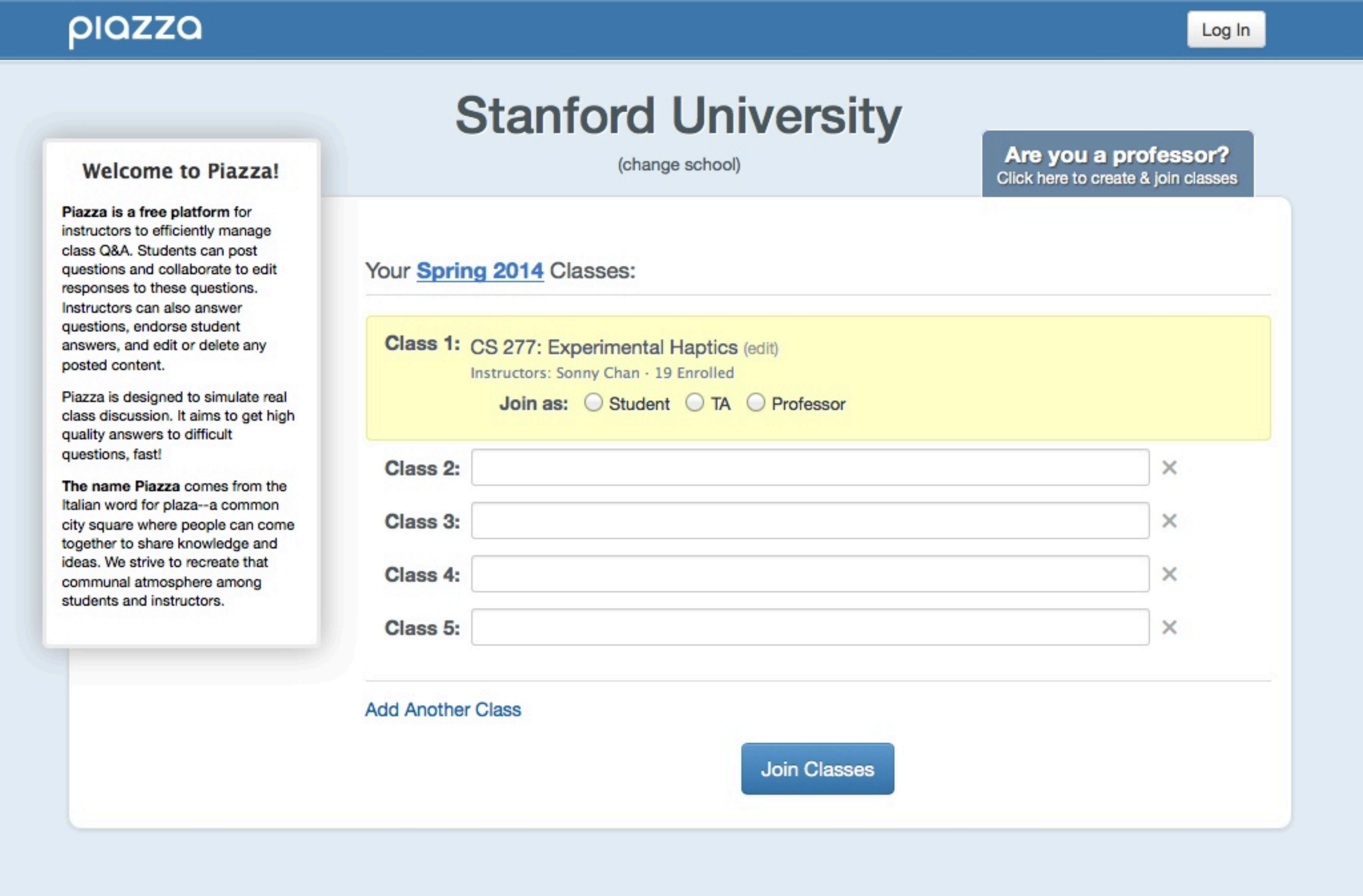
CS277 - Experimental Haptics
Lecture 2

Haptic Rendering

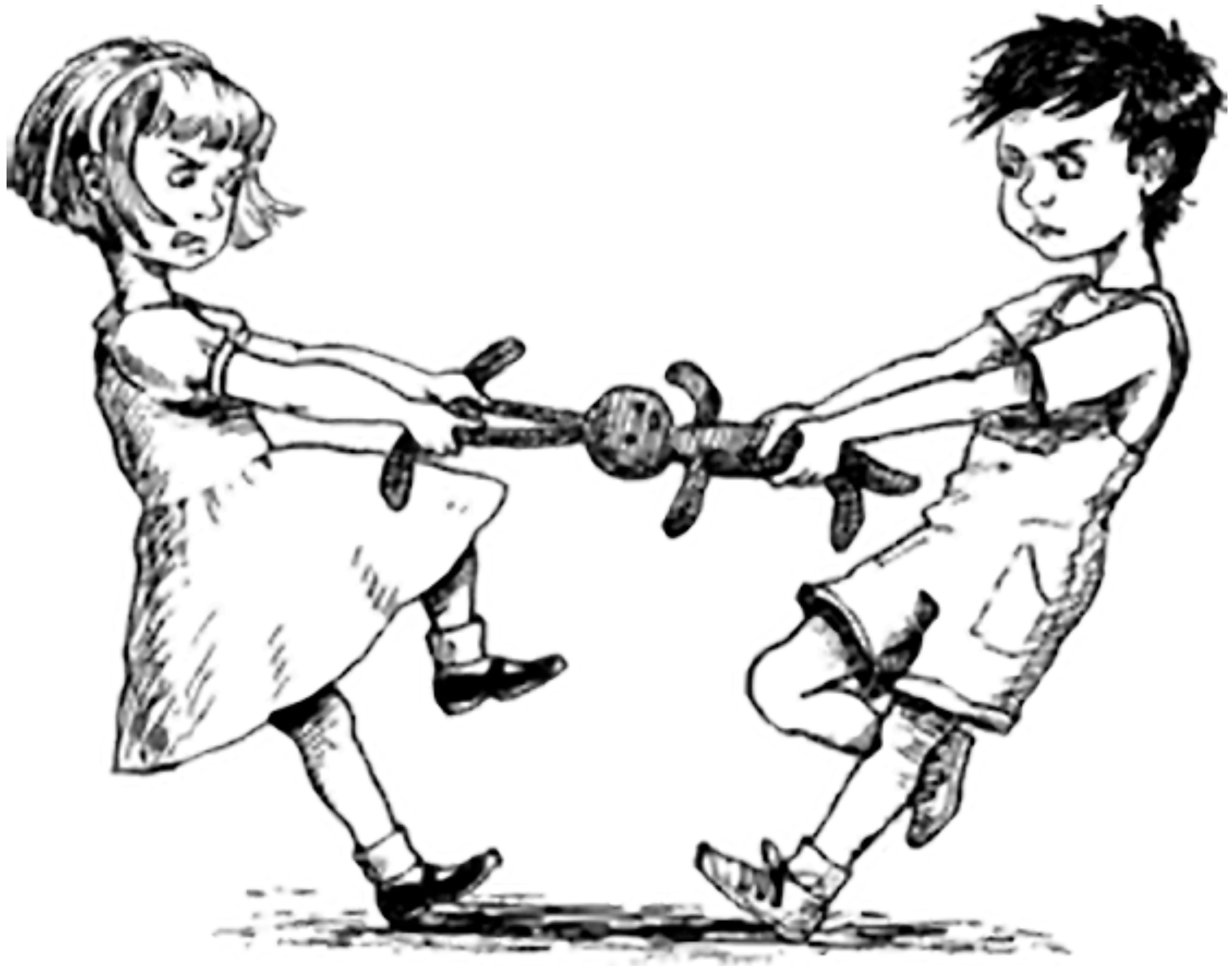
Outline

- Announcements
- Human haptic perception
- Anatomy of a visual-haptic simulation
- Virtual wall and potential field rendering
- A note on timing...



https://piazza.com/stanford/spring2014/cs277

Sharing Devices...



