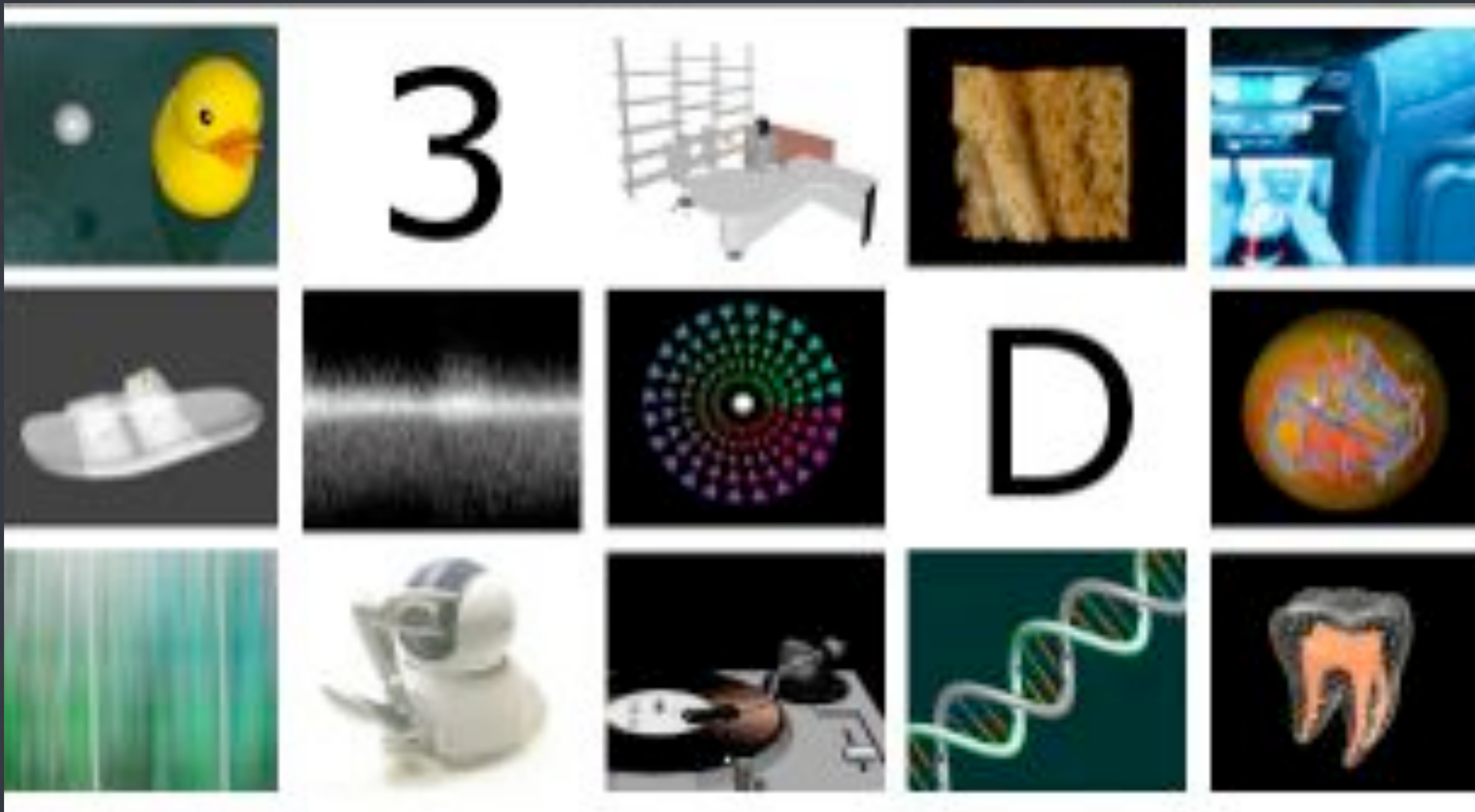


TEACHING HAPTIC RENDERING

SONNY CHAN, STANFORD UNIVERSITY

MARCH 4, 2012 | HAPTICS SYMPOSIUM

Overview

- A brief introduction to CS 277 @ Stanford
- Core topics in haptic rendering
- Use of the CHAI3D framework
- Development of homework assignments
- Haptic rendering course projects

CS 277

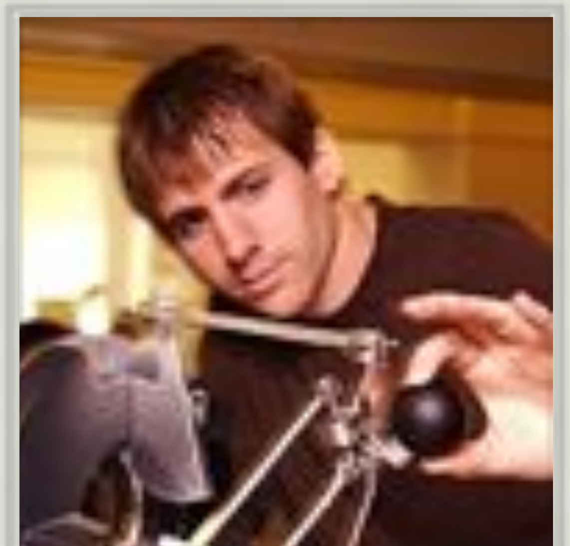
Experimental Haptics

2002-2012 @ Stanford

CS 277: Experimental Haptics

- Really a *haptic rendering* course
- Has its roots in the *computer science* department, but we get a good mix of students
- Workload is 4 programming assignments plus open-ended course project
  - Students usually design a game, but other projects, including mechanisms, are encouraged

