15-462: Computer Graphics

Doug James
Assistant Professor
Robotics Institute and
Computer Science Department

Introduction

- Administrivia
- Who am I?
- What is Computer Graphics?

Administrivia

Administration

- Web page
  - **http://www.cs.cmu.edu/~djames/15-462**
- Teaching assistants:
  - **Robert Wang** & **Shafeeq Sinnamohideen**
  - Office hours and contact info on course webpage
  - TAs available in graphics lab (Wean 5336)
  - Card reader for access (email me if denied)
- Textbook: Angel, 3rd edition
- Textbook: Open GL “Redbook”

Administration

- Prerequisites (talk to me if you're missing these!)

  15-213: Introduction to Computer Systems

  21-241: Matrix Algebra (matrix & vector algebra)

  21-259: Calculus in Three Dimensions (i.e. planes, quadratic surfaces, basic 3-D geometry, partial derivatives) or equivalent

- Midterm and Final (13% and 22%)
- Four programming assignments (10-13% each)
- Three written assignments (20% total)
- No collaboration!

Assignment Policies

- Programming assignments
  - Hand in via AFS by end of due date
  - Evaluation:
    - Functionality and features
    - Style and documentation
    - Artistic impression
- Written assignments
  - Hand in on paper before lecture
  - Correctness is central
  - Show your reasoning

Administration

- Late Policy: 3 late days that you can use for any assignment. More than three requires a really good excuse.
- Cheating: Please don't! The detailed definition is in the syllabus. We will pursue the case…
- If you didn't get into this class, talk to me—the waitlist is empty


You will do fun things in this class!!

Alan Goykhman

Alan Goykhman

Alan Goykhman

Previous class projects:

Paint program

Spline roller coaster

Cube of jello

Ray tracer

Warning: mathematical programming may be different than what you've done in the past.

Other Graphics-related Courses

- 15-???: Computer Animation, Hodgins, Duesing (F03)
- 15-???: Video Games, Kuffner (S03)
- 15-385: Computer Vision
- 05-331: Building Virtual Worlds, Pausch
- 24-384A: Computational Geometry, Shimada
- 60-41x: 3-D Animation, Duesing

- 15-???: Advanced Computer Graphics, James (S03)
- 15-863: Physically Based Modeling and Interactive Simulation, James …

15-863 Physically Based Modeling and Interactive Simulation

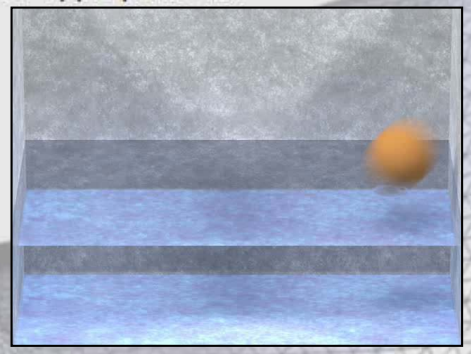
INSTRUCTOR:	Doug James (CS/Robotics)
COORDINATES:	NSH 3002, TH 1:30--2:50
UNIVERSITY UNITS:	12
FIRST CLASS:	Tuesday, January 14, 2003

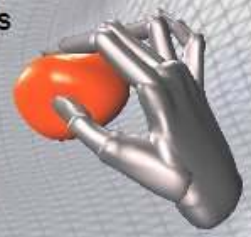
DESCRIPTION:
This course introduces students to physically based modeling for computer graphics and related fields, and summarizes current research issues. Efficient numerical methods for simulating a host of visually interesting physical phenomena will be covered, and discussed in the context of both interactive and offline simulation. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

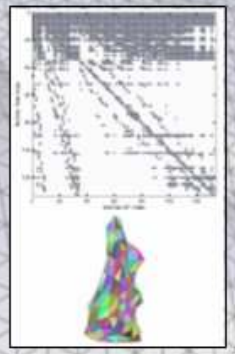
METHOD OF EVALUATION:
Grading will be based on a set of assignments and a final class project.

