

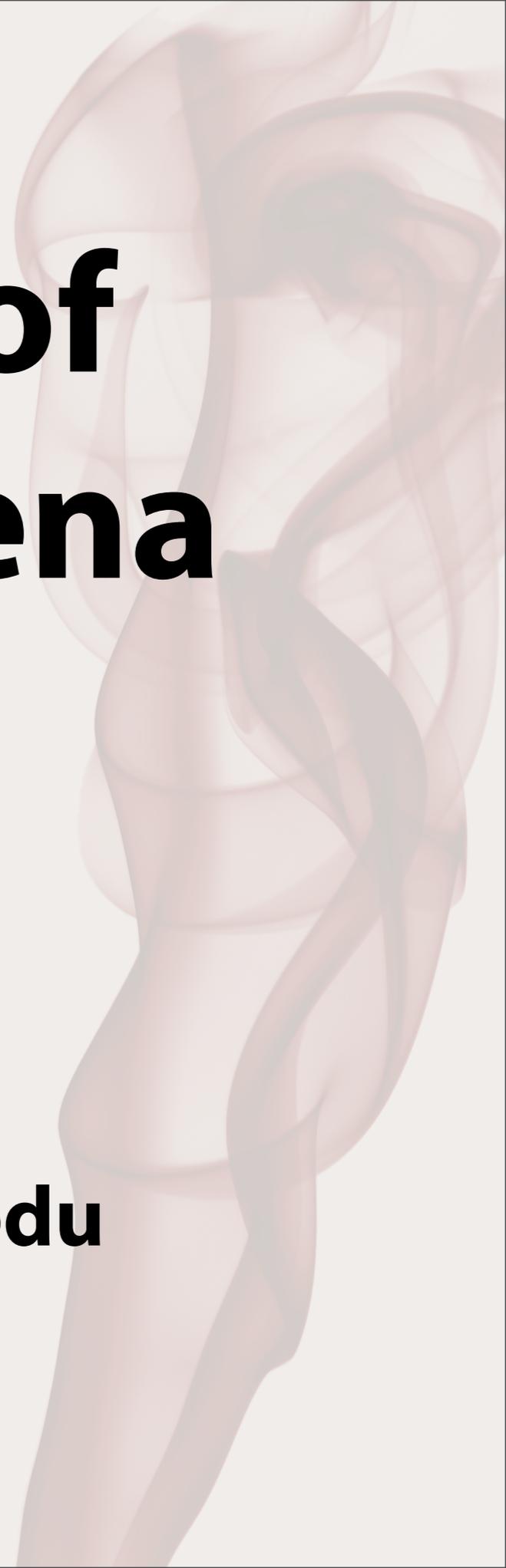
The Animation of Natural Phenomena

Instructor: Adrien Treuille

**Office Hours: After Class &
By Appointment**

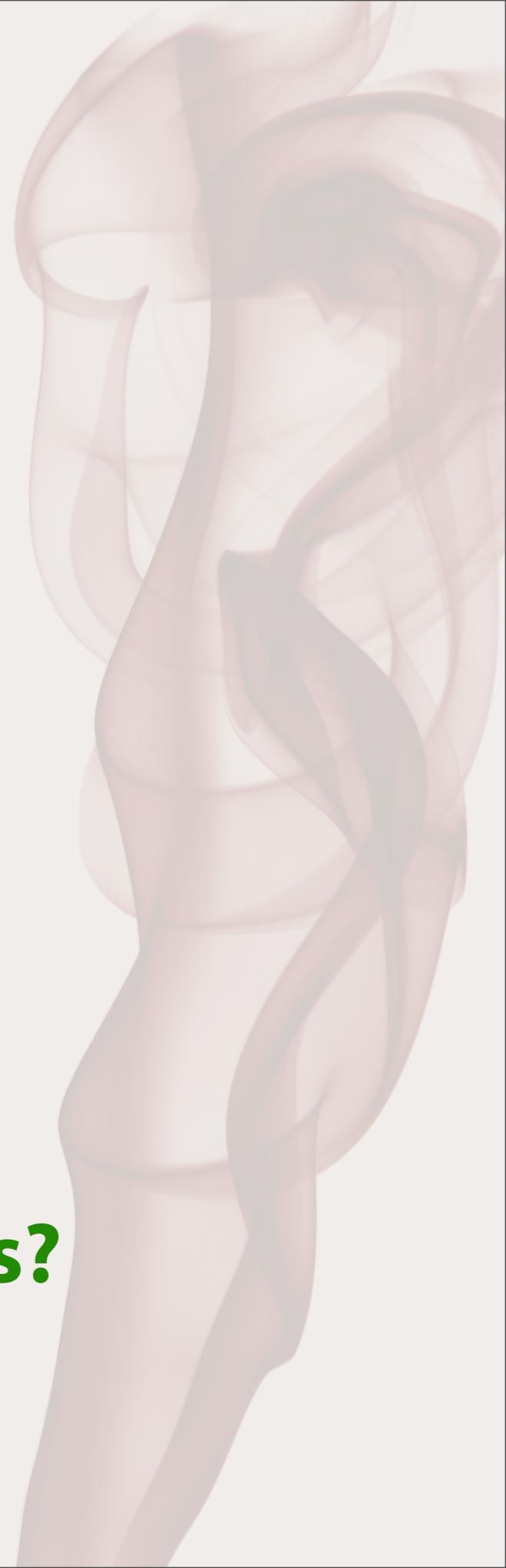
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E-mail: treuille@cs.cmu.edu



Questions

- **What is your name?**
- **Tell us about yourself.**
- **Experience...**
 - **OpenGL?**
 - **C++**
 - **Math?**
- **Why did you sign up for this class?**
- **What do you hope to learn?**



What is Physics-Based Animation?



Physics of our everyday lives...