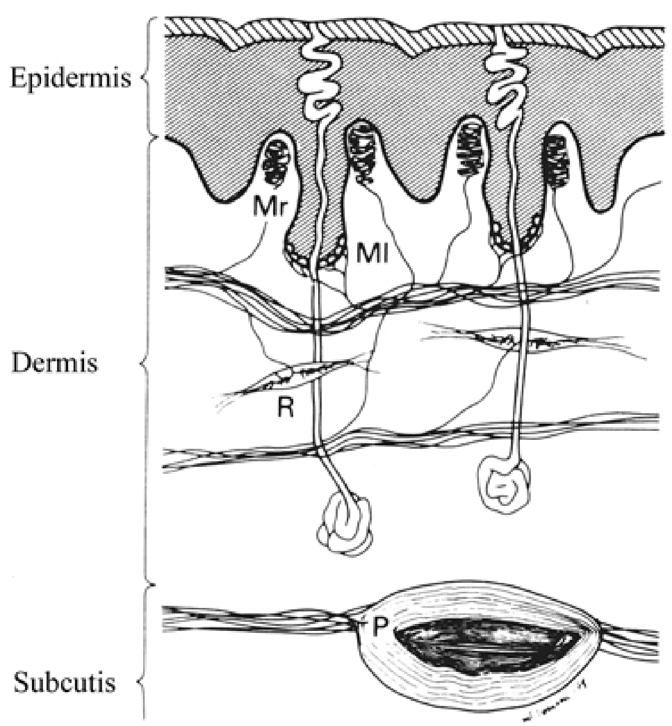
Haptic Perception

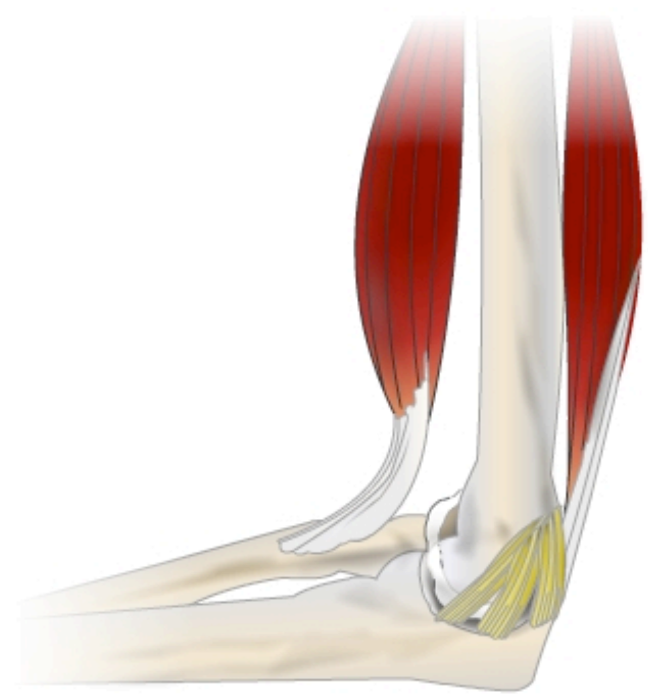
Touch Perception

haptic perceptual system

cutaneous receptors

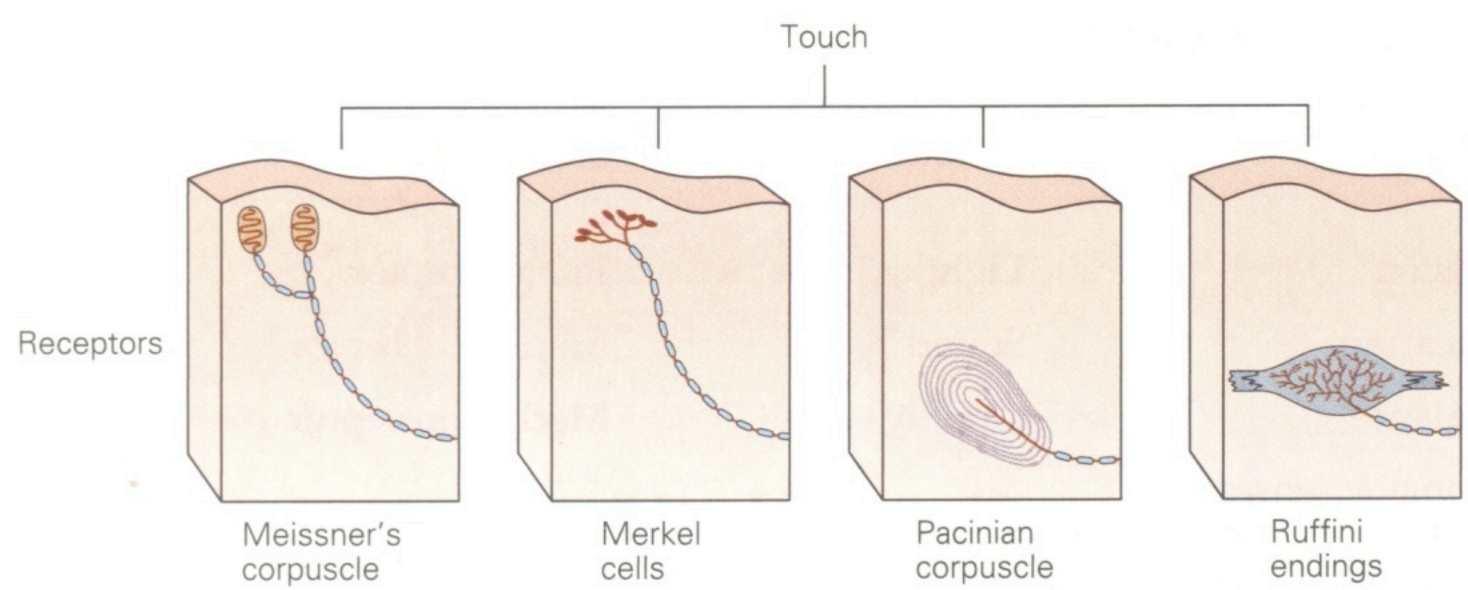
kinaesthetic receptors





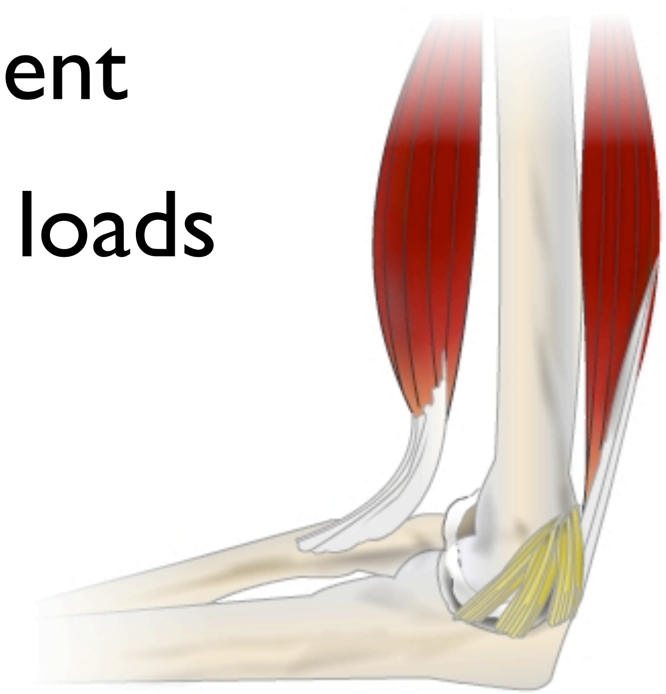
Cutaneous Perception

- Inputs from different types of mechanoreceptors embedded in the skin
  - vibration and texture perception
  - pressure and skin stretch (grasped object)



Kinaesthetic Perception

- Inputs from mechanoreceptors in muscles, tendons, and joints
  - limb position and movement
  - larger contact forces and loads



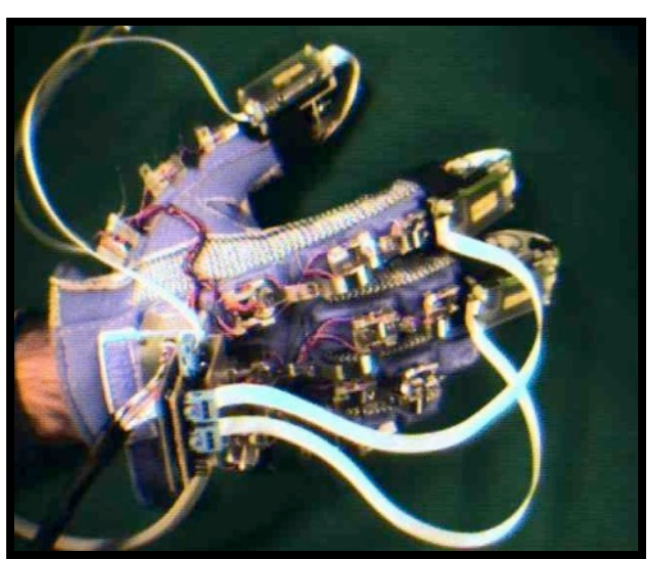
Cutaneous/Tactile Feedback

- Devices can be very difficult to realize
  - requires high spatial actuator resolution



Kinaesthetic Feedback

- Key realization: tool-mediated interaction
  - system need only render tool contact forces



or

Kinaesthetic Devices

- Driven by two common types of control strategies
  - *Impedance-control* haptic devices simulate mechanical impedance
  - *Admittance-control* haptic devices simulate mechanical admittance

Impedance vs Admittance

- Impedance devices
  - sense position
  - commanded force
- Admittance devices
  - sense force
  - commanded position

Impedance vs Admittance

- Impedance haptic devices
  - are cheeper to build
  - back-drivable

- Admittance haptic devices
  - higher range of forces
  - requires force sensor ($$$)
  - generally less common