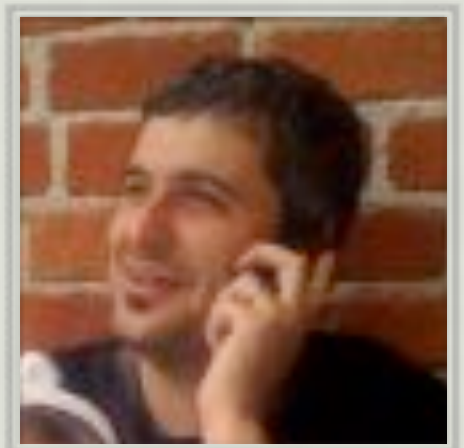
THE FOUNDERS



F. Conti

J. K. Salisbury

AND THE TORCH BEARERS



F. Barbagli

C. Sewell

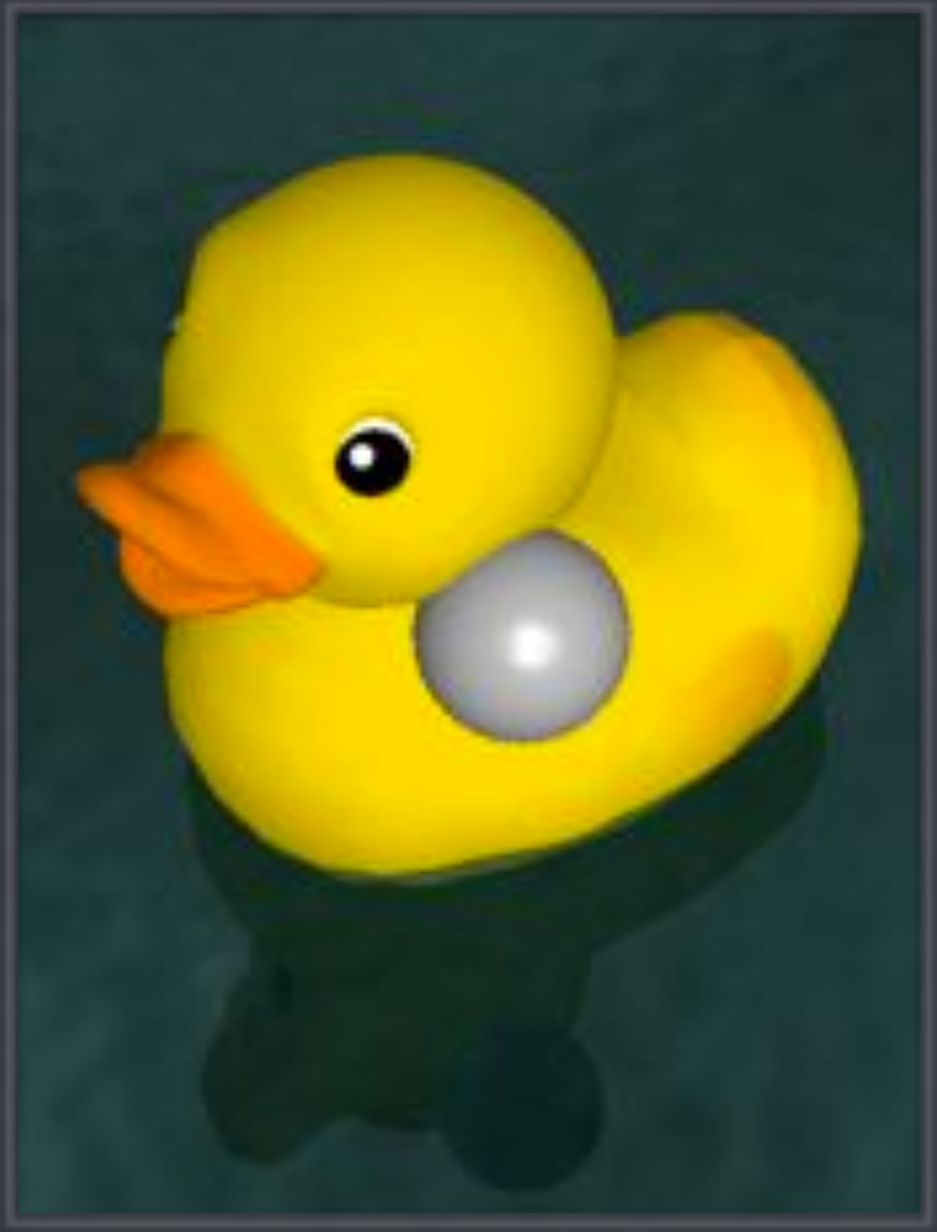
D. Morris

S. Chan

A. Leeper

Core Topics

in Haptic Rendering

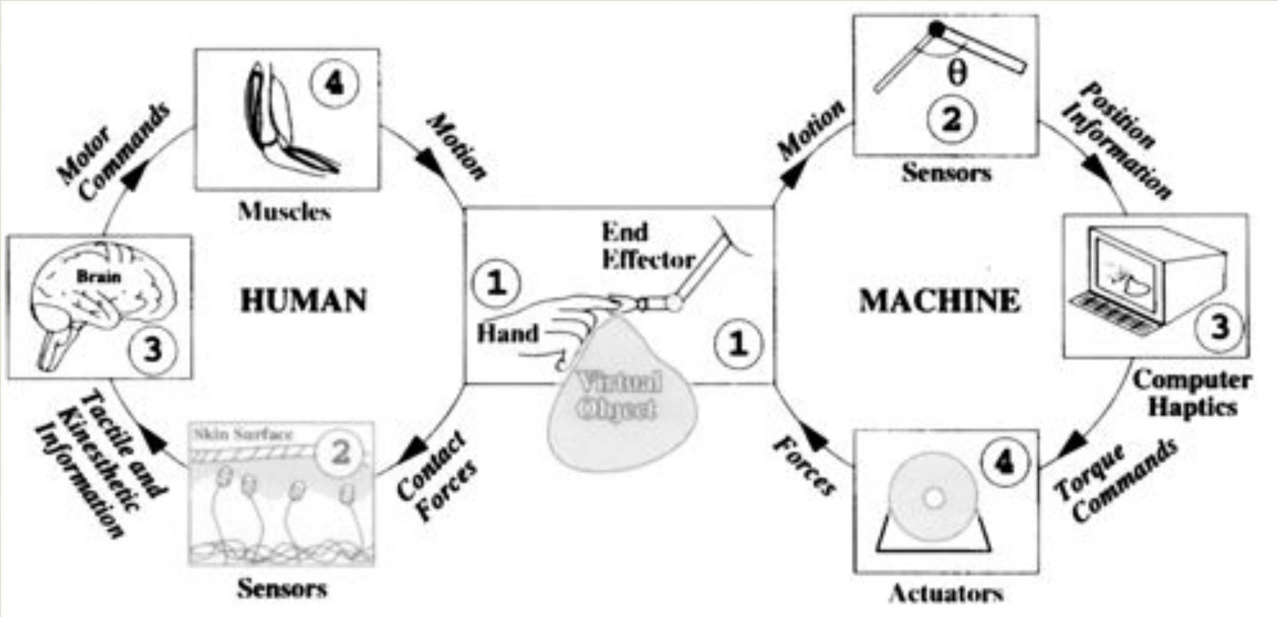


Teaching Haptic Rendering

- Identify key computational algorithms and data structures required for haptic rendering
- Present the algorithms in a progressive, coherent, and consistent style
- We’ve settled on a syllabus that roughly follows historic progression