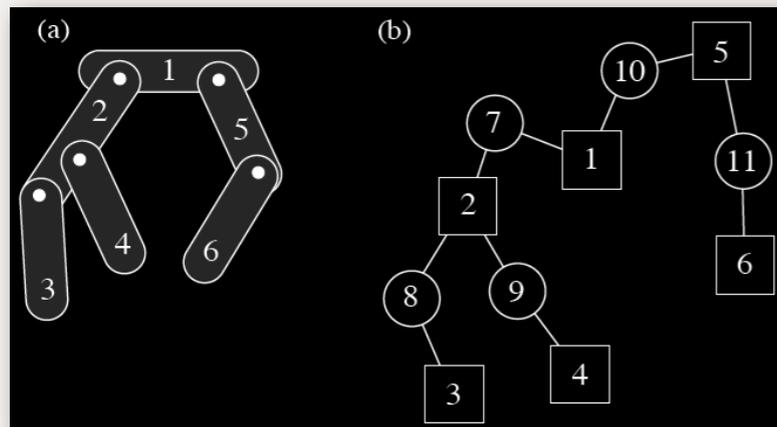
What is Physics-Based Animation?

FLOW

100% Full CG Water from R&D to Final



What is Physics-Based Animation?



[Baraf 1996]

Data Structures

DERIVATION OF SIMPLE HAIR BENDING FORCES Jan 29/07

$$\sin^2 \frac{\theta}{2} = \frac{1 - \cos \theta}{2}$$

$$\Rightarrow E = k \sin^2 \frac{\theta}{2} = \frac{k}{2} [1 - \cos \theta]$$

but $\cos \theta = \frac{\vec{a} \cdot \vec{b}}{|\vec{a}| |\vec{b}|} = \frac{\vec{a} \cdot \vec{b}}{ab}$

$$\Rightarrow f_0 = -\partial_{\vec{a}} E = +\frac{k}{2} \left\{ \frac{1}{ab} (0 + -b) \right\} - \frac{a \cdot b}{(ab)^2} \left[\frac{|\vec{a}|}{|\vec{b}|} \vec{b} + \frac{|\vec{b}|}{|\vec{a}|} \vec{a} \right]$$

$$f_2 = -\partial_{\vec{b}} E = +\frac{k}{2} \left\{ \frac{1}{ab} [\vec{a} + 0] \right\} - \frac{a \cdot b}{(ab)^2} \left[\frac{|\vec{a}|}{|\vec{b}|} \vec{b} - 0 \right]$$

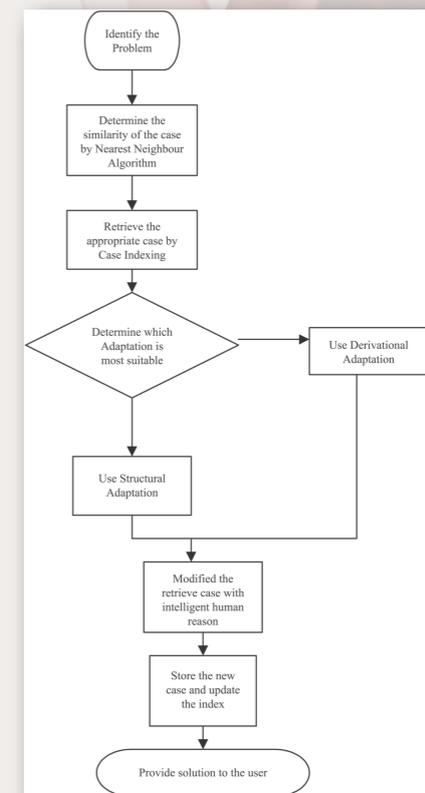
$$f_1 = -f_0 - f_2$$

$$f_0 = +\frac{k}{2|\vec{a}||\vec{b}|} \left\{ -\vec{b} + \frac{(\vec{a} \cdot \vec{b})}{ab} \frac{|\vec{b}|}{|\vec{a}|} \vec{a} \right\} = \frac{k}{2|\vec{a}||\vec{b}|} \left\{ -\vec{b} + \frac{(\vec{a} \cdot \vec{b})}{|\vec{a}|^2} \vec{a} \right\}$$

$$f_2 = +\frac{k}{2|\vec{a}||\vec{b}|} \left\{ \vec{a} - \frac{(\vec{a} \cdot \vec{b})}{ab} \frac{|\vec{a}|}{|\vec{b}|} \vec{b} \right\} = \frac{k}{2|\vec{a}||\vec{b}|} \left\{ +\vec{a} - \frac{(\vec{a} \cdot \vec{b})}{|\vec{b}|^2} \vec{b} \right\}$$

$$\begin{cases} \partial_{\vec{a}} \vec{a} = -\mathbf{I}, & \partial_{\vec{a}} \vec{a} = \mathbf{I}, & \partial_{\vec{a}} \vec{a} = 0 \\ \partial_{\vec{b}} \vec{b} = 0, & \partial_{\vec{a}} \vec{b} = -\mathbf{I}, & \partial_{\vec{b}} \vec{b} = \mathbf{I} \end{cases}$$

Mathematical Techniques



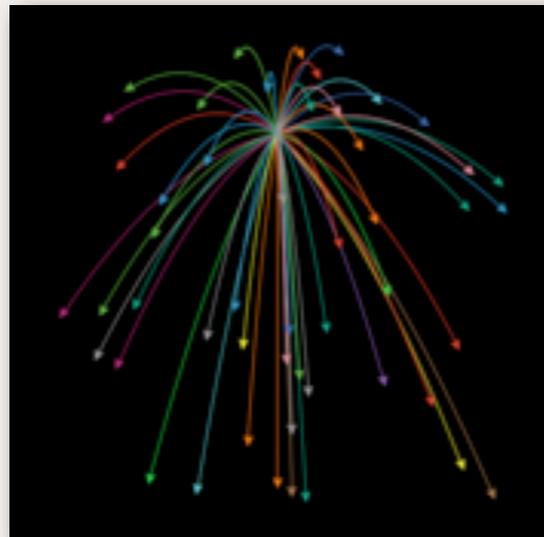
Algorithms

Overview The Class

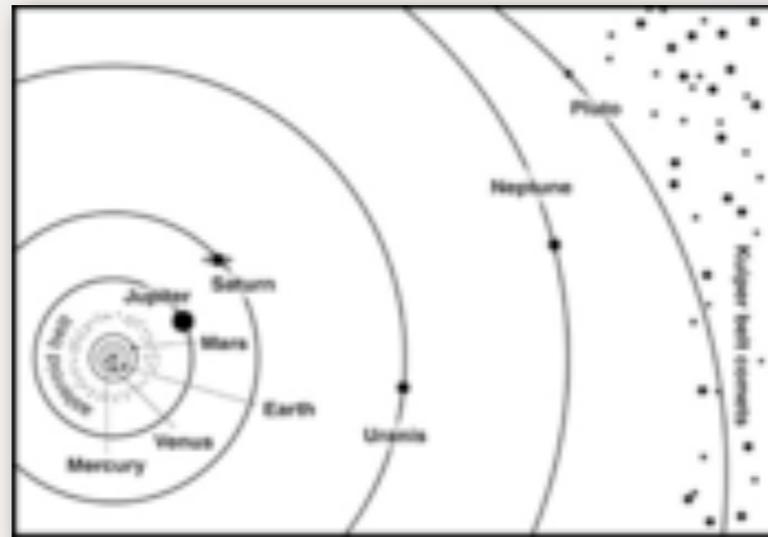
- **Will explore various phenomena...**
- **Questions you should ask:**
 - **What should we simulate?**
 - **How do you simulate it?**
 - **Interactively?**
 - **How can we break it?**
 - **How can we control it?**
 - **How can we couple it with other objects?**
 - **How do we measure success?**