Devices for CS277

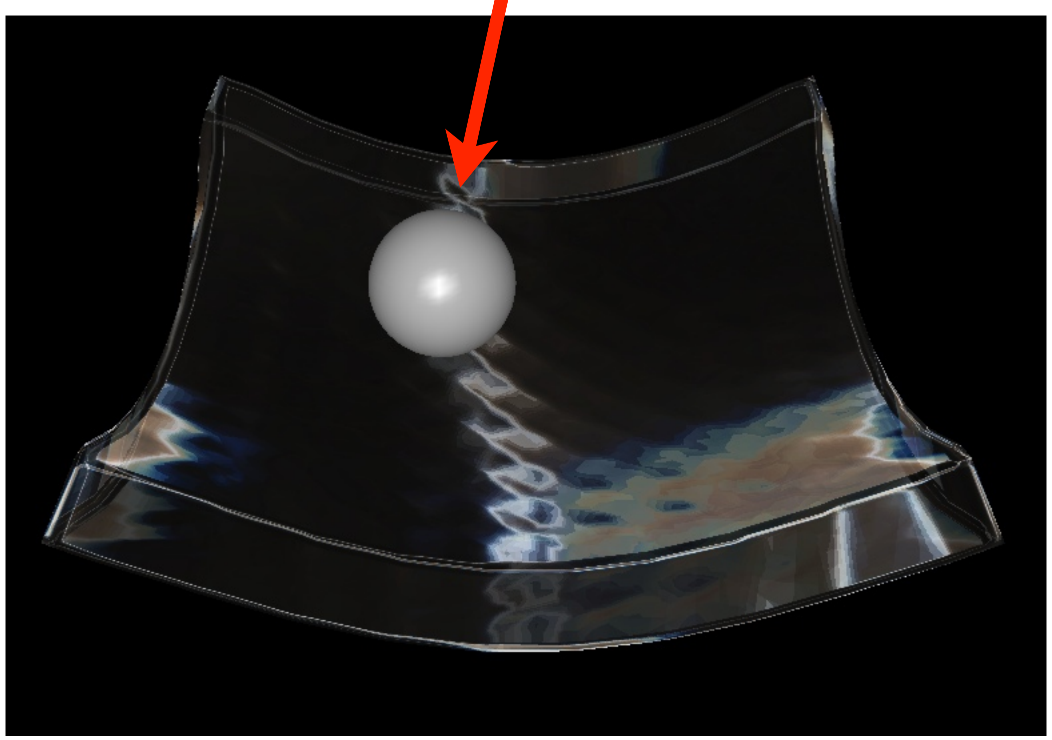
- We will focus on studying
  - kinaesthetic devices: tool-mediated interaction
  - impedance control: render forces (impedances)
  - 3-DOF actuated devices, 3- or 6-DOF sensed

Visual-Haptic Simulation

The Basics

How does a basic visual-haptic simulation work?

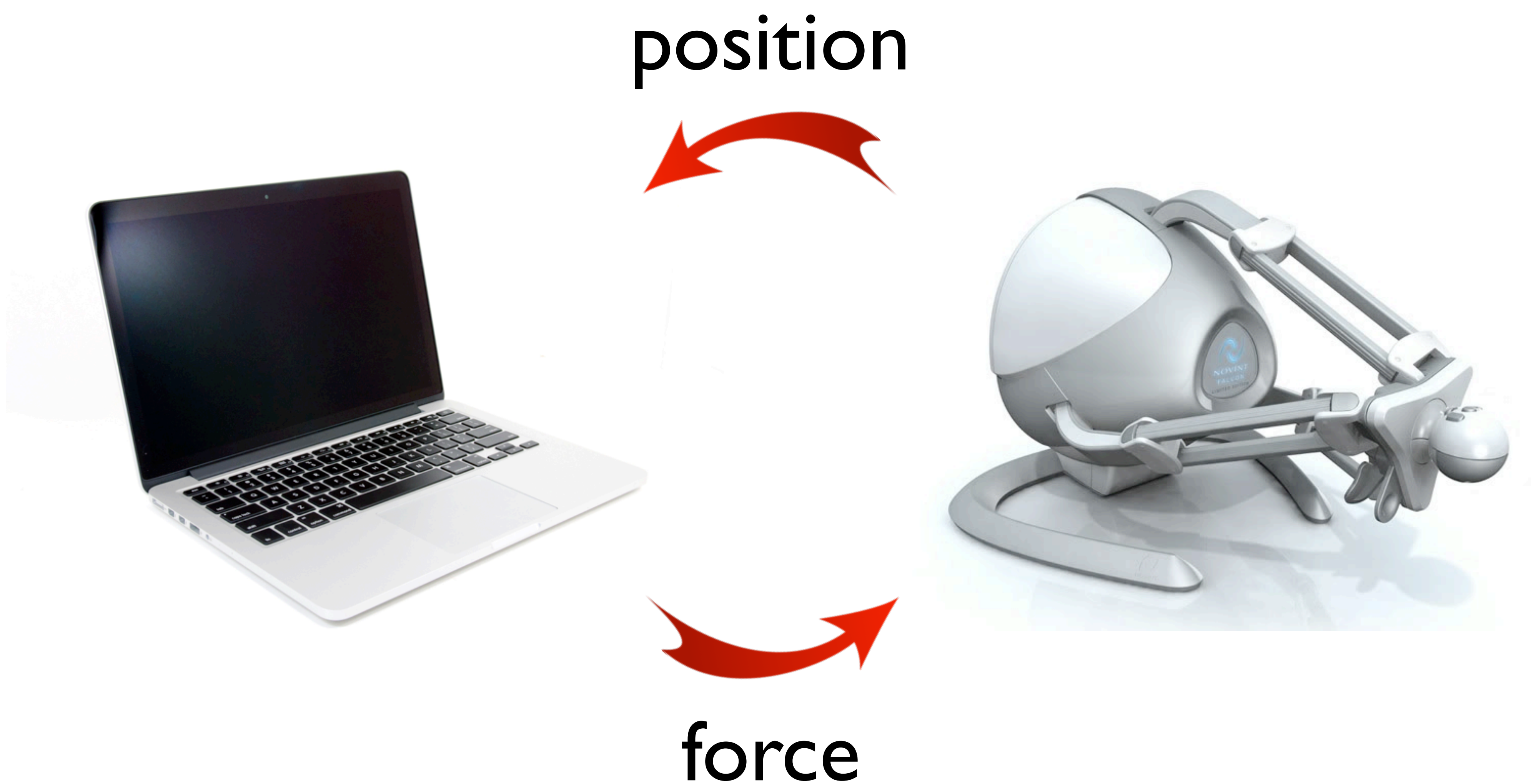
Avatar



Virtual Environment (VE)

Haptic Device

The Interface



Haptic Rendering

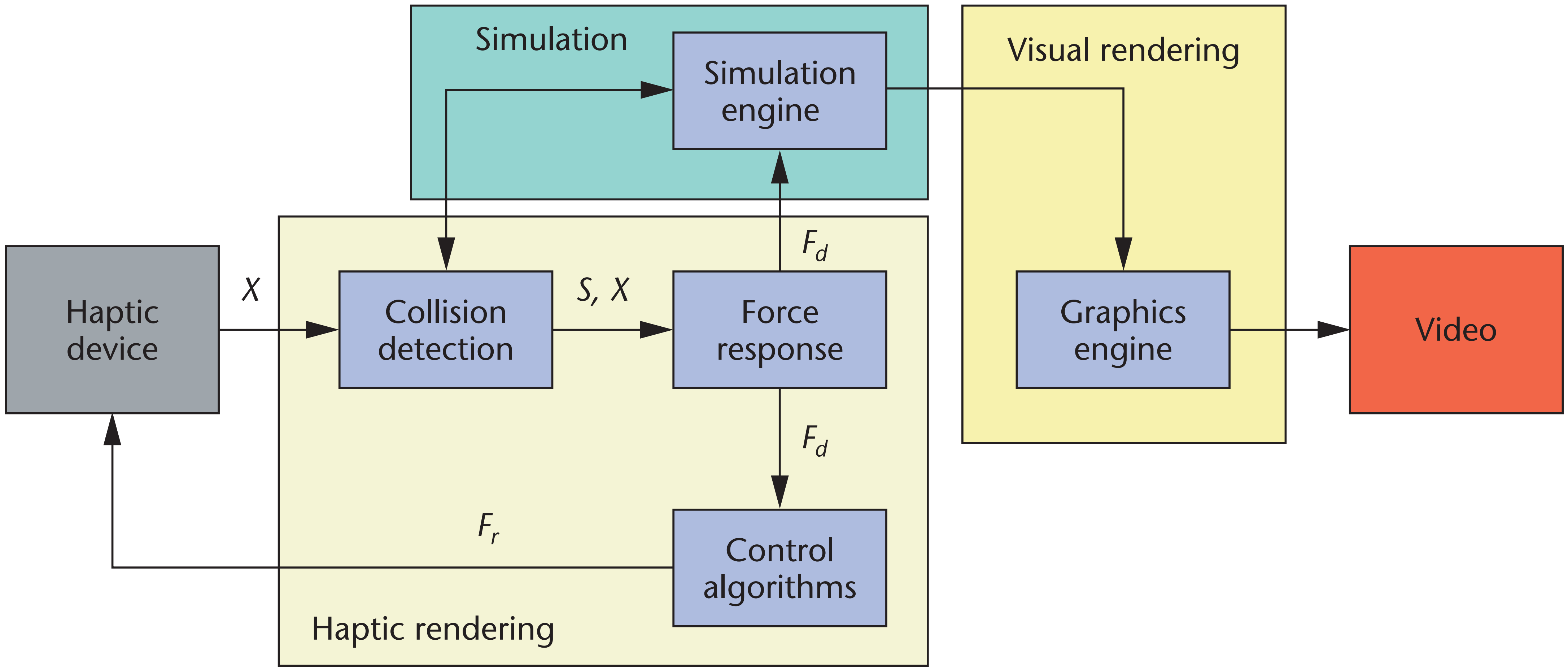
“

Haptic rendering is the process of computing and generating forces in response to user interactions with virtual objects.