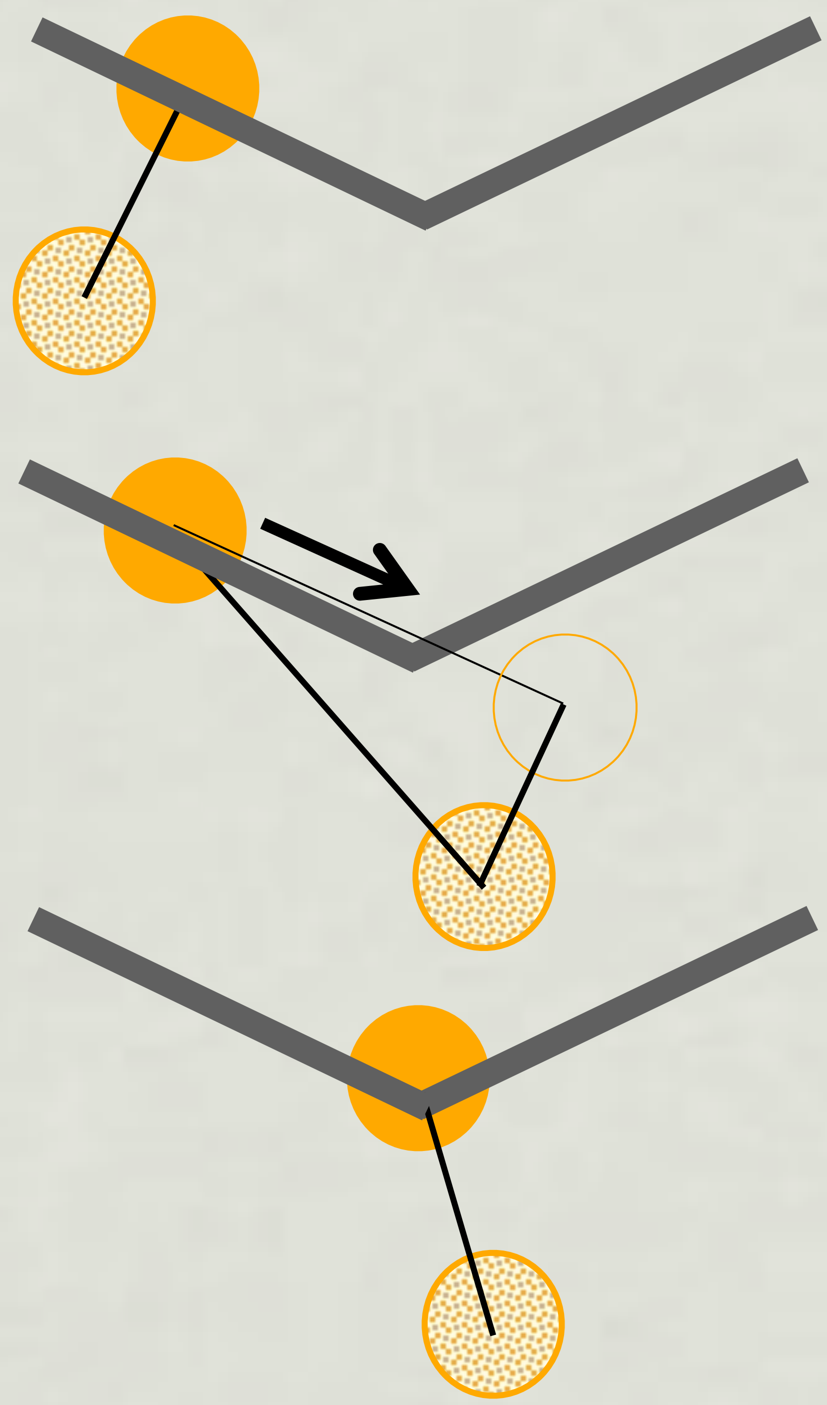
Introductory Concepts

- Haptic interfaces
- Impedence rendering
- 1000 Hz control loop
- Virtual wall
- Force field rendering



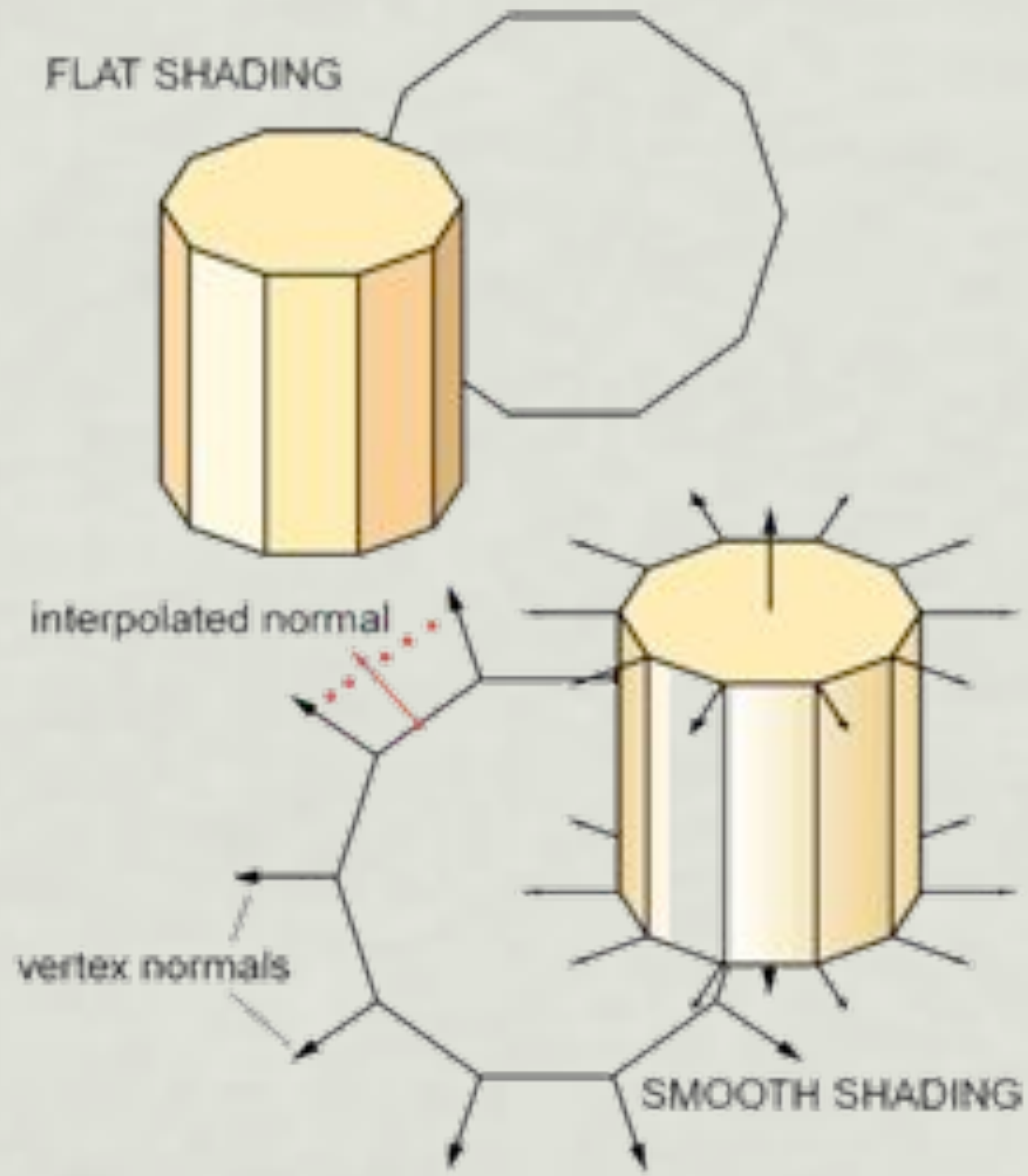
Proxy-Based Rendering

- God object & proxy rendering algorithms
- Implicit surface representations



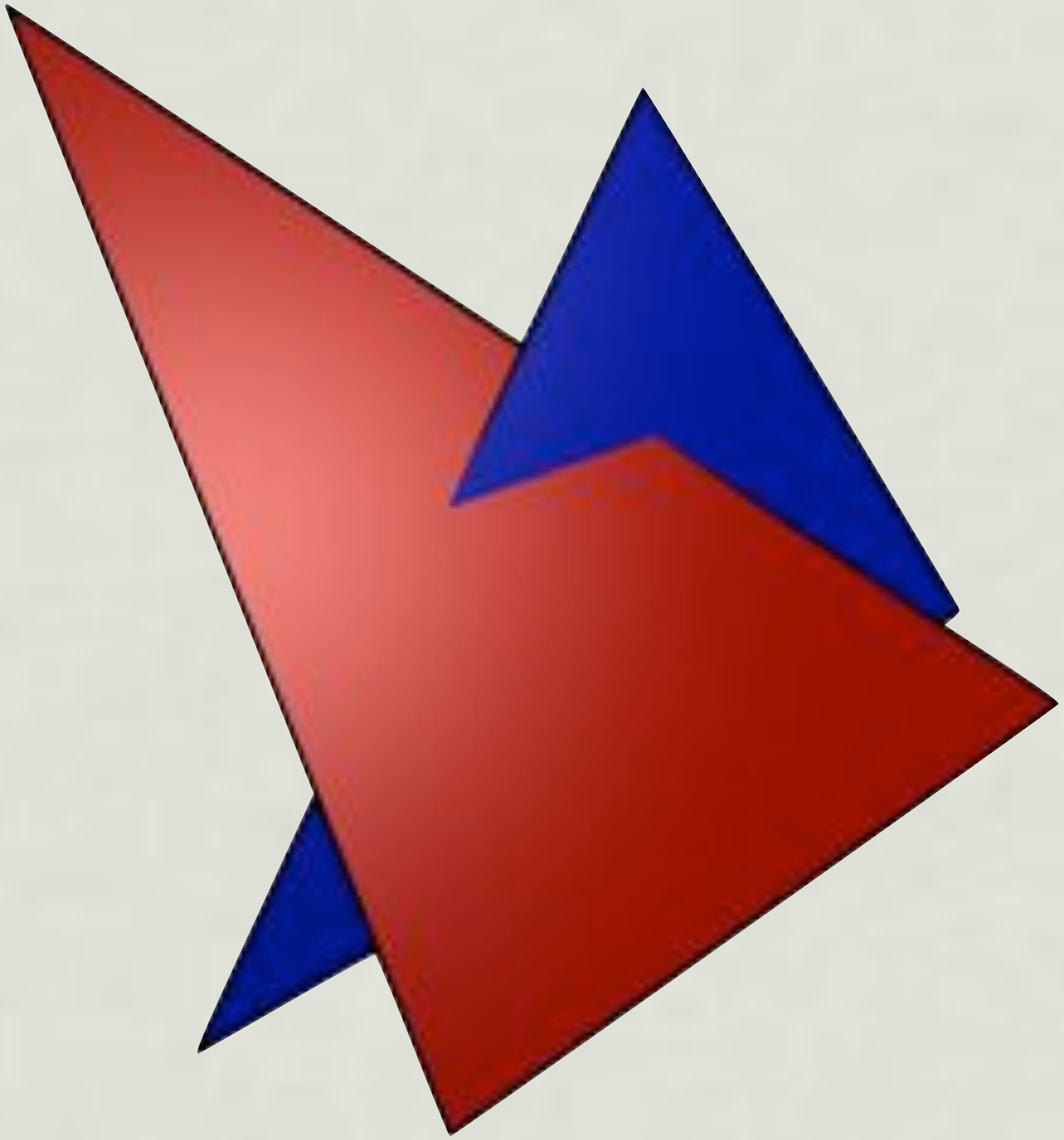
Haptic Rendering « Tricks »