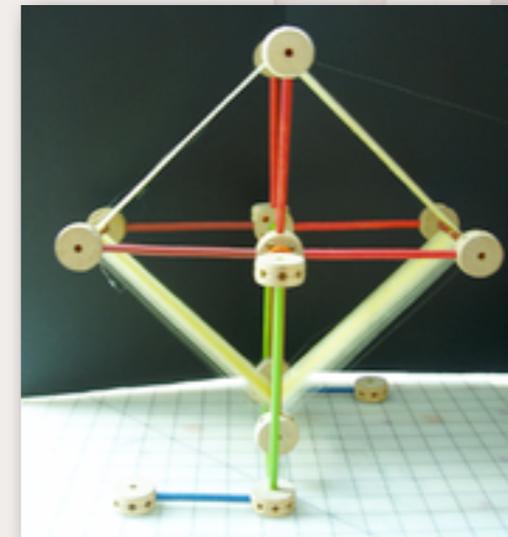
Particles



Data Structures



DiffEQ



Constraints



Hair (1D)

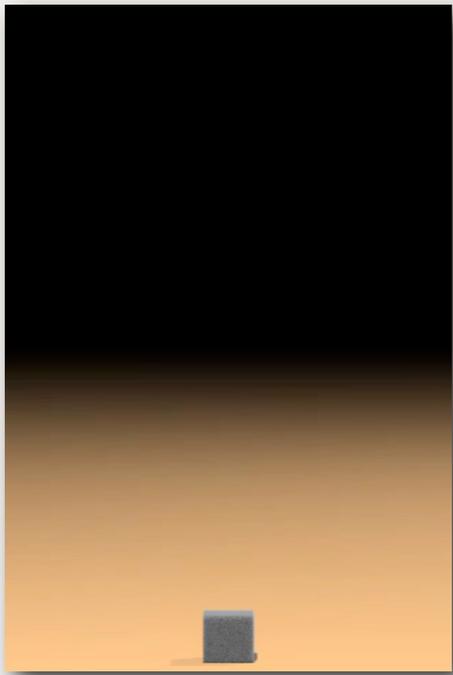


Cloth (2D)