”

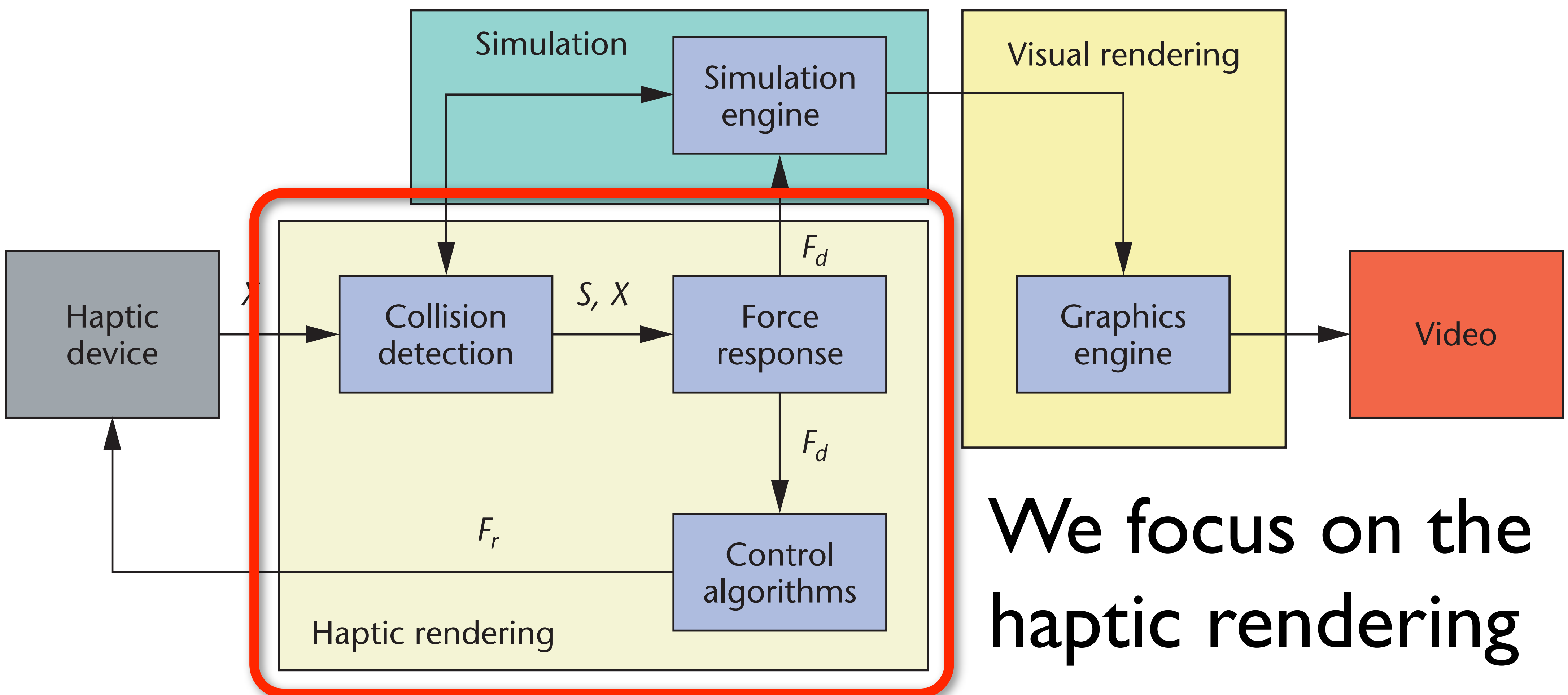
[from K. Salisbury *et al.*, *Proc. Symposium on Interactive 3D Graphics*, 1995.]

Components



[From K. Salisbury *et al.*, *IEEE Computer Graphics & Applications* 24(2), 2004.]

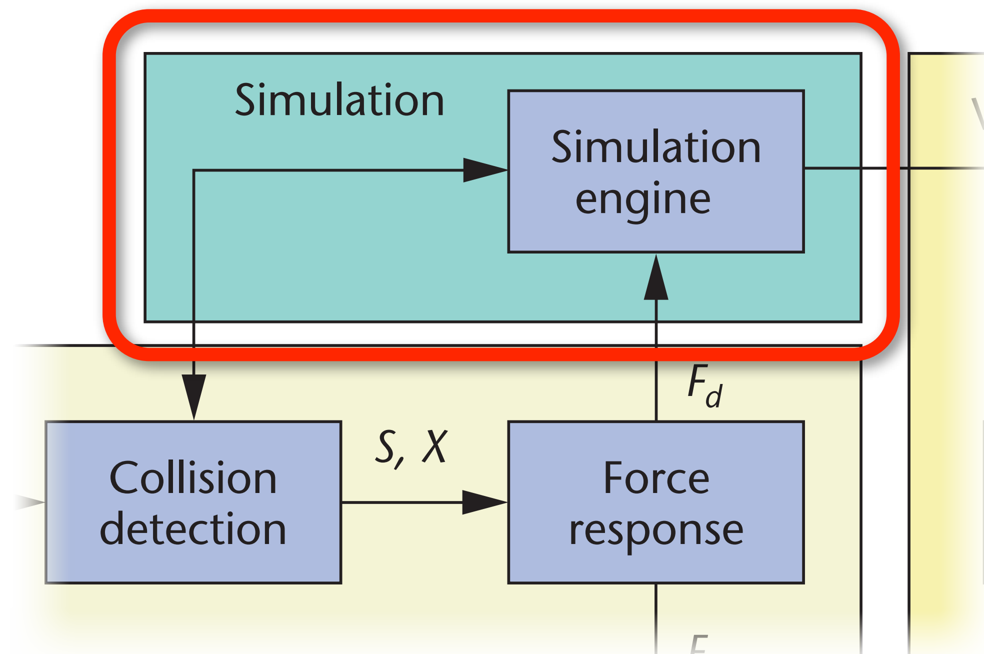
In this course...



We focus on the haptic rendering component.

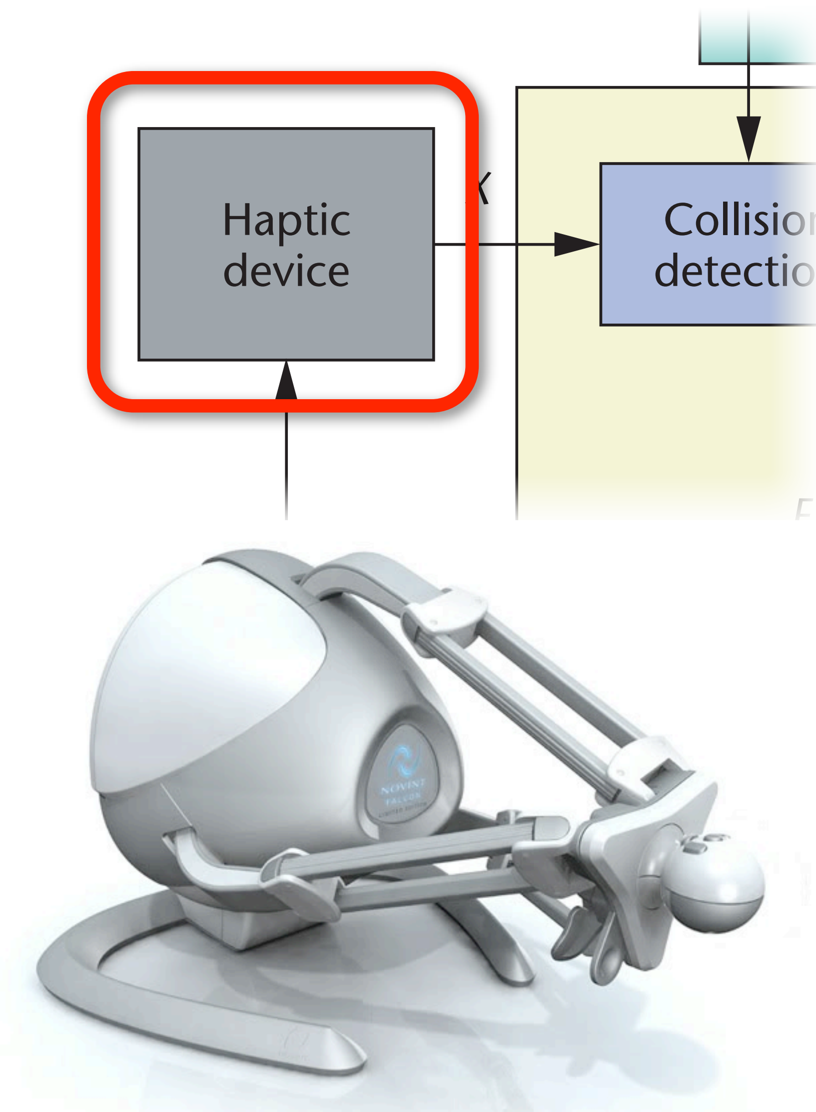
The Virtual Environment

- representations of virtual objects
- real-time simulation of physical behaviour
- *geometric modeling* and *computer animation* (CS348a, CS205b)