- Surface properties
  - Friction
  - Texture
- Underactuated rendering
- Device workspace management



Collision Detection

- Intersection tests for primitives
- Spatial partitioning
- Bounding volume hierarchies

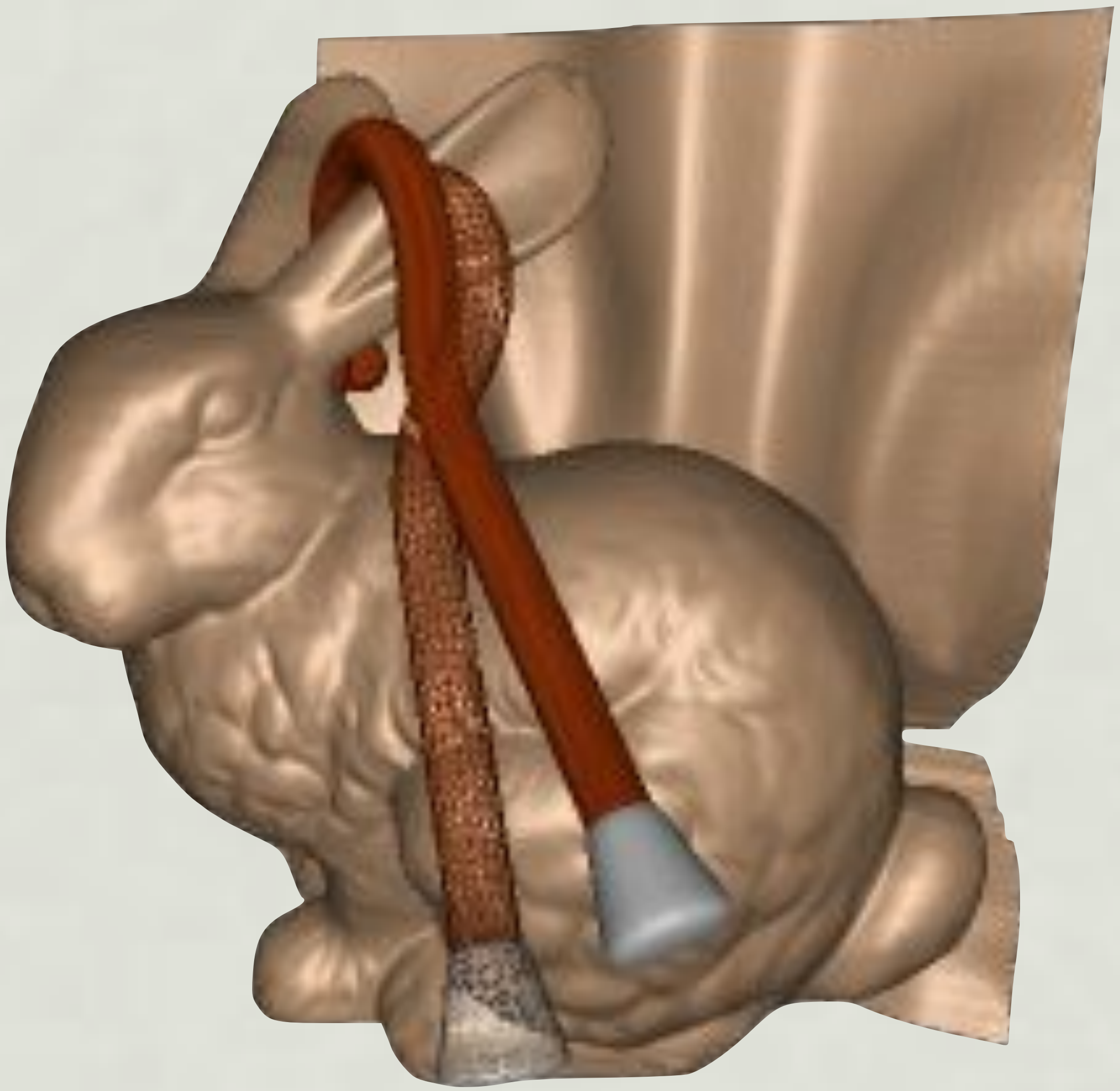


Dynamics Simulation

- Laws of motion
- Time integration
- Mass-spring models
- Modelling dynamic & deformable bodies