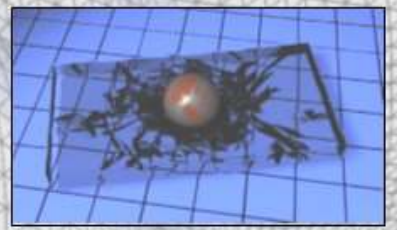
TOPICS TO BE COVERED:
Depending on time and class interest we will cover topics from:

- Overview of physical simulation in graphics and interactive applications
- Dynamical systems
- Numerical integration of ODEs
- Rigid body dynamics
- Deformable objects
- Fluids & gases
- Constraints and contact
- Collision detection
- Multiresolution modeling
- Rendering issues: graphics, haptics and acoustics
- Simulation on programmable graphics hardware
- Data-driven approaches to simulation
- Reality based measurement & inverse problems
- Other applications of physically based modeling in graphics









Introduction

- Administrivia
- Who am I?
- What is Computer Graphics

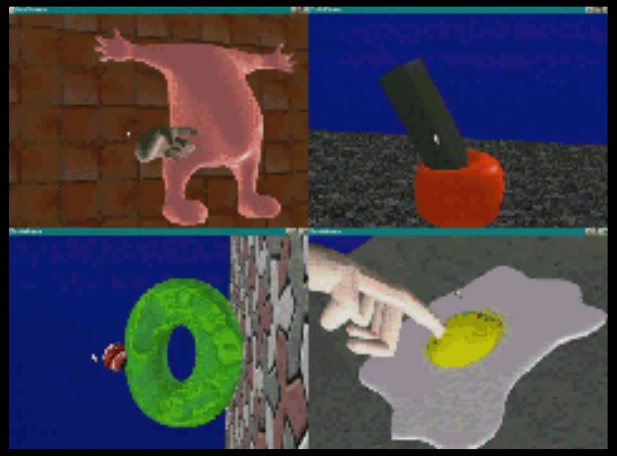
Any questions?

Who am I?

Who Am I?

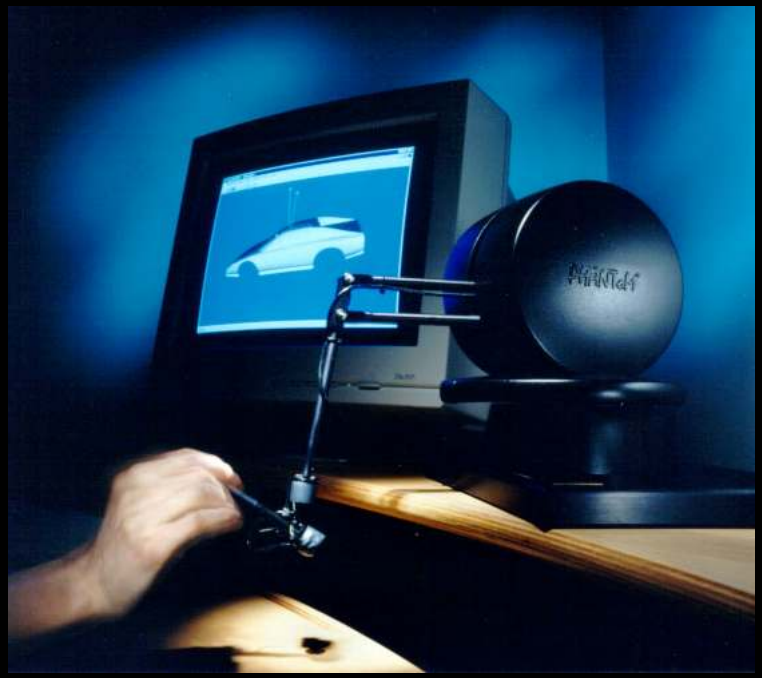
- Doug James
  - Interactive Multimodal Physical Simulation
  - Data-driven Deformable Models
- http://www.cs.cmu.edu/~djames
- NSH 4229
- Office Hours:
  - Tues 1-2 pm, NSH 4229
  - By appointment

Interactive Computer Animation



Doug L. James and Dinesh K. Pai,
ARTDEFO: Accurate Real Time Deformable Objects,
Proceedings of ACM SIGGRAPH 99, pp. 65-72, 1999.

Force-feedback Rendering



Haptic Interaction with
Linear Elastic Models

Doug L. James
Dinesh K. Pai
Univ. British Columbia
April 2000

Doug L. James and Dinesh K. Pai,
A Unified Treatment of Elastostatic Contact Simulation for Real Time Haptics,
Haptics-e, The Electronic Journal of Haptics Research (www.haptics-e.org), 2(1), September 27, 2001.