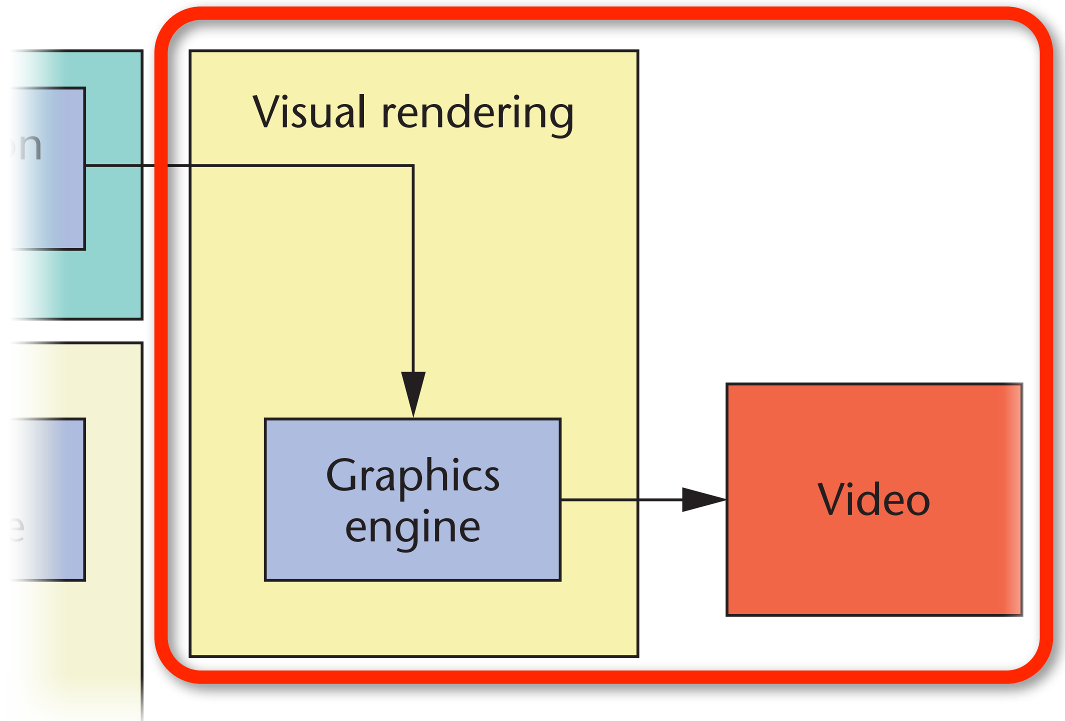
Haptic Device

- We treat the device as a “black box”
- We’ll crack it open near the end of the course
- Take ME347 to learn more!

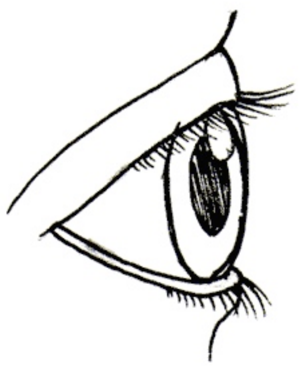


Visual Rendering

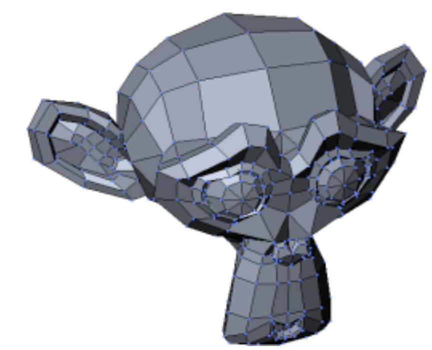
- Given a virtual environment, render its state on the screen (in real time)
- We will let CHAI3D do this for us
- CS148, CS248, CS348b

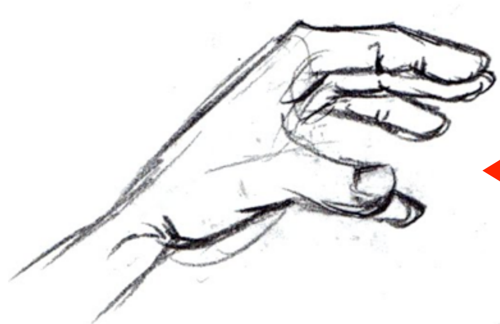


Haptic vs. Visual Rendering

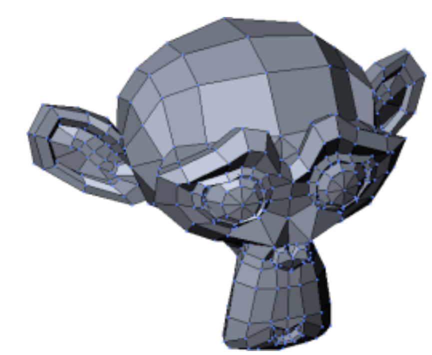


Visual Rendering



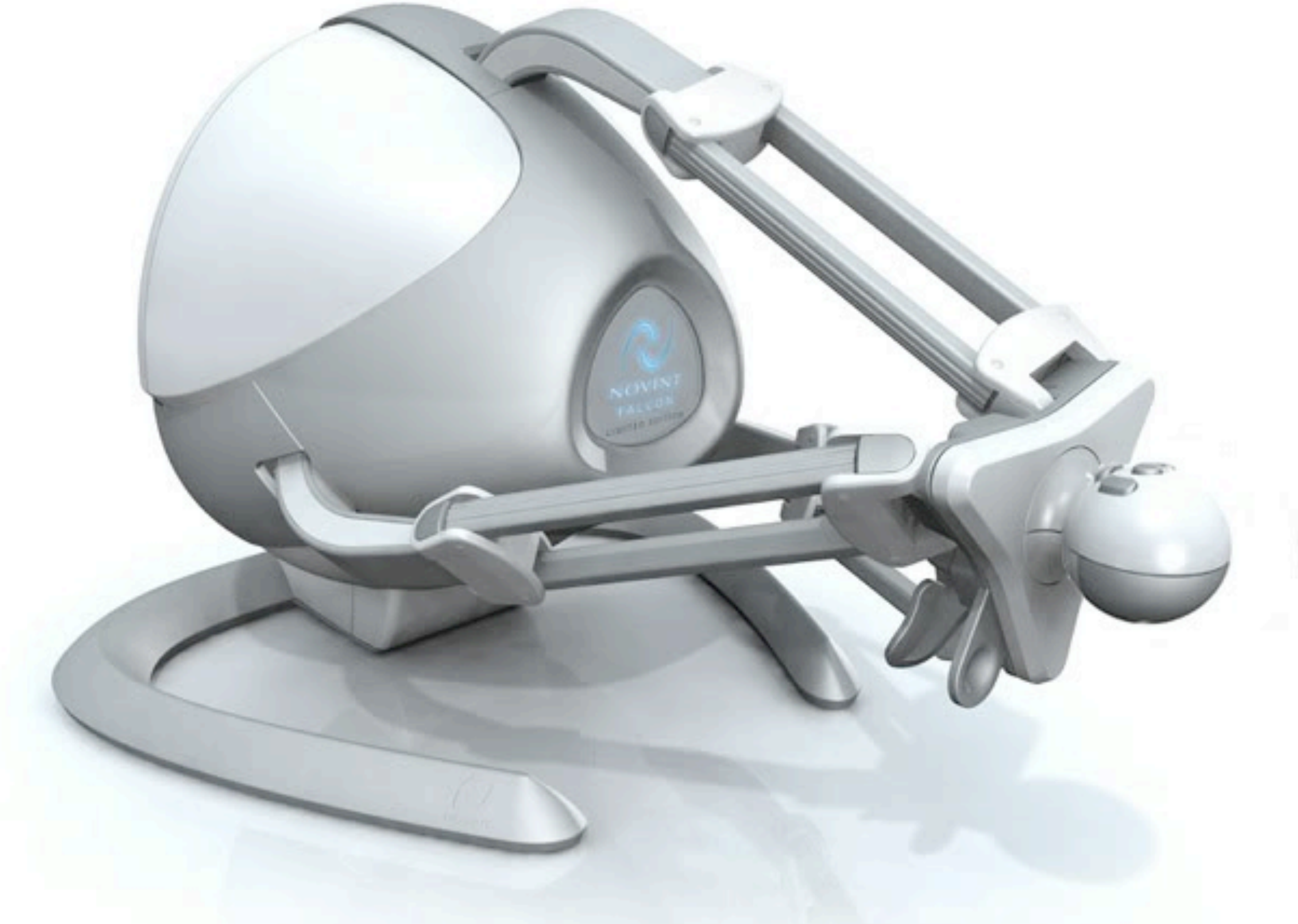


Haptic Rendering



Bi-Directionality

- Bi-directional information flow is the most distinguishing feature of haptic interfaces
- This has many consequences that we will visit in later classes