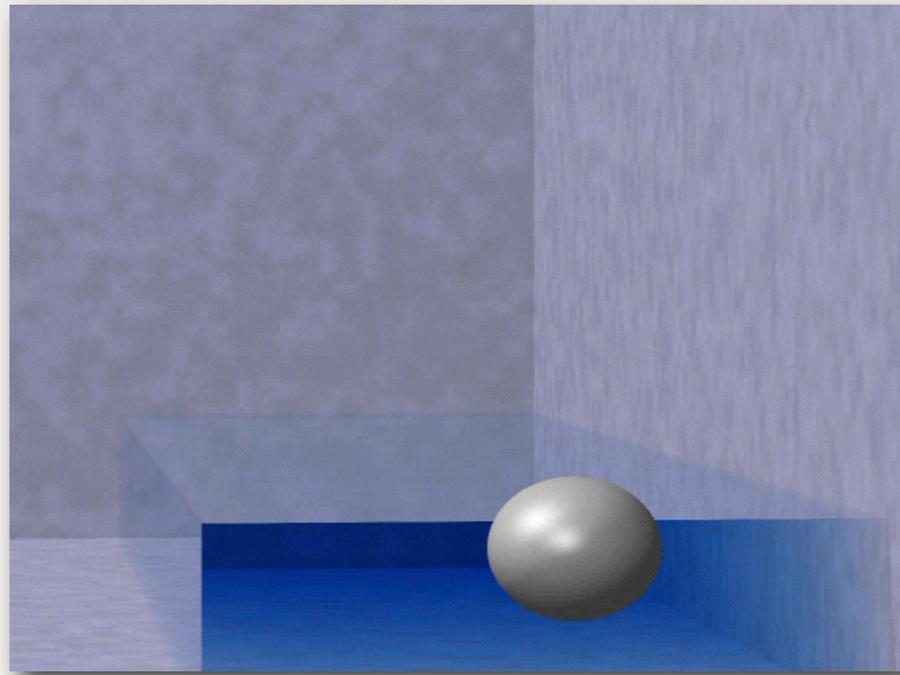


Crowds

Fluids



**Incompressible
Fluids**



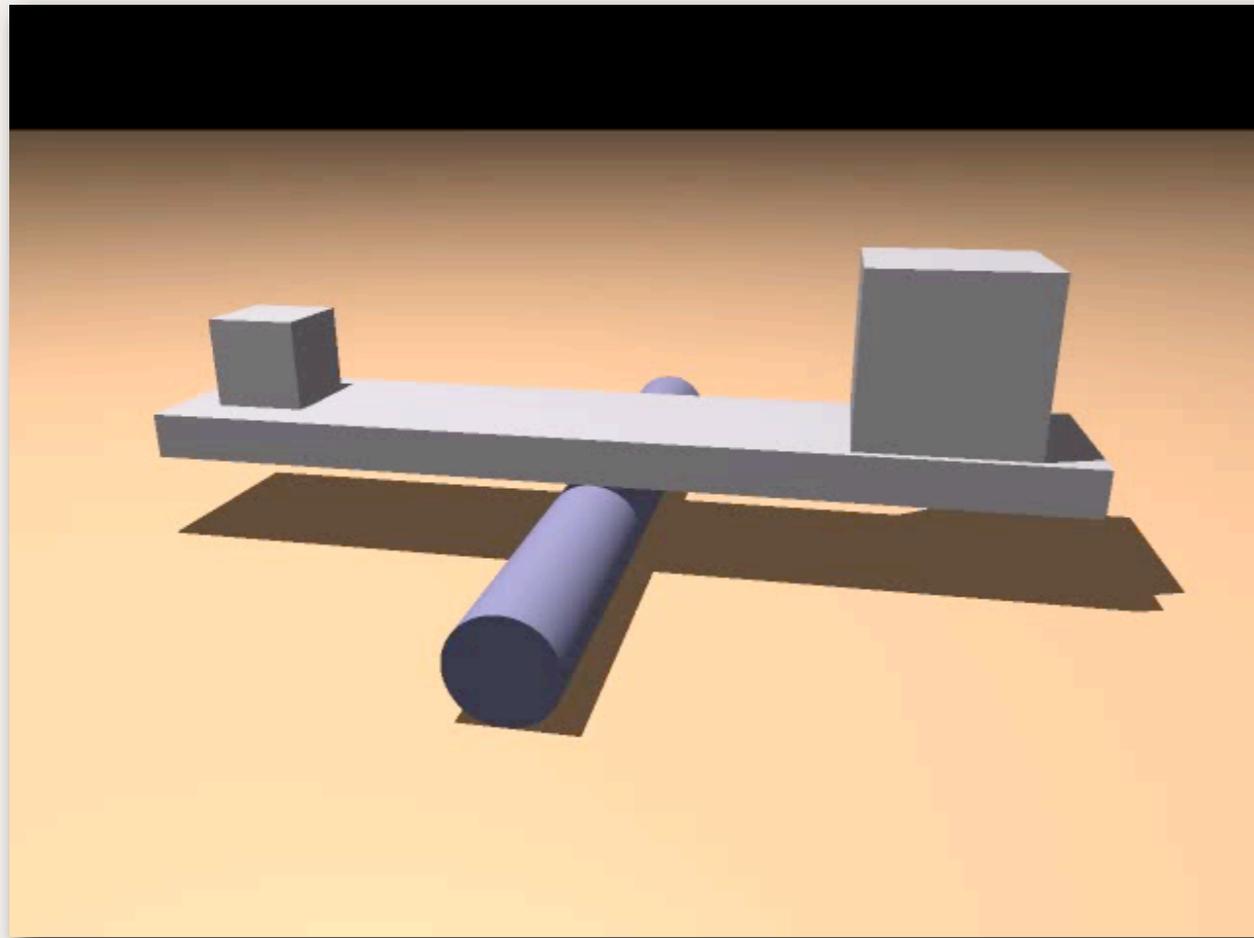
**Free-surface
Fluids**



**Particle
Fluids**

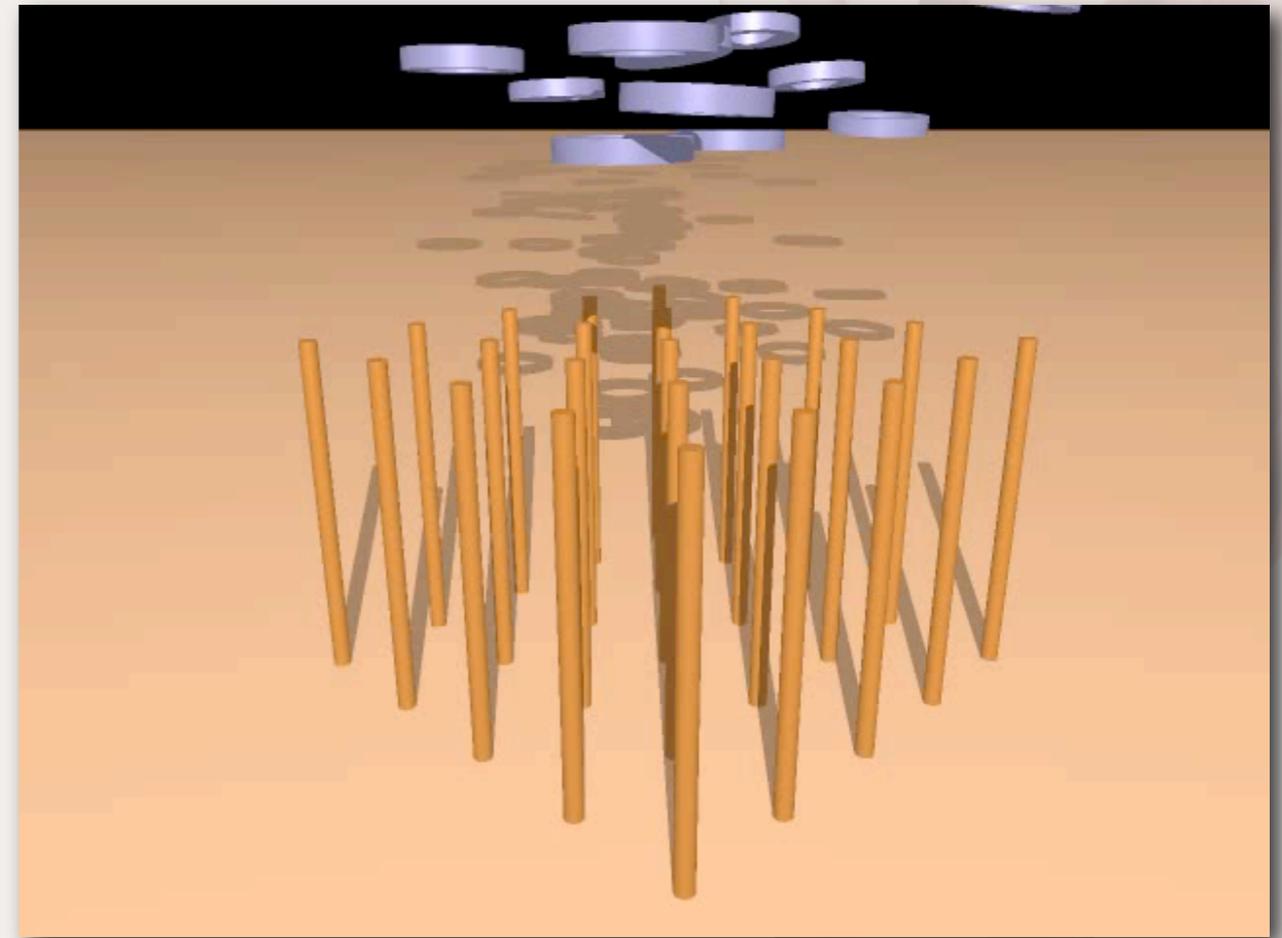


Rigid Bodies



[Guendelman 2003]