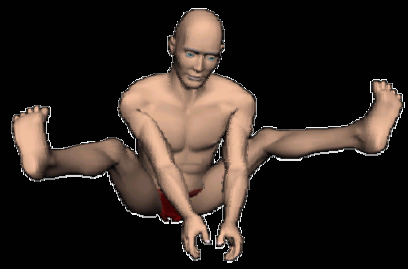
Force-feedback Rendering

Doug L. James and Dinesh K. Pai,
Multiresolution Green's Function Methods for Interactive Simulation of Large-scale Elastostatic Objects,
ACM Transactions on Graphics, *22(1)*, pp. 47-82, 2003.

Surgical Simulation

Doug L. James and Dinesh K. Pai,
DyRT: Dynamic Response Textures for Real Time Deformation Simulation with Graphics Hardware,
ACM Transactions on Graphics (Proc. of SIGGRAPH 2002), *21(3)*, pp. 582-585, 2002.

Virtual Humans



Doug L. James and Dinesh K. Pai,
DyRT: Dynamic Response Textures for Real Time Deformation Simulation with Graphics Hardware,
ACM Transactions on Graphics (Proc. of SIGGRAPH 2002), *21(3)*, pp. 582-585, 2002.

Interactive Deformable Scenes

Doug L. James and Kayvon Fatahalian,
Precomputing Interactive Dynamic Deformable Scenes,
ACM Transactions on Graphics (Proc. of ACM SIGGRAPH 2003), 22(3), pp. 879-887, 2003.

What is this course about?

Computer Graphics…

One agenda: Faking Reality

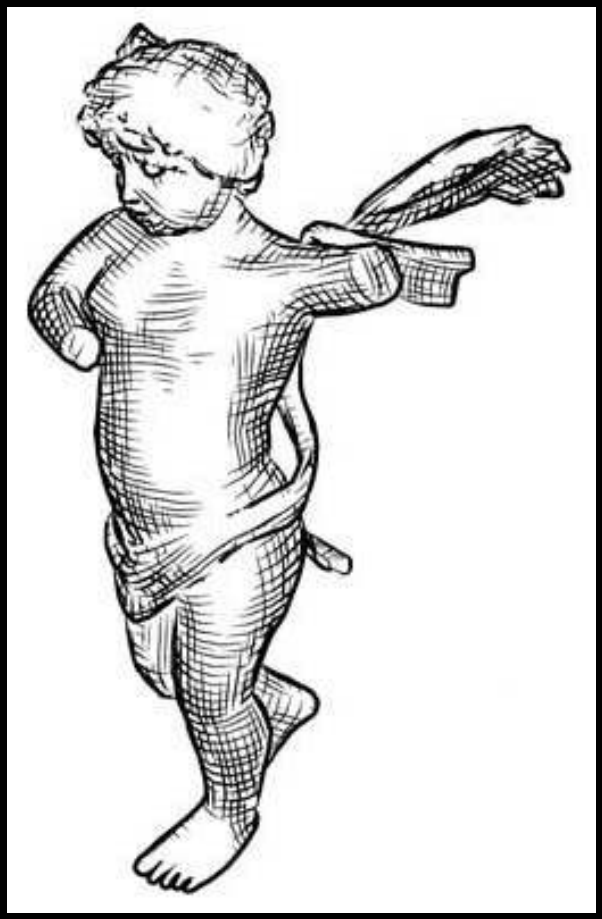
- Make synthetic images that are *indistinguishable* from the real thing
- Do it in a way that's both practical and scientifically sound**.** In real time, obviously.

And make it look easy…

Another Agenda: Create a new Reality

- Non-photorealistic Rendering
- Example:

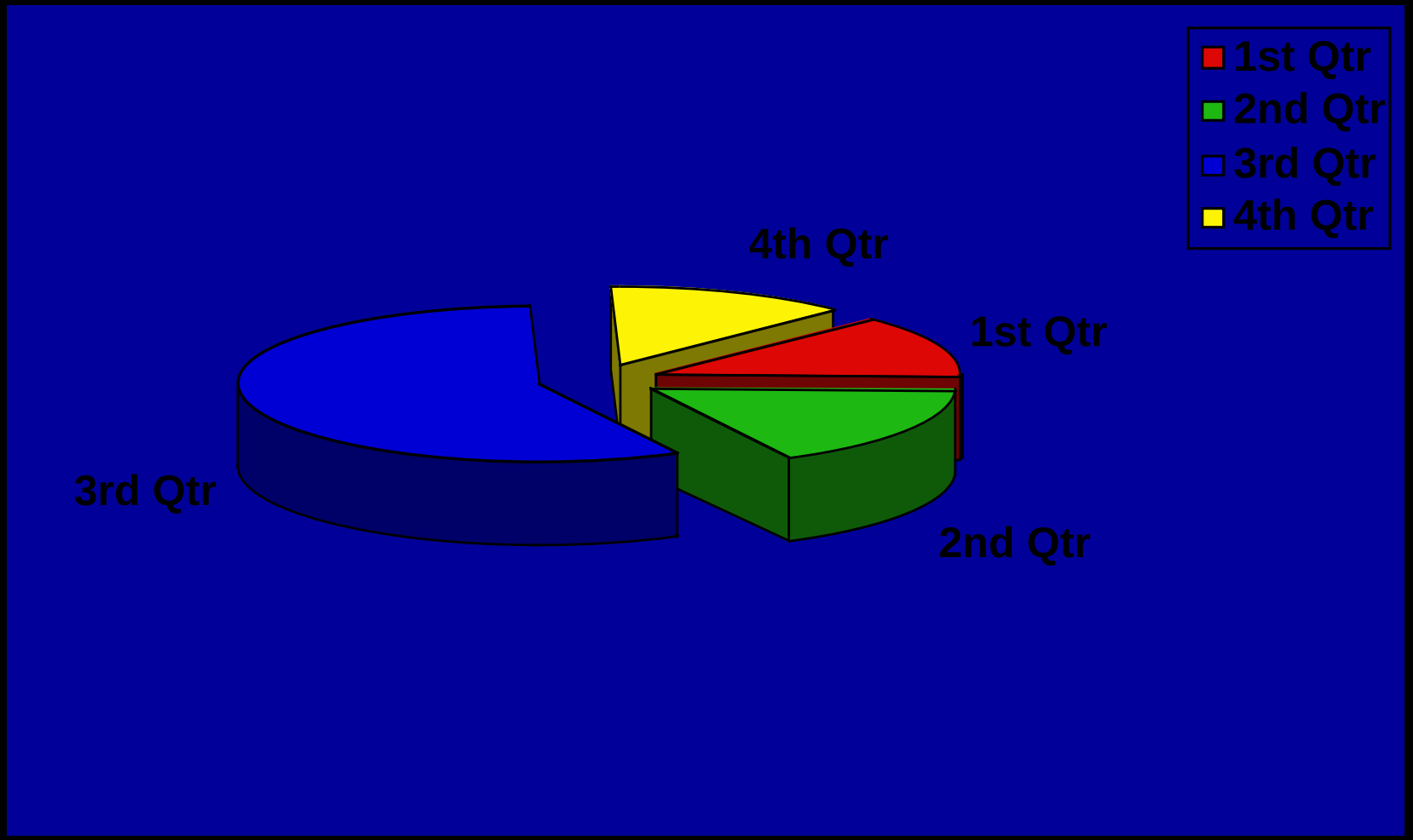
  Illustrating smooth surfaces, A.Hertzmann, D. Zorin. ACM SIGGRAPH 2000 Conference Proceedings.



Another Example

- Image Analogies A. Hertzmann, C. Jacobs, N. Oliver, B. Curless, D. Salesin. SIGGRAPH 2001 Conference Proceedings.