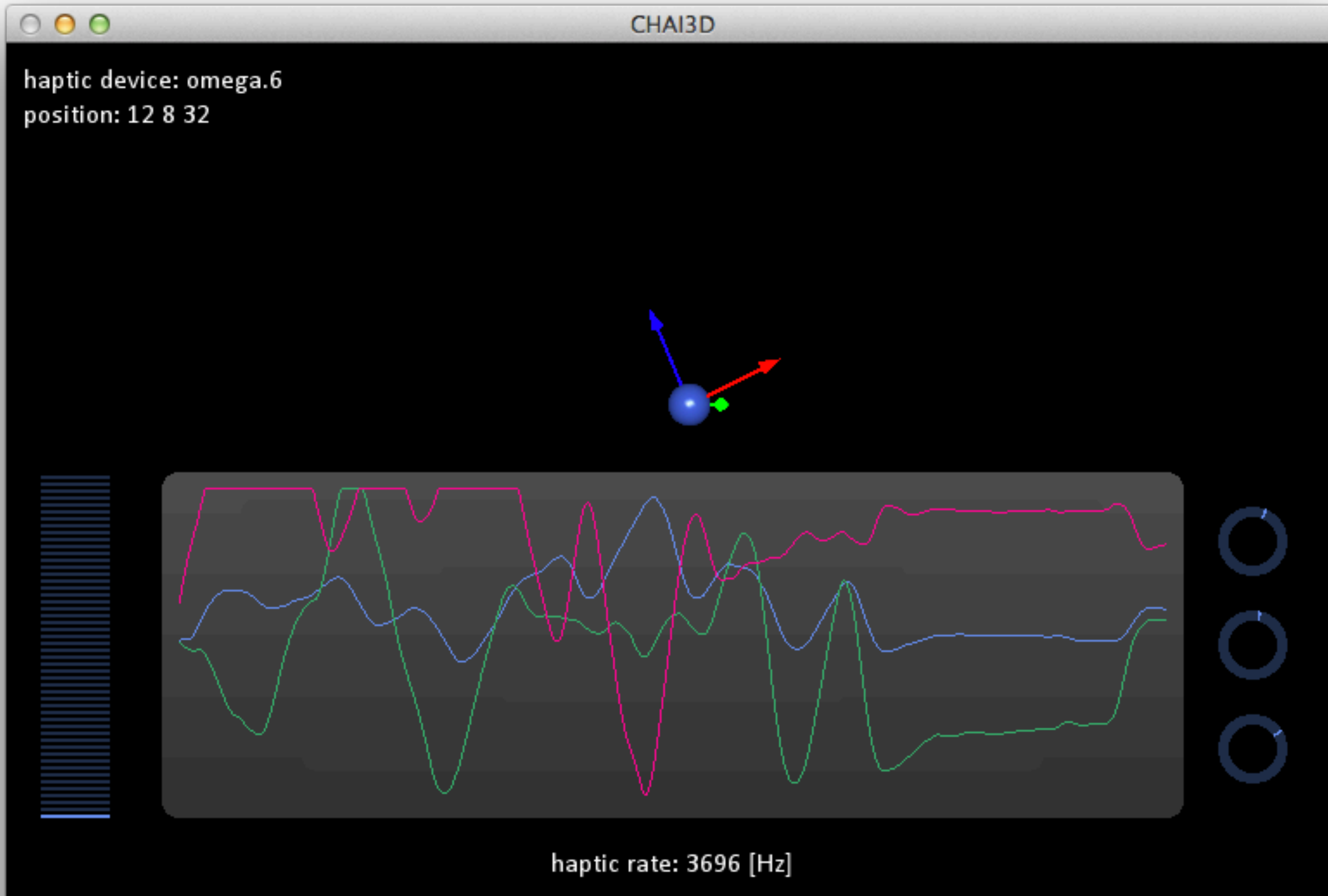
Getting to Know Your Falcon

The Hardware

The Software

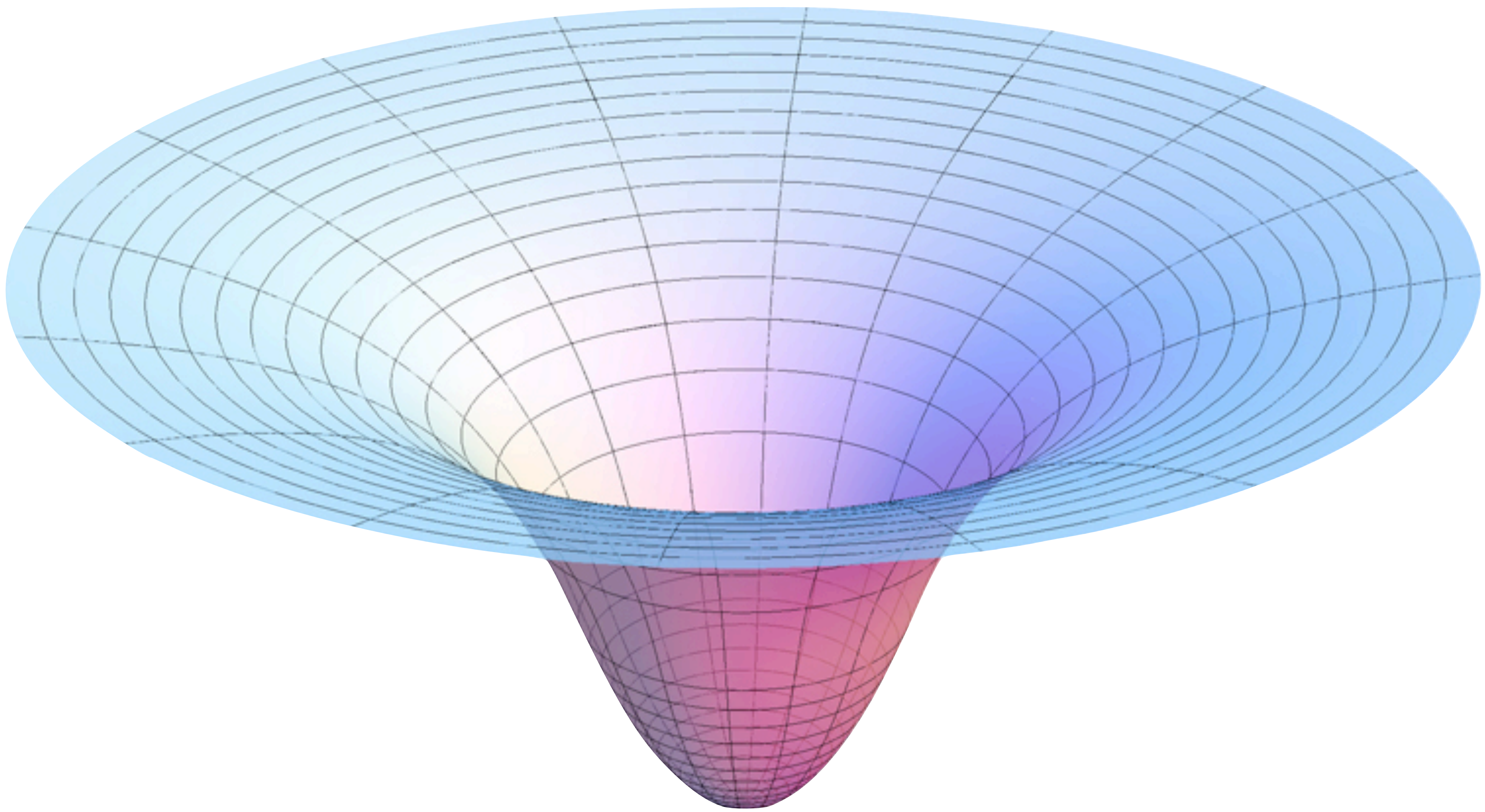
- Download, compile the CHAI3D library
- No drivers necessary on Mac/Linux
- Three platforms supported:
  - Mac OS X → Xcode
  - MS Windows → Visual Studio
  - Linux → makefiles
  - CMake?