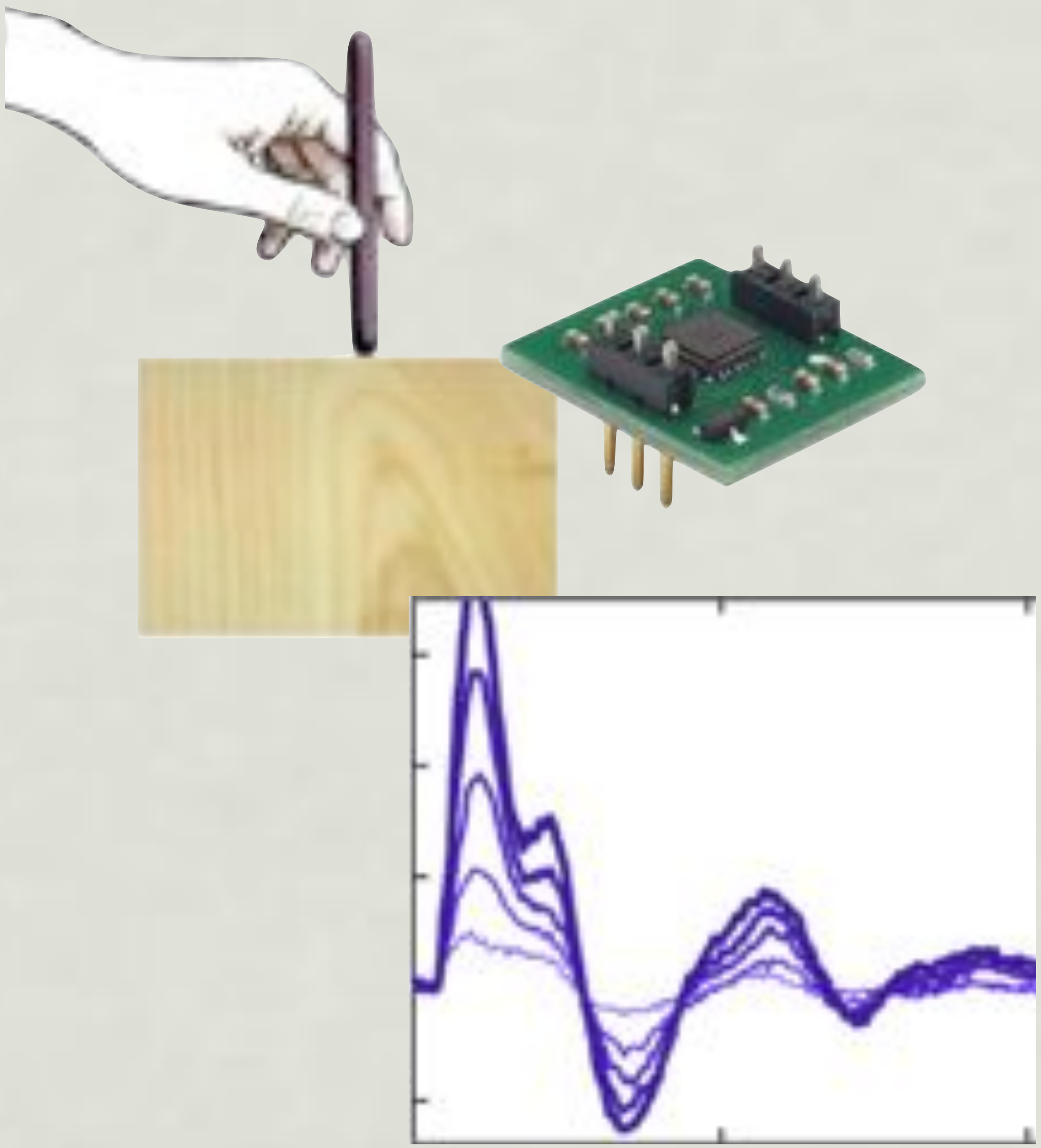
Six Degrees of Freedom

- Penalty force / dynamic proxy methods
- Constraint-based methods (6-DOF god object)



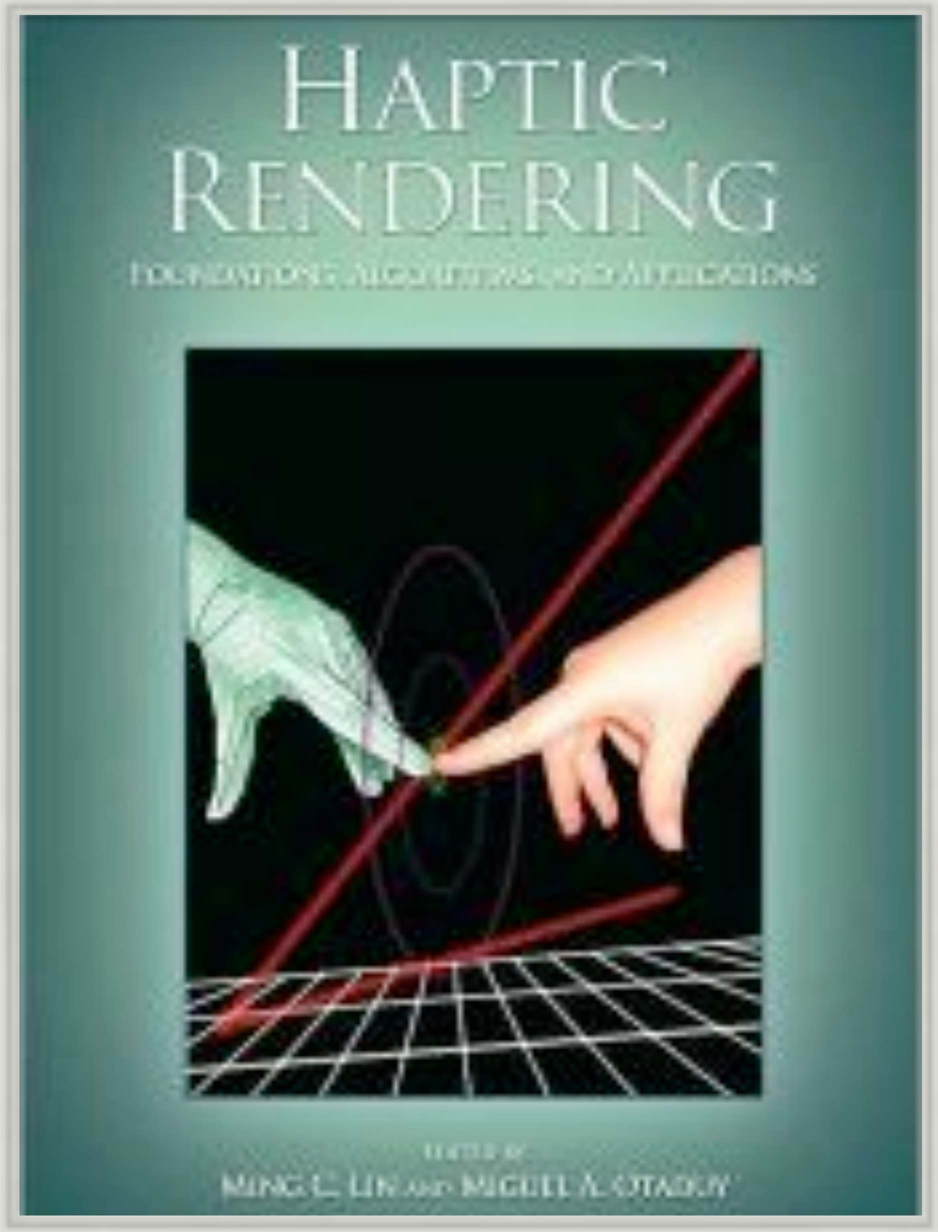
Event-Based Haptics

- Human vs. device bandwidth
- Open-loop playback
- Synthesized and sampled transients



A Course Text?

- We distribute key papers as readings
- Lin & Otaduy appear to agree with our selection of core topics
- Text is a collection of many seminal papers
- Is it mature enough?



