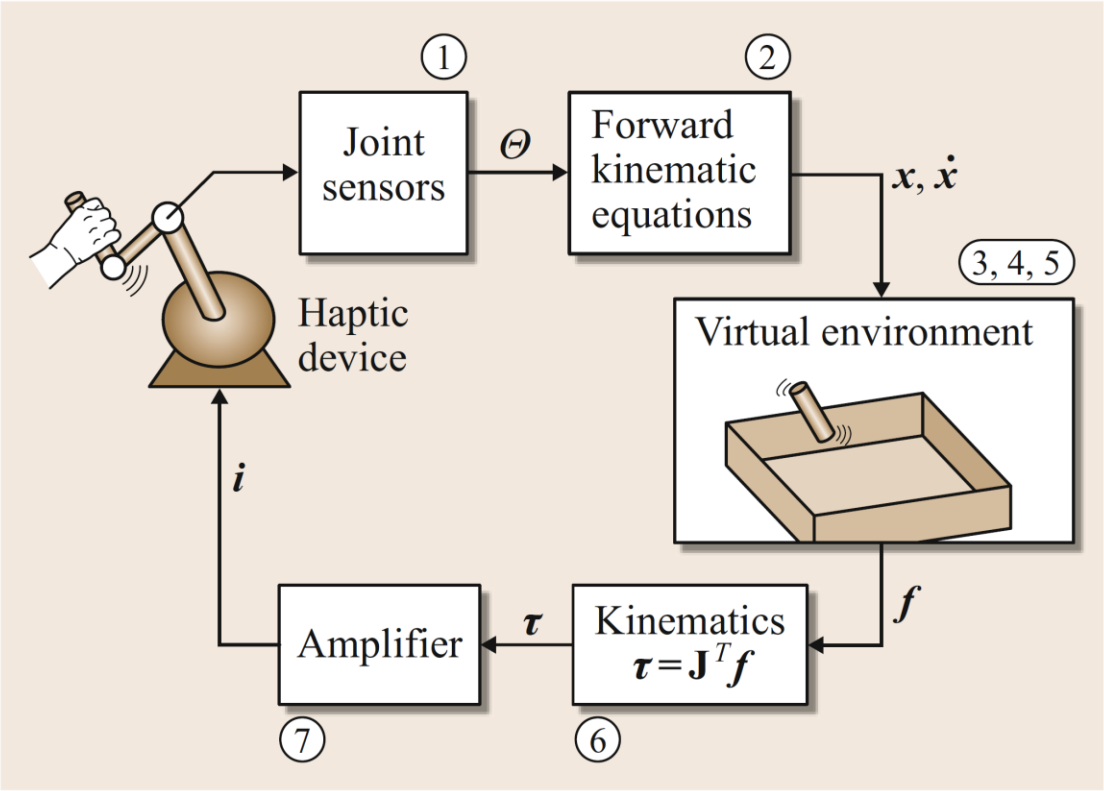
Novint Falcon (3 DOF)