Run CHAI3D Demo to Test



Device Distribution

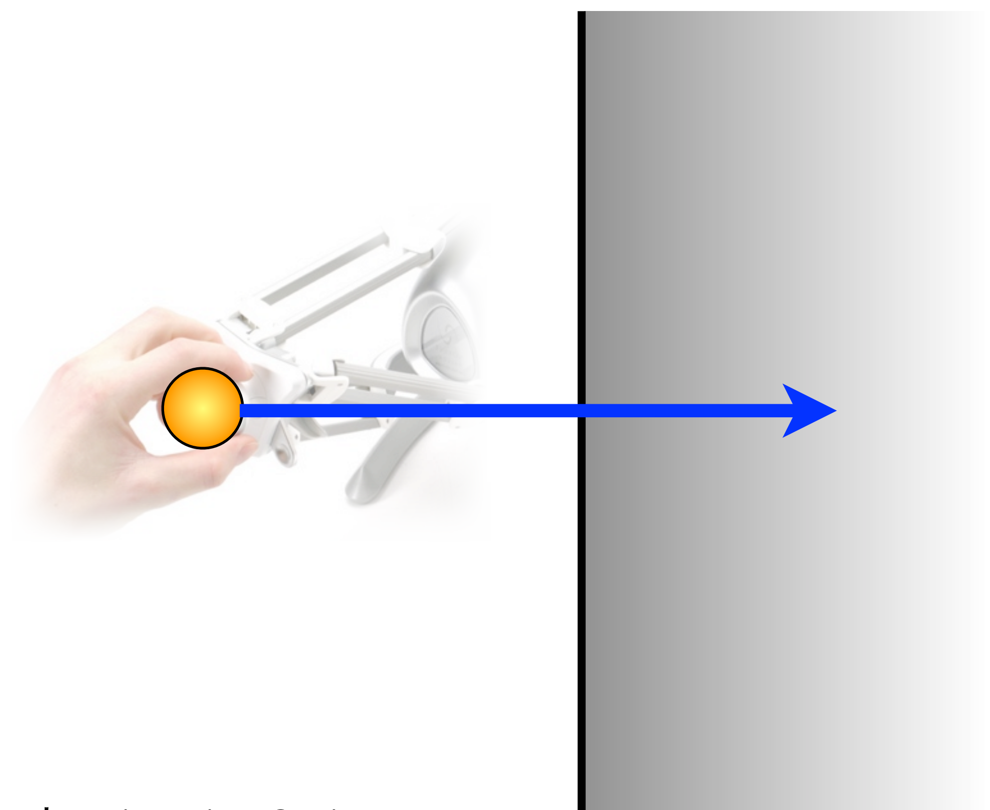
- April 7 (Mon) and April 8 (Tue)
- See Sonny in Clark Center E100 (Salisbury Robotics Lab)
- Times TBD, but will be announced on class email and on Piazza.



Potential Fields

Starting Simple

- A plane is one of the simplest virtual environments we can conceive and render
- How can we render such a "virtual wall"?



$$F = f(x) = ?$$

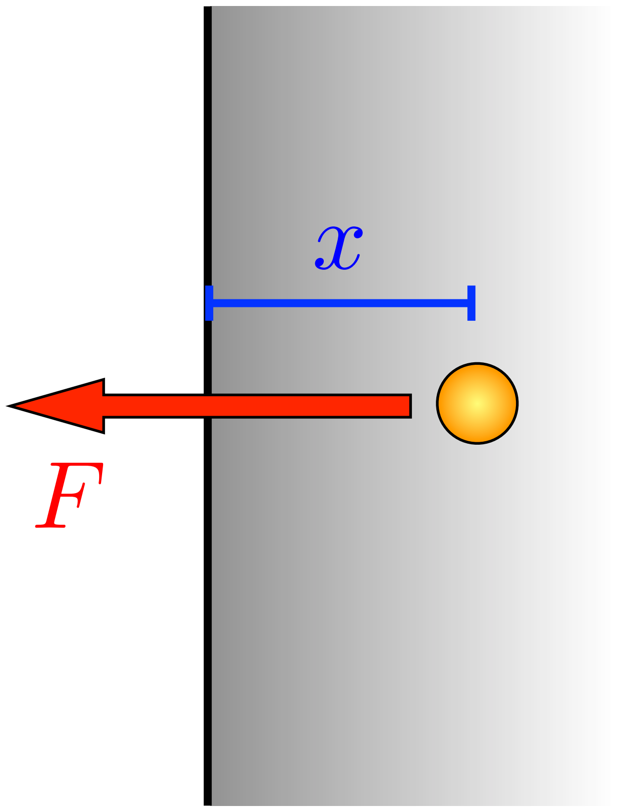

1 and 2 and
3 and 4...

Virtual Walls

- The simplest VE: a linear spring in 3D
- Can be used to study stability
- Useful building block for more complex virtual environments and interactions

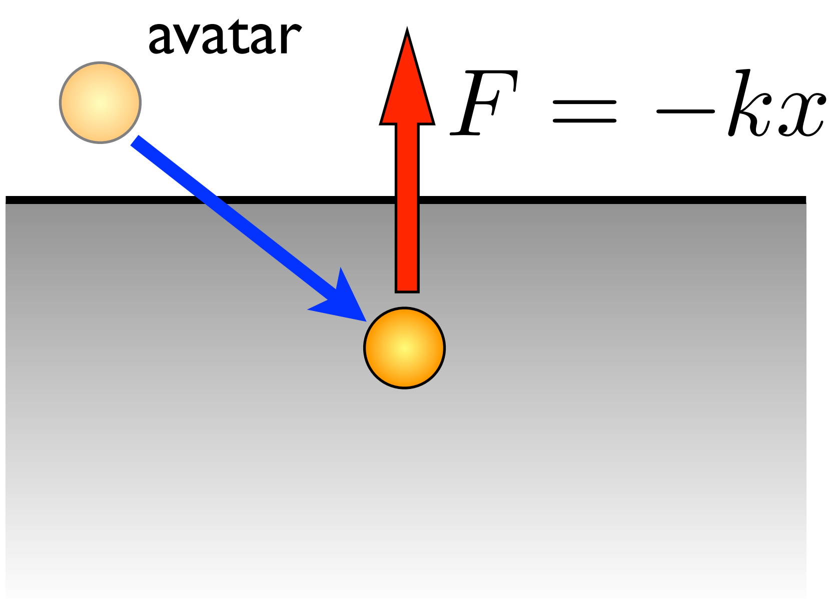
Virtual Wall Algorithm

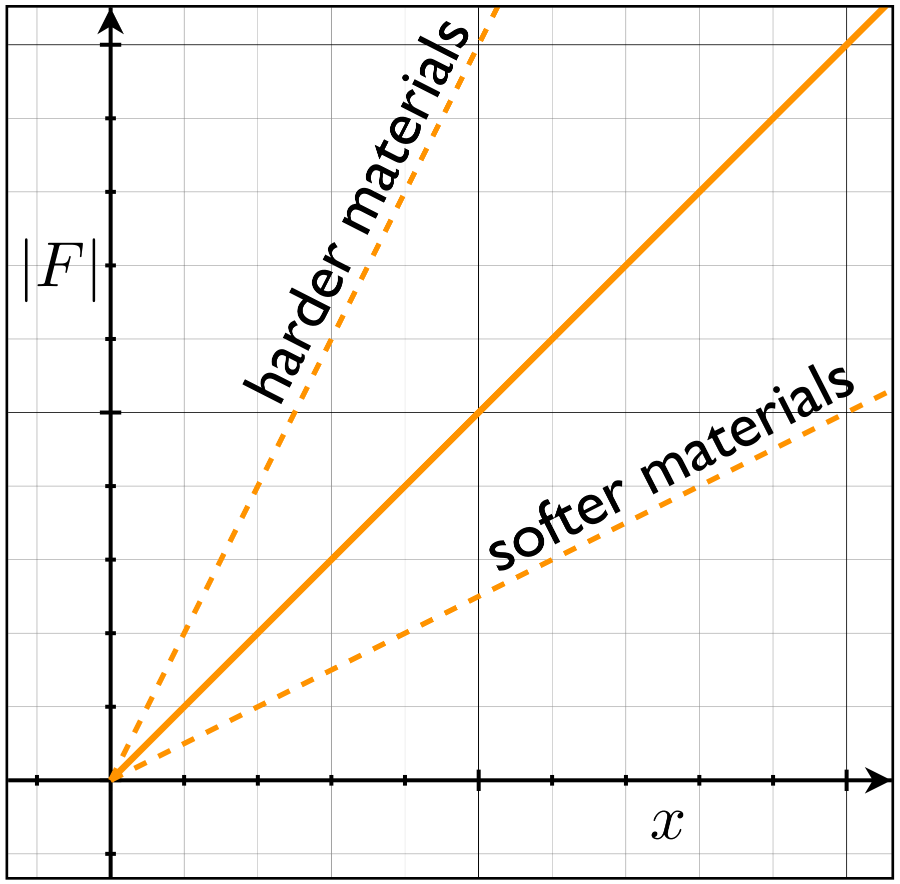
$$F(x) = \begin{cases} -kx & \text{if } x > 0 \\ 0 & \text{otherwise} \end{cases}$$