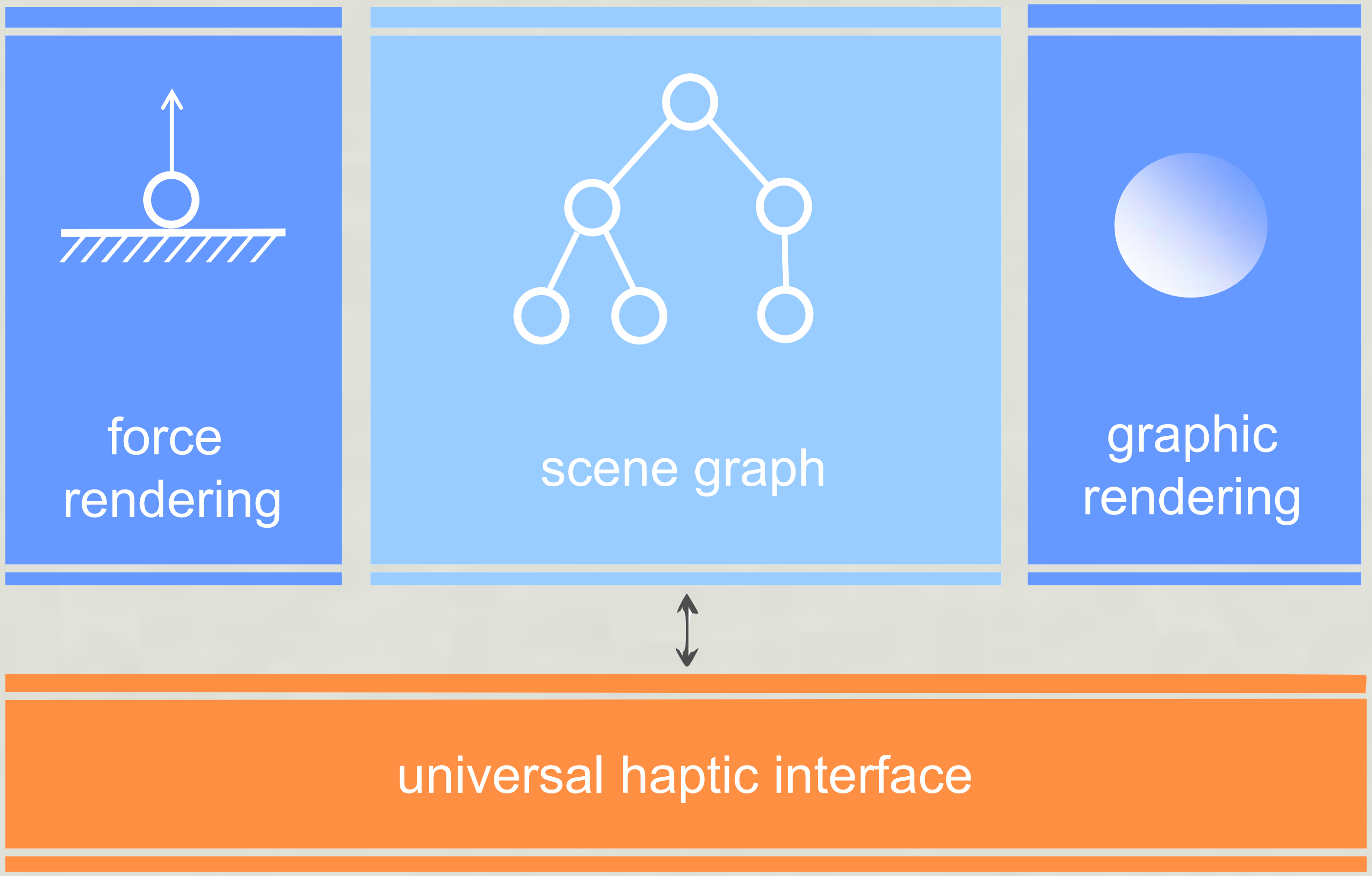
CHAI 3D

www.chai3d.org

Excellent Teaching Aid

- CHAI3D was developed at Stanford in conjunction with CS 277
- Both platform and device agnostic
- Reduces image/geometry manipulation and graphical rendering burden
- Can be a double-edged sword!

CHAI3D can do a lot...



- Implements direct rendering, god-object, force shading, friction, surface effects, mesh structures, collision detection, mass-spring simulation, etc.

...but has its drawbacks

- Can be difficult for someone not versed in object-oriented programming in C++ to ramp up
- Code internals could be much more pedagogical

- **It already implements most of the concepts we're trying to teach!**

To use or not to use?

- One solution is to distribute a reduced CHAI3D
  - Device communication and basic graphics
- Alternatively, design assignments that exercise key concepts but are not implemented in CHAI3D
  - Can be difficult! (and gets trickier every year...)

DESIGNING PEDAGOGICAL EXERCISES

FOR HOMEWORK OR LABORATORIES

Pedagogical Exercises

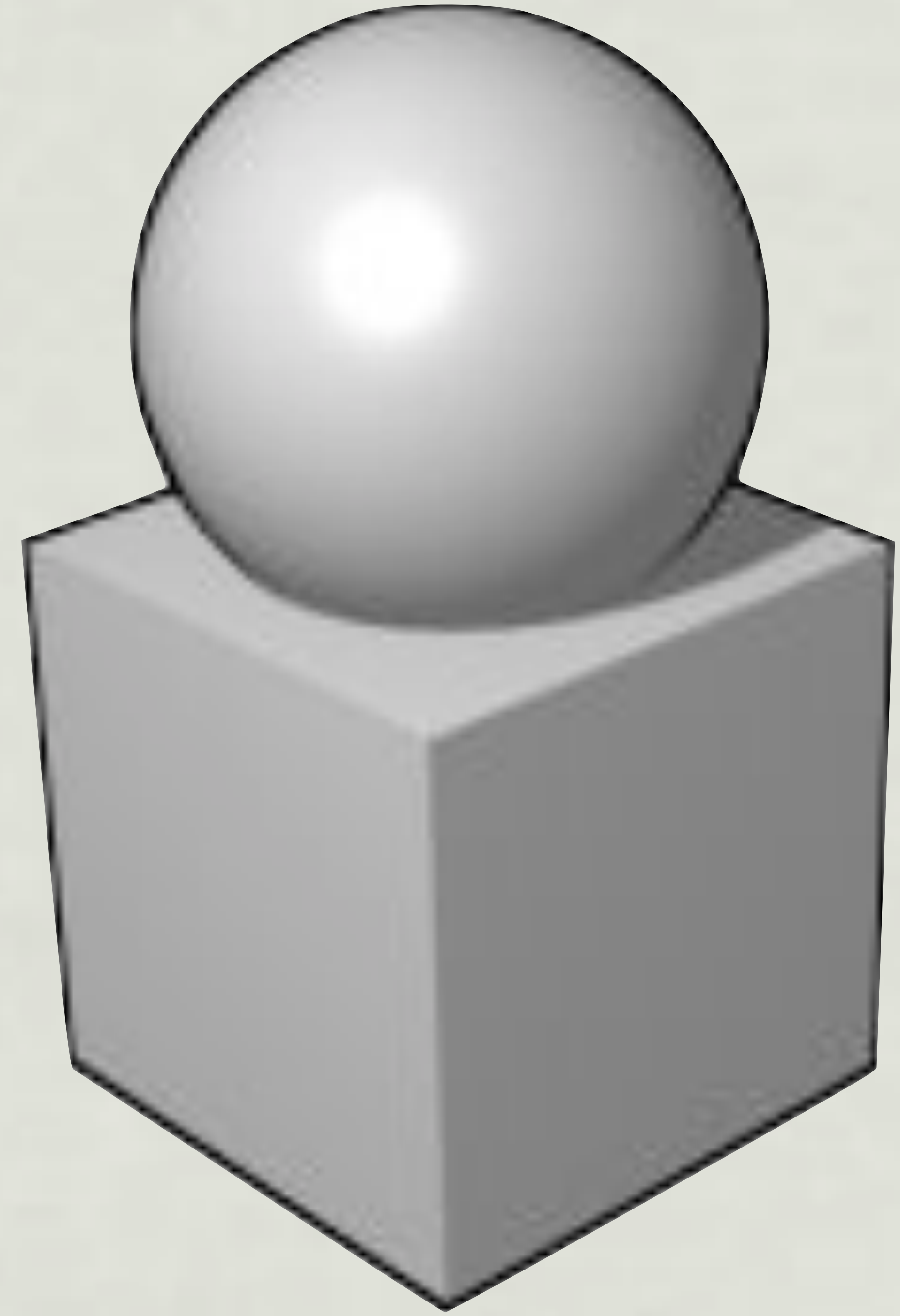
- Use it or lose it!
- We converged on 1-2 week assignments
- Covers a good cross-section of haptic rendering
- Challenge: CHAI3D already has implementations of all the key algorithms!
    - Extensions to CHAI3D?