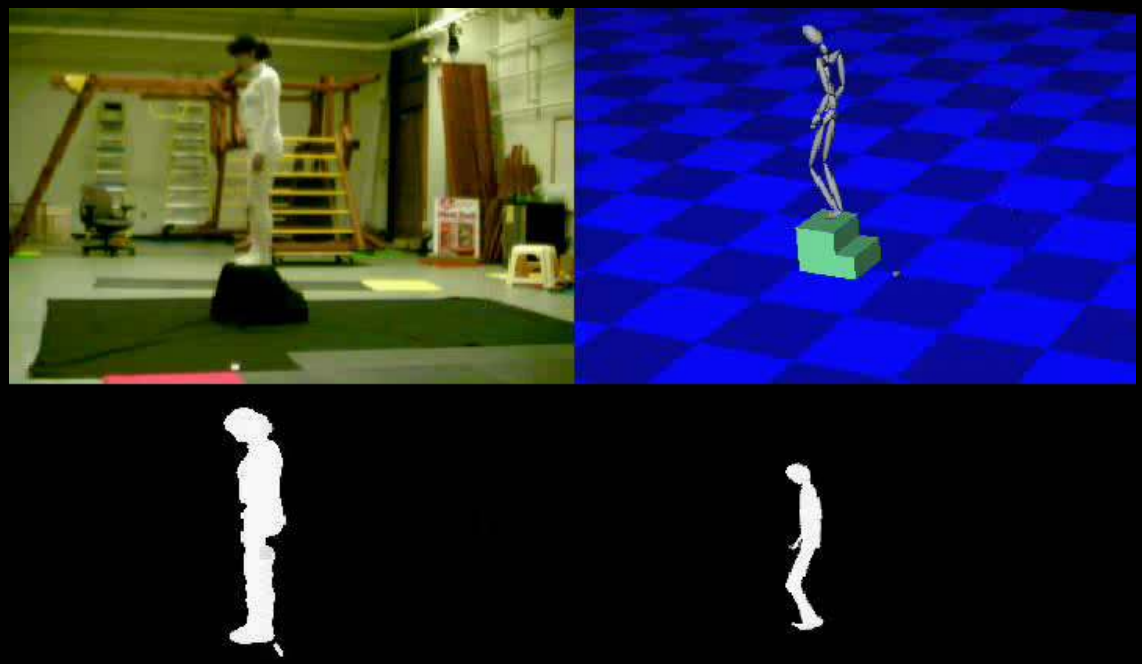
Things that this course isn’t about



Or Graphic design, Software packages (as opposed to software API’s like GL), and much about graphics hardware

User-interfaces

That rely on graphics, e.g., interactive simulation and vision-based interfaces…



J. Lee, J. Chai, P. S. A. Reitsma, J. K. Hodgins, and N. S. Pollard
Interactive Control of Avatars Animated with Human Motion Data,
ACM Transactions on Graphics, SIGGRAPH 2002 Proceedings, 21(3), pp. 491-500, 2002.

The three big topics:

1. **Modeling**: how to represent objects; how to *build* those representations.
2. **Animation**: representing/controlling the way things move.
3. **Rendering**: how to create images

Modeling

Modeling

- How to represent real environments
  - geometry: modeling surfaces, volumes
  - photometry: light, color, reflectance
- How to *build* these representations
  - declaratively: write it down
  - interactively: sculpt it
  - programmatically: let it grow
  - via 3D sensing: scan it in

Modeling by Sculpting

Freeform from Sensable Technologies

Synapse Modelmaking

Modeling by Growing

Reproduction of the topiary garden at Levens, England. R. Mech, P. Prusinkiewicz, SIGGRAPH 1994

Modeling by Growing

Modeling Seashells

P. Prusinkiewicz, Deborah Fowler, Hans Meinhardt,

SIGGRAPH 92.