Medical Simulation

https://www.theengineer.co.uk/haptic-technologies-revolution/

Haptic Rendering

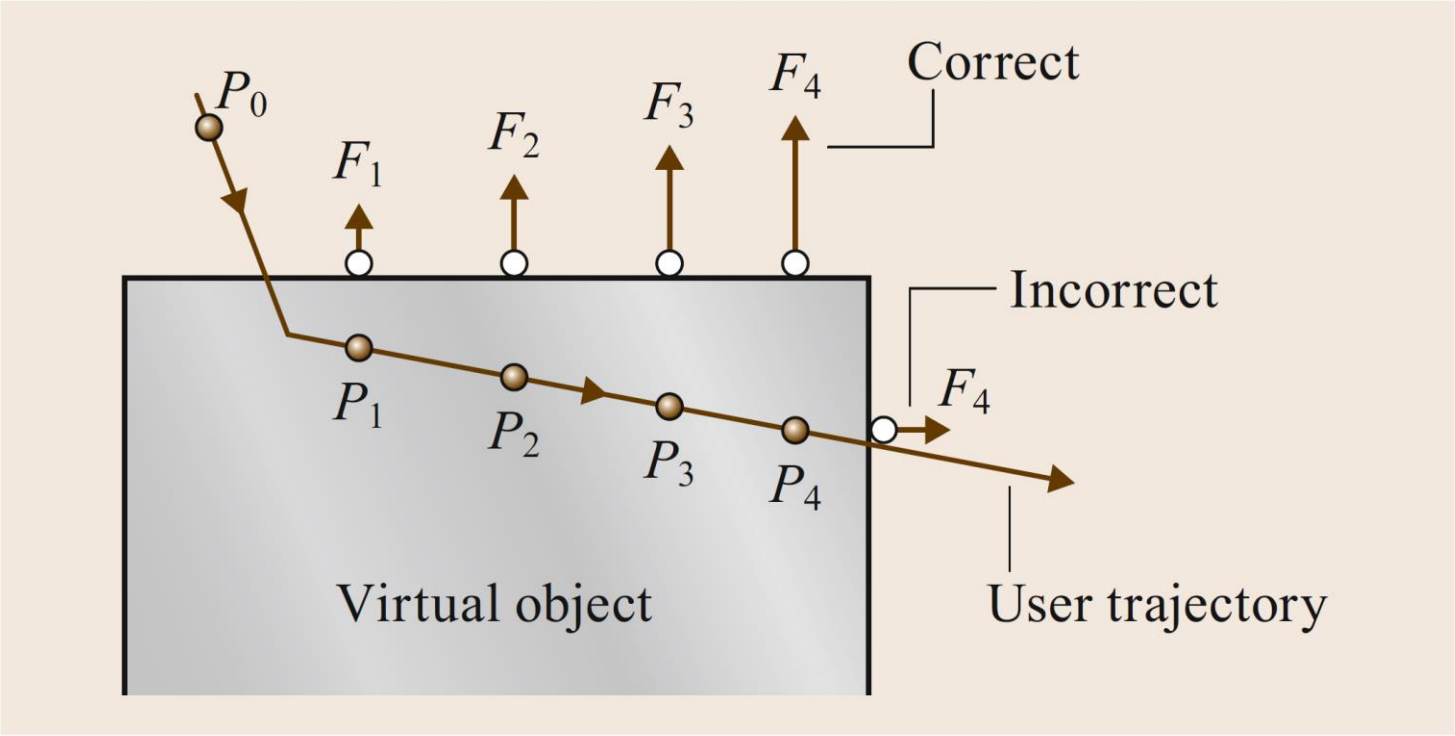
- The process of computing the force required by contacts with virtual objects based on measurements of the operator's motion
  - The rendering cycle must typically be completed in under 1 ms for stability and realism



1. Sensing (Sect. 42.2.2)
2. Kinematics
3. Collision detection
4. Determining surface point
5. Force calculation
6. Kinematics
7. Actuation (Sect. 42.2.3).

Haptics. Blake Hannaford, Allison M. Okamura

Force Calculation



- Spring model

$$\boldsymbol{f} = k\boldsymbol{x}$$

- Adding damping

$$\boldsymbol{f} = k\boldsymbol{x} + b\dot{\boldsymbol{x}}$$

Tactile Sensor: SynTouch BioTac

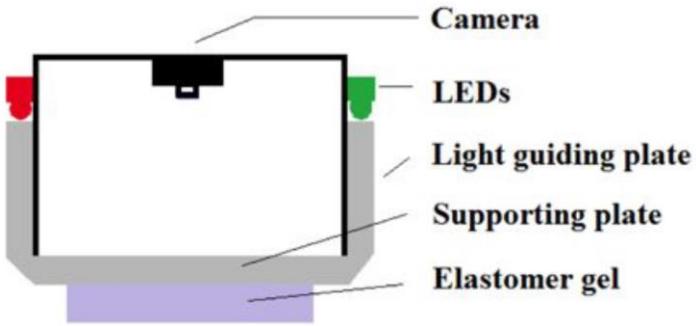
- SynTouch BioTac
  - A flexible rubber skin
  - An ionically-conductive fluidic layer
  - A rigid core

- Measurements: forces, micro-vibrations, and temperature
  - 19 sensing electrodes and 4 excitation electrodes located on the outer surface of the core

Tactile Sensor: GelSight

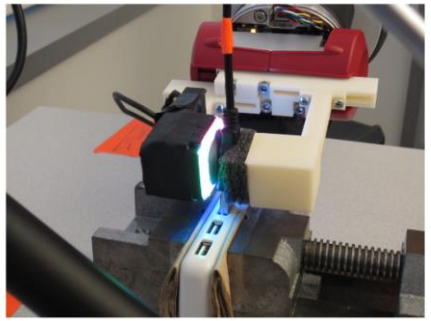


GelSight operating concept

Sensor design

- Illuminate the gel from four sides simultaneously in four different colors: red (R), green (G), blue (B), and white (W)
- Retrieve surface normals from the color values on any contacted surface in real time
- The height map is calculated using Poisson integration from the surface normals




Localization and Manipulation of Small Parts Using GelSight Tactile Sensing. Li et al., IROS'14

Further Reading

- Section 13.1, Virtual Reality, Steven LaValle

- Haptics https://web.stanford.edu/class/me327/readings/Hannaford16-RH-Haptics.pdf

- Stanford ME 327 Design and Control of Haptic Systems https://web.stanford.edu/class/me327/