The Novint Falcon

- A huge boon for teaching our course!
- Every student takes one home on loan for the quarter
- Inexpensive and virtually indestructible

Potential Fields

- Force field rendering
  - Experience pop-through problems
- Attractive fields
  - Identify stability limitations

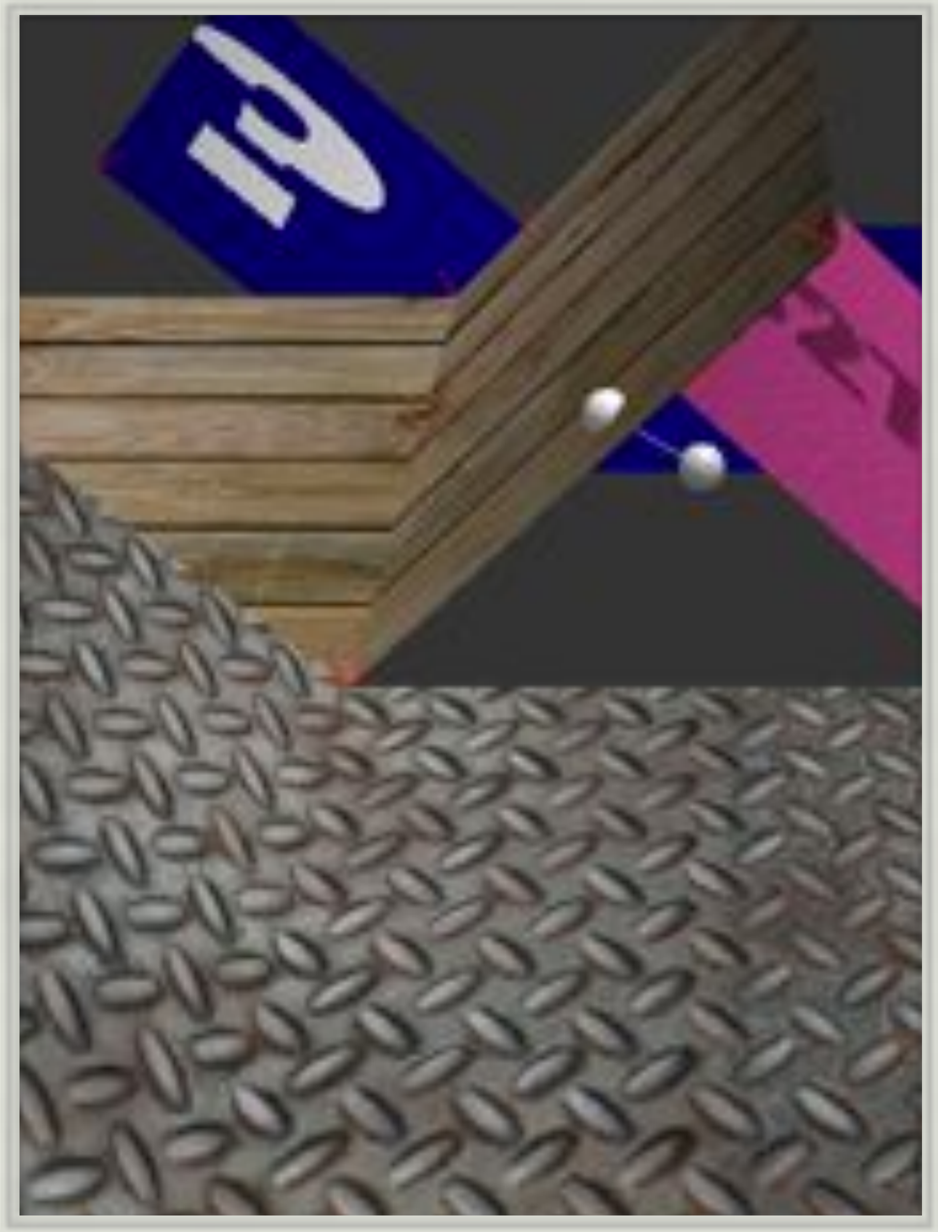


Proxy-Based Rendering

- Implict surface rendering algorithm
  - 3-DOF planar constraint tracking
  - Virtual spring
- Coulomb friction effect

Surface Effects

- Force shading
  - Barycentric normal interpolation
- Texture-mapped surface effects
  - Image gradients for normal modulation

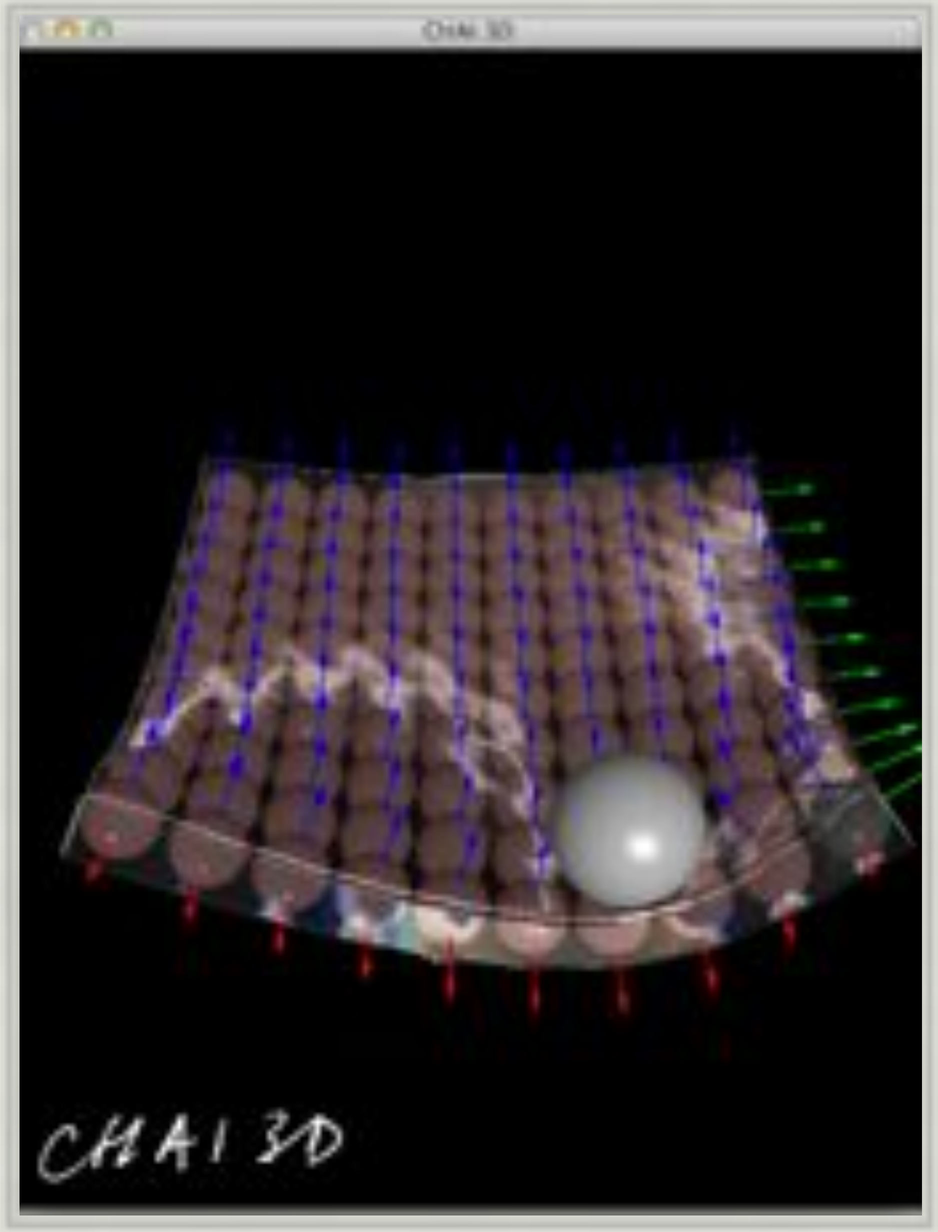


Collision Detection

- Point cloud scene representation
- Metaball implicit surface
- k-D Tree to find points within support radius

Deformable Objects

- Mass-spring system
  - Penalty force model
  - Time integration
  - Stiffness vs. stability



HAPTIC RENDERING COURSE PROJECTS

A SMALL SAMPLE FROM 2008-2011

Fair Warning

- Open-ended projects require extremely heavy guidance from the instructors!
- Most students learn just enough to get intro trouble, but not enough to get out...
- This selective sample of excludes many a misguided project