Virtual Wall Stiffness

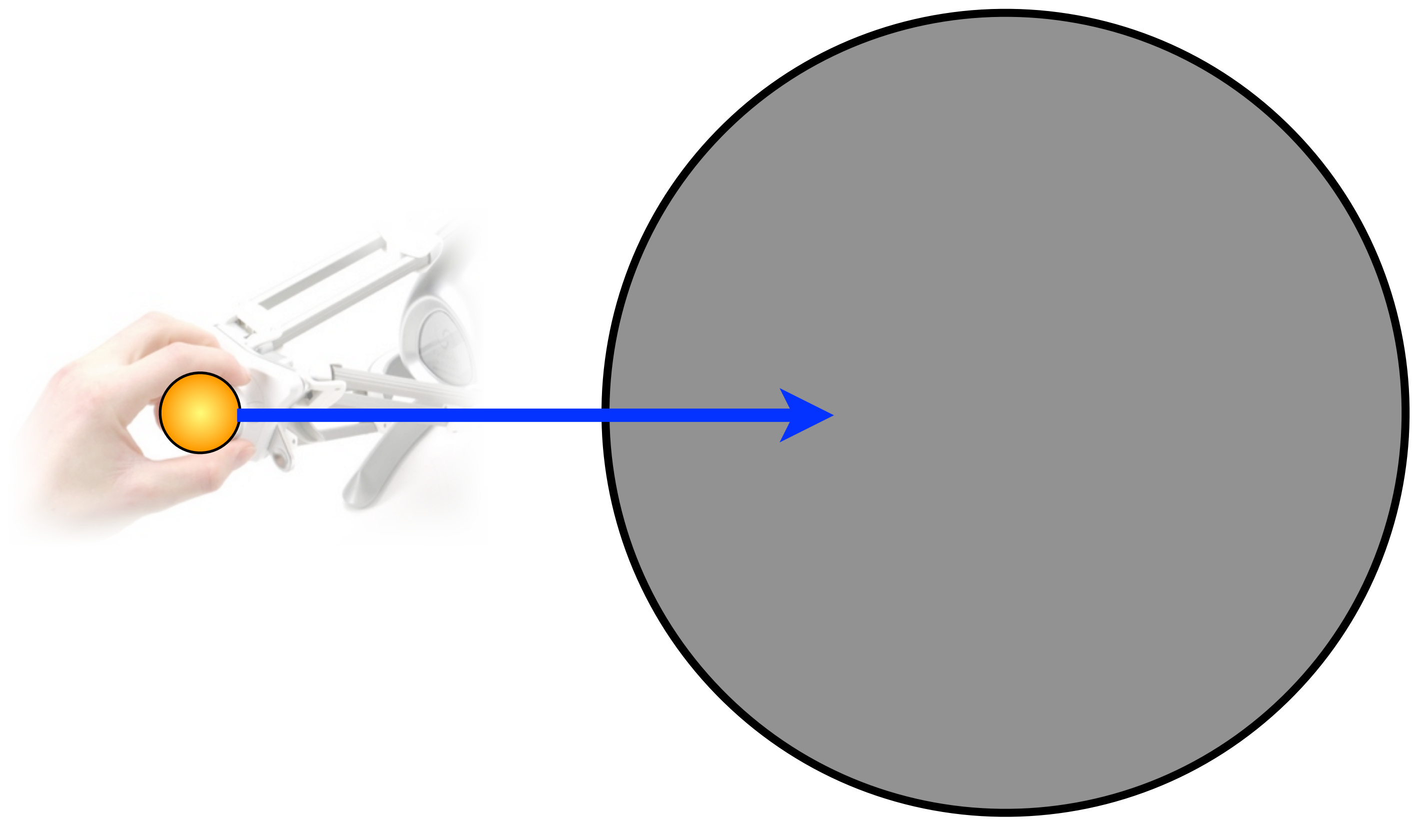
- Stiffness (k) affects how the wall feels





Another Shape

- What is the simplest way to render a sphere in 3D?




1 and 2 and
3 and 4...

Potential Field Examples

- Virtual wall is the simplest one
- A sphere that attracts toward its surface

$$F(x,y,z) = -k(x^2 + y^2 + z^2 - r^2)$$

- A sphere

$$F(x,y,z) = \begin{cases} -k(x^2 + y^2 + z^2 - r^2) & \text{if } x^2 + y^2 + z^2 < r^2 \\ 0 & \text{otherwise} \end{cases}$$

- A box...

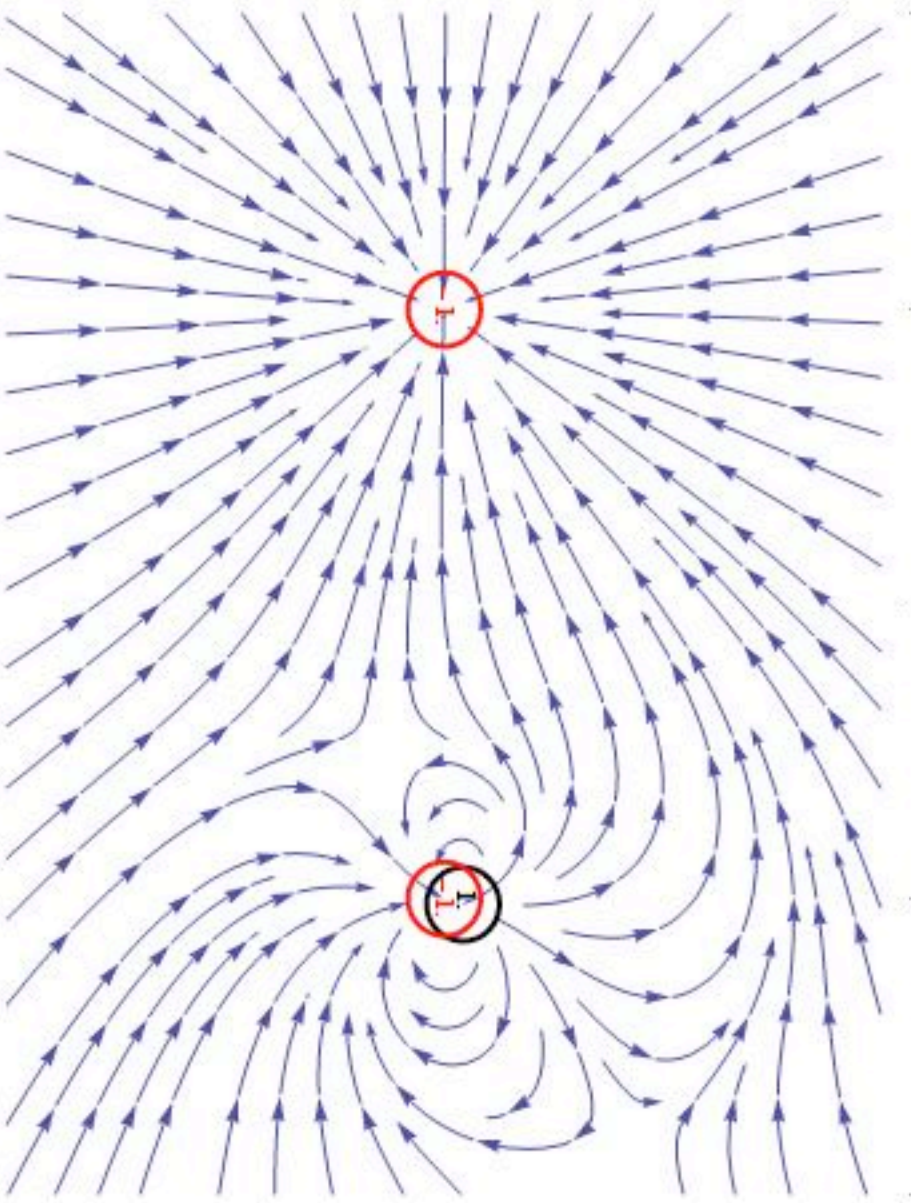
Potential Fields

- The term *potential field* is borrowed from physics/mechanics

- Force is a vector field gradient of potential

$$\vec{F} = \nabla U$$

- We normally just skip to defining force field



Why Potential Fields?

- They make intuitive sense (3D springs)
- They are easy to compute

- ... but with simplicity comes limitations

Summary

- Human haptic perception
  - kinaesthetic feedback and impedance devices
- Anatomy of a visual-haptic simulation
  - we'll focus on haptic rendering
- Virtual wall and potential field rendering
- Time is of the essence!