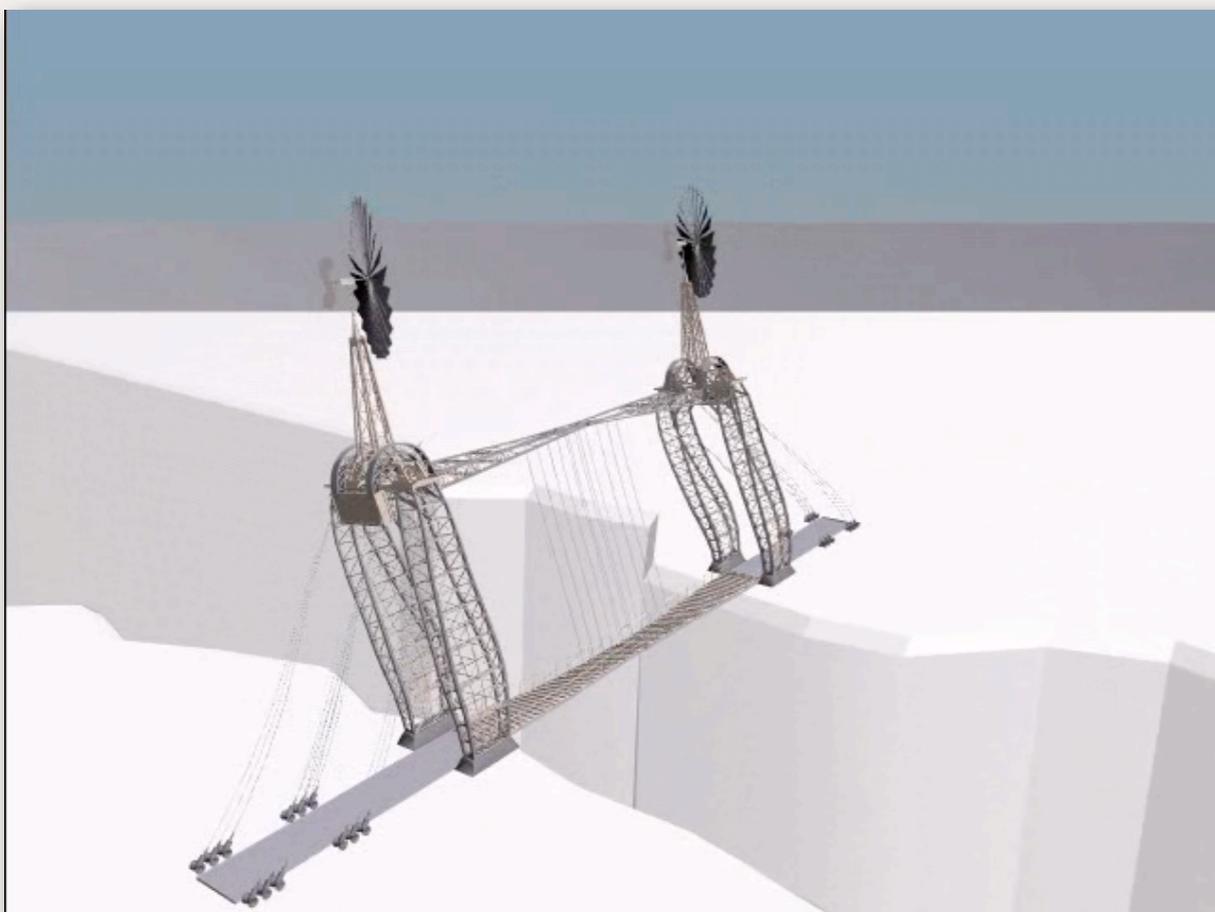
Rigid Bodies



[Guendelman 2003]

Collisions and Stacking

Deformable Objects



[Barbić and James 2008]

Deformable Objects

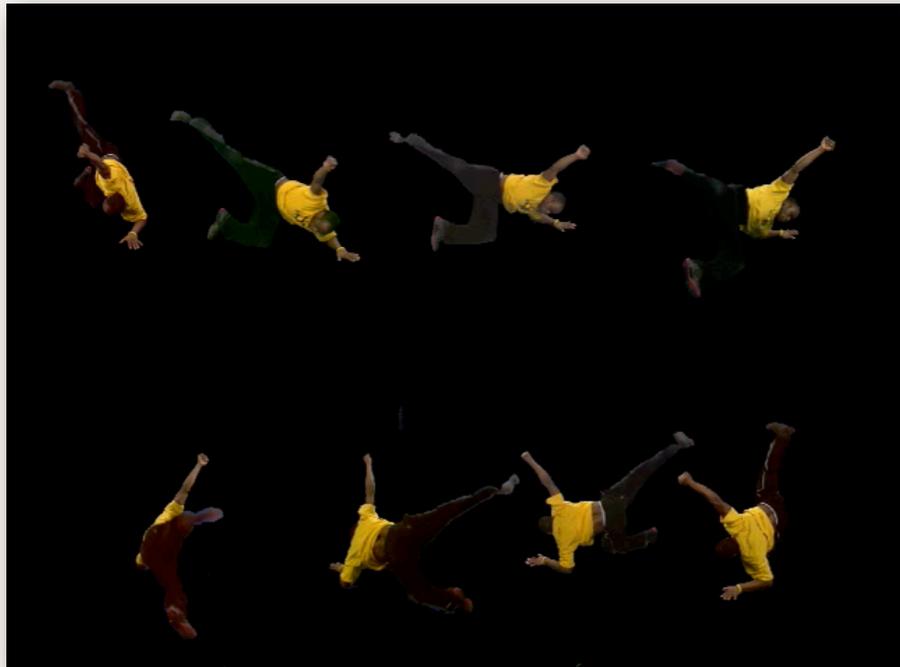
**Animating Water Bottle
Recycling Rates**

**Doug James
Cornell University**

[James 2008]