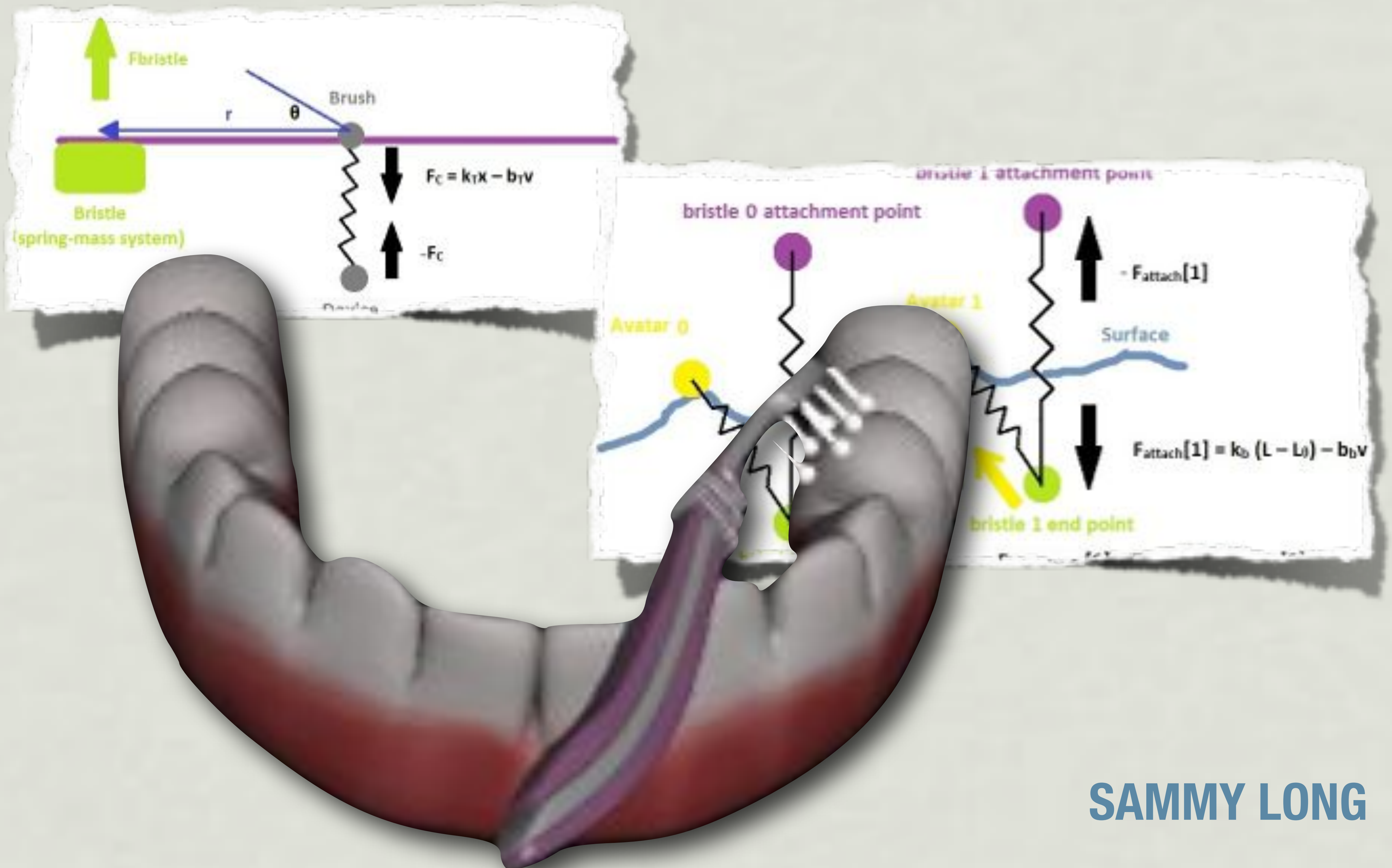
Crosscut Saw Simulation

JOHN JESSEN

Haptic Pottery

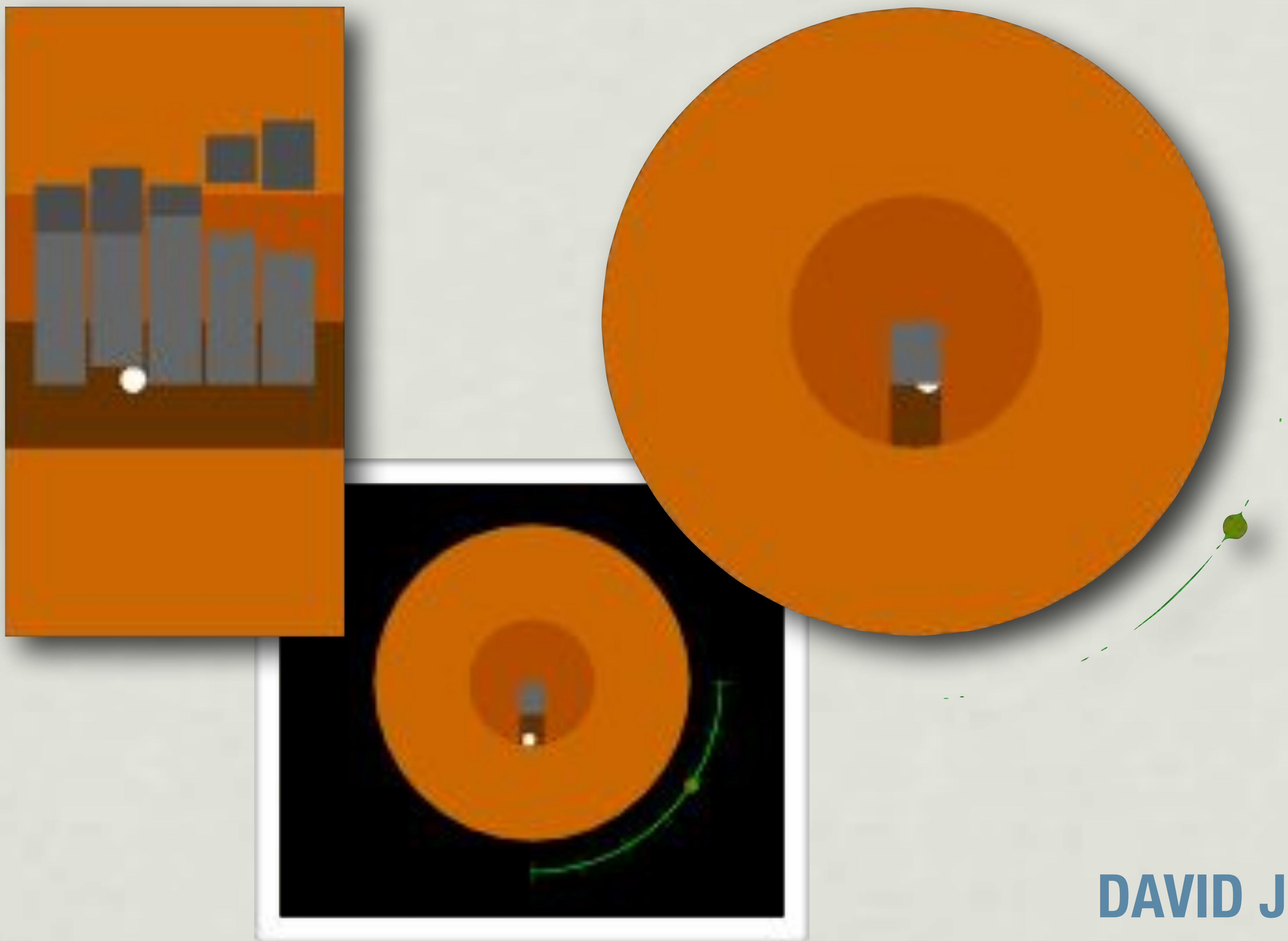
RIFAT JOYEE
NARENDRAN THIAGARAJAN

Haptic Toothbrushing



SAMMY LONG

Lock Picking Simulation



DAVID JOHNSON

Summary

- Identified core topics in haptic rendering
- Discussed use of CHAI3D for teaching
- Examined pedagogical haptic rendering exercises
- Reviewed a sample of course projects

Thank You!

Questions?

http://cs277.stanford.edu