Modeling by Scanning

Cyberware

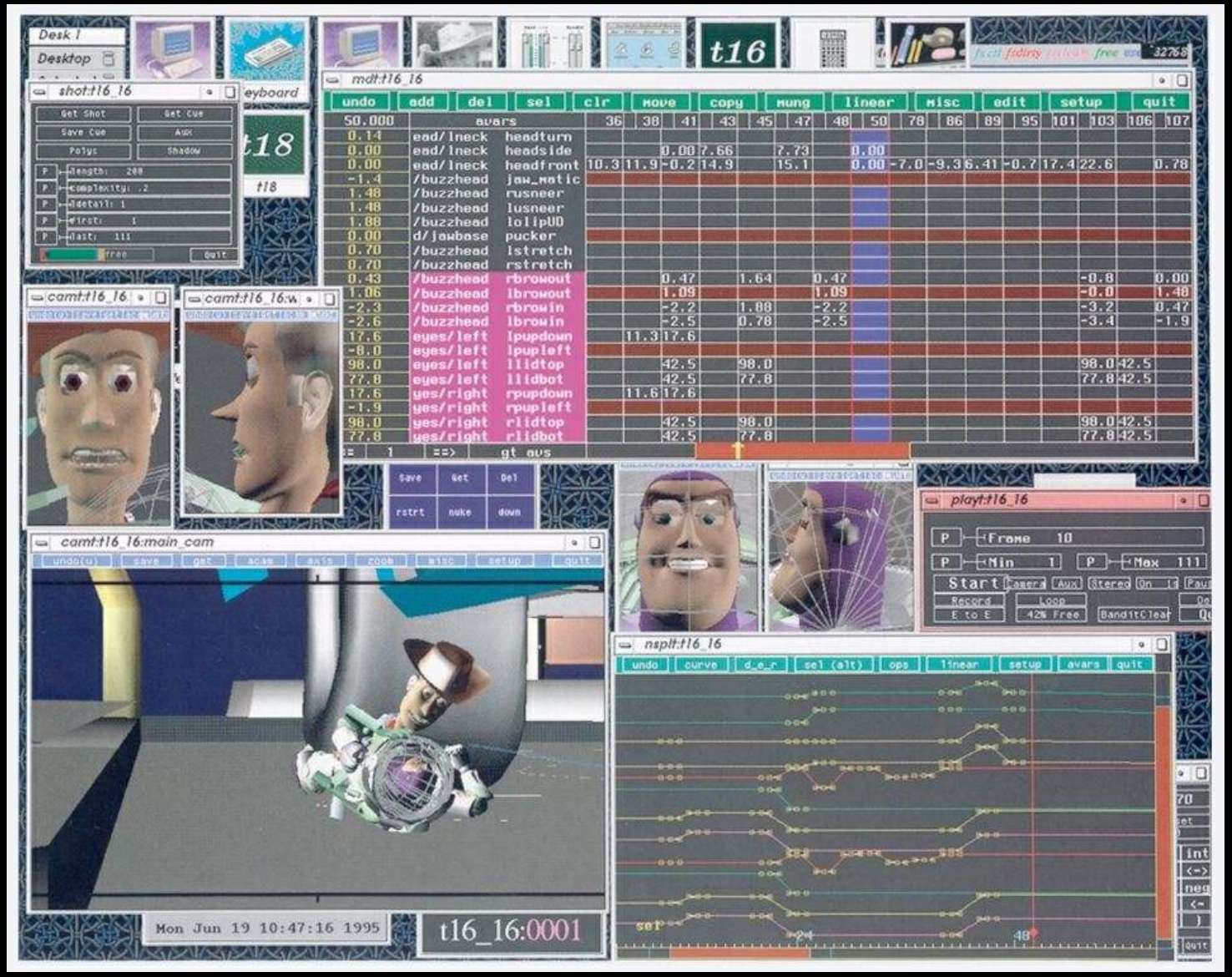
Szymon Rusinkiewicz, Olaf Hall-Holt & Marc Levoy,
Real-Time 3D Model Acquisition,
in *Transactions on Graphics* (SIGGRAPH proceedings), 2002.

Animation

Animation

- Model how things *move*
- How to represent motion
  - sequence of stills, parameter curves
- How to specify motion
  - by hand: tweak it till it looks right
    - key-framing, constraints
  - rule-based behaviors: artificial life
  - physics: simulate Newton's laws
  - motion capture: data from the real world

Hand Animation



Making of Toy Story

Rule-based Behaviors

COURSE: 07
COURSE ORGANIZER: DEMETRI TERZOPOULOS

"BOIDS DEMOS"
CRAIG REYNOLDS
SILICON STUDIOS, MS 3L-980
2011 NORTH SHORELINE BLVD.
MOUNTAIN VIEW, CA 94039-7311

Rule-based Behaviors

from *Stanley and Stella in: Breaking the Ice* (1987)

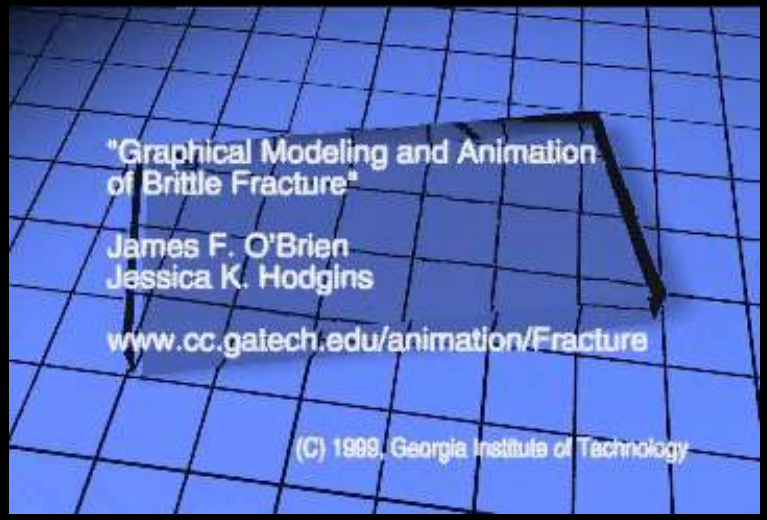
Physics for Natural Phenomena

Antz water simulation (related techniques were used in Shrek)