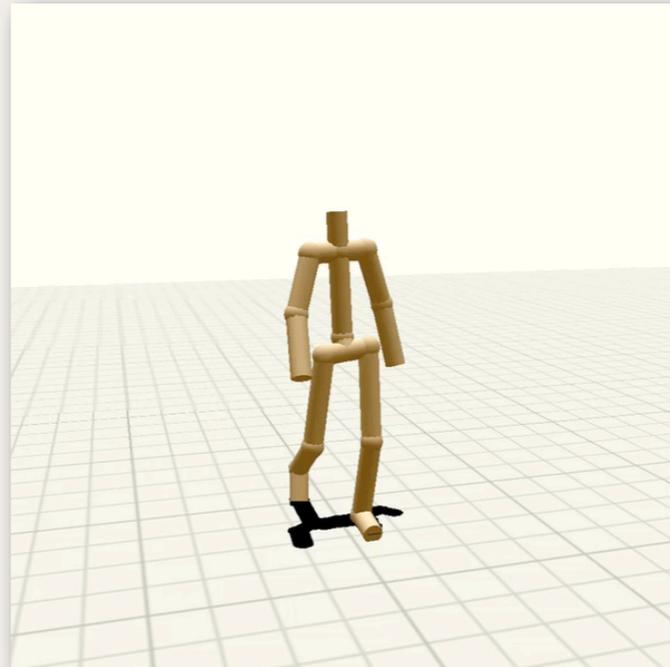
Deformable Object Collisions

Humans



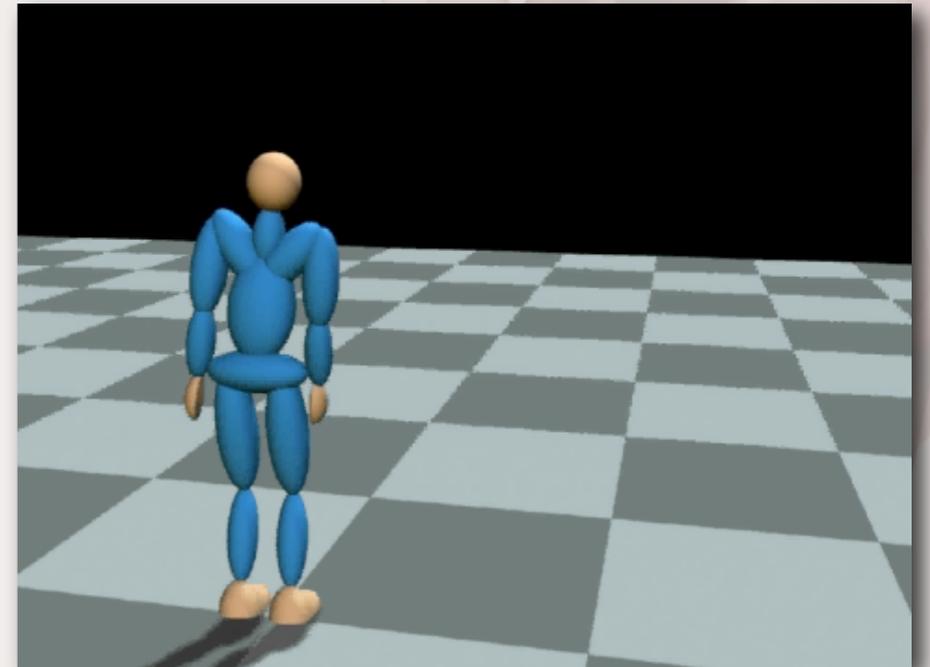
[Vlasic et al 2003]

**Performance
Capture**



[Treuille et al 2007]

**Data-Driven
Motion**



[Lui and Popović et al 2002]

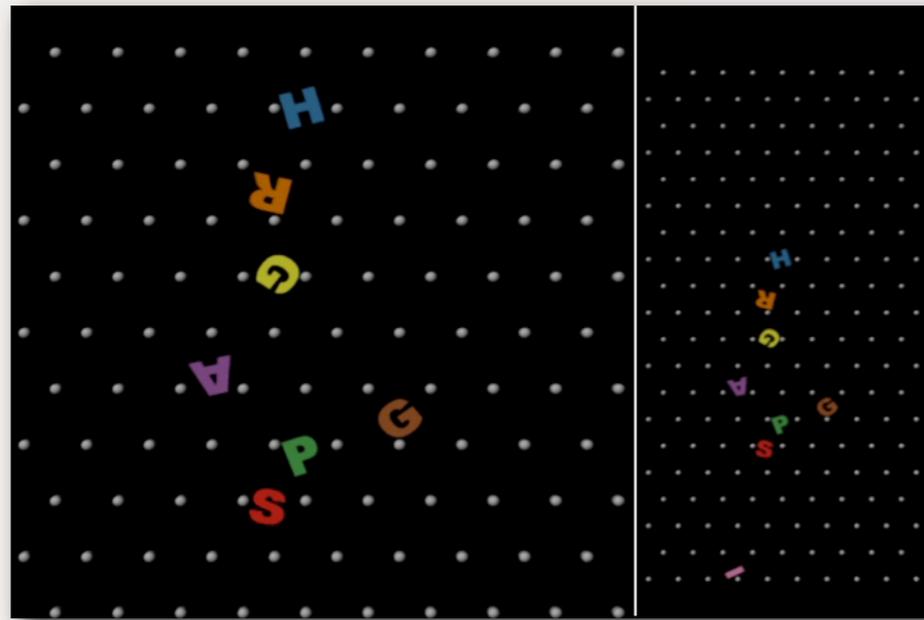
**Physical
Simulation**

Advanced



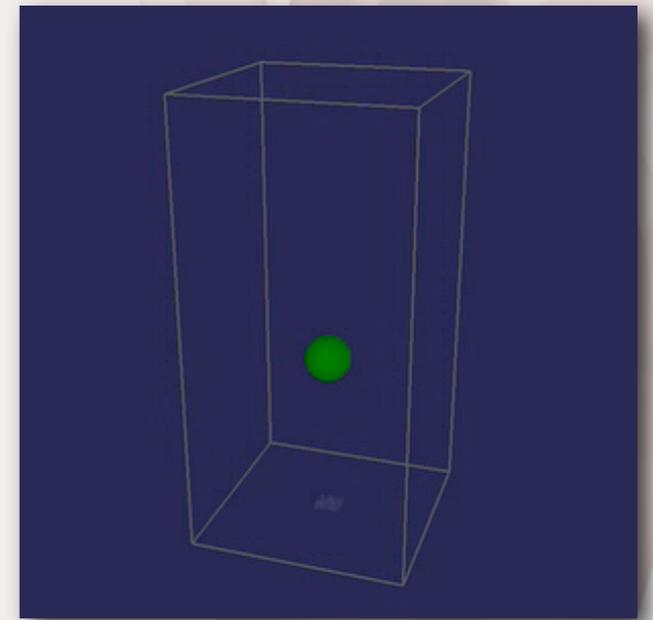
[Fattal and Lischinski *et al* 2003]

Optimization



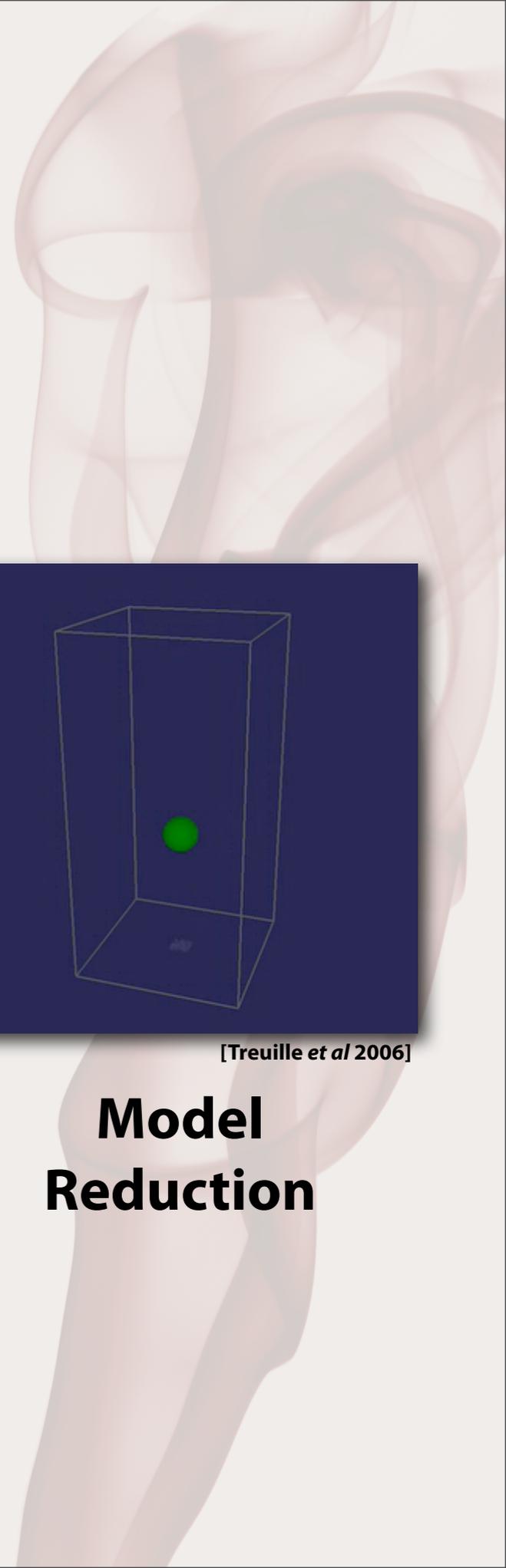
[Twig and James 2007]

Control



[Treuille *et al* 2006]

**Model
Reduction**



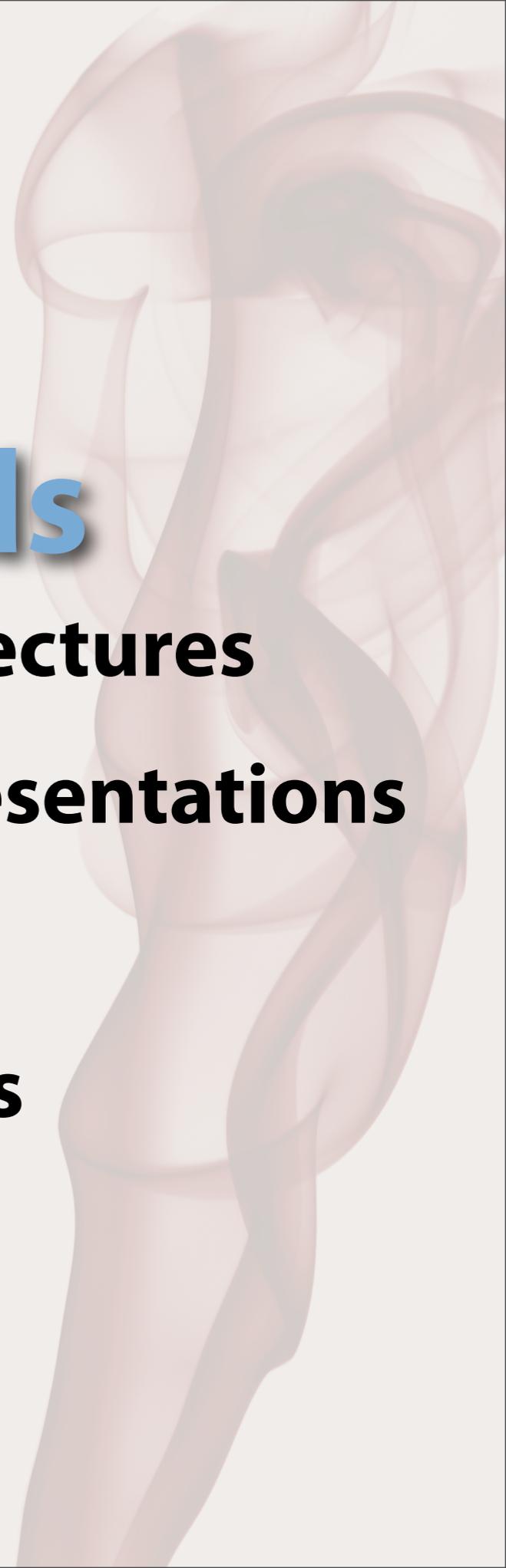
Objectives

Goals

- **Learn Techniques**
- **Fun Coding**
- **Quick Problem Solving**
- **Presentation Skills**

Methods

- **Weekly Lectures**
- **Paper Presentations**
- **Projects**
- **Questions**



Logistics



Class n

Class $n+1$

Class $n+2$

Paper Presentation

Paper Presentation

Paper Presentation

Lecture

Lecture

Lecture

Question

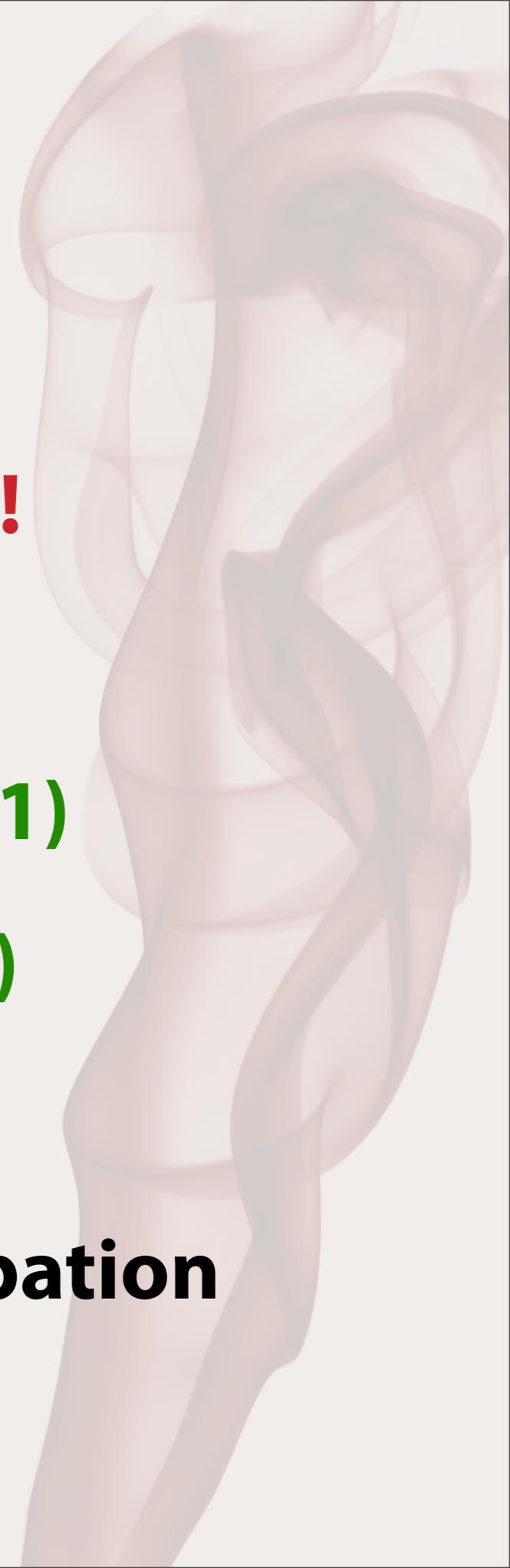
Question

Question

<http://graphics.cs.cmu.edu/courses/15-869-F08/>

Grading

- **Do *not* take this class for a grade!**
- **24% Project 1: Particles (due 10/1)**
- **24% Project 2: Fluids (due 10/22)**
- **36% Final Project (due 12/3)**
- **16% Class Presentation / Participation**



Logistics

Anonymous Feedback:

<http://www.cmu.edu/blackboard/>

Lab:

WeH 5336

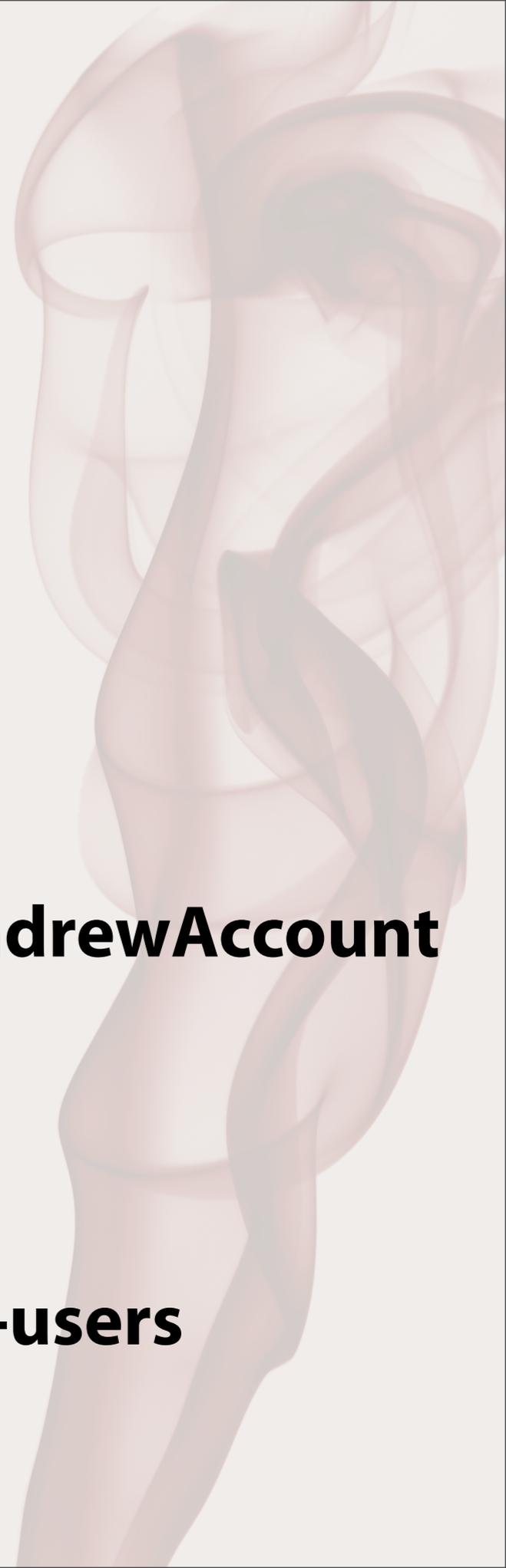
</afs/cs.cmu.edu/project/weh5336/SetupAndrewAccount>

Use Caps: hbovik@ANDREW.CMU.EDU

Disk Space:

</afs/cs.cmu.edu/academic/class/15869-f08-users>

10GB per user



Questions

- **What everyday things are we missing here?**
 - ***These could be final projects!***
- **How can we measure success?**
 - **How do we measure “success” for chaotic systems that cannot be recreated?**
 - **Can we come up with an objective notion of “visual correctness?”**



Homework 1

Read:

Differential Equation Basics

**Andrew Witkin and David Baraff
(on the website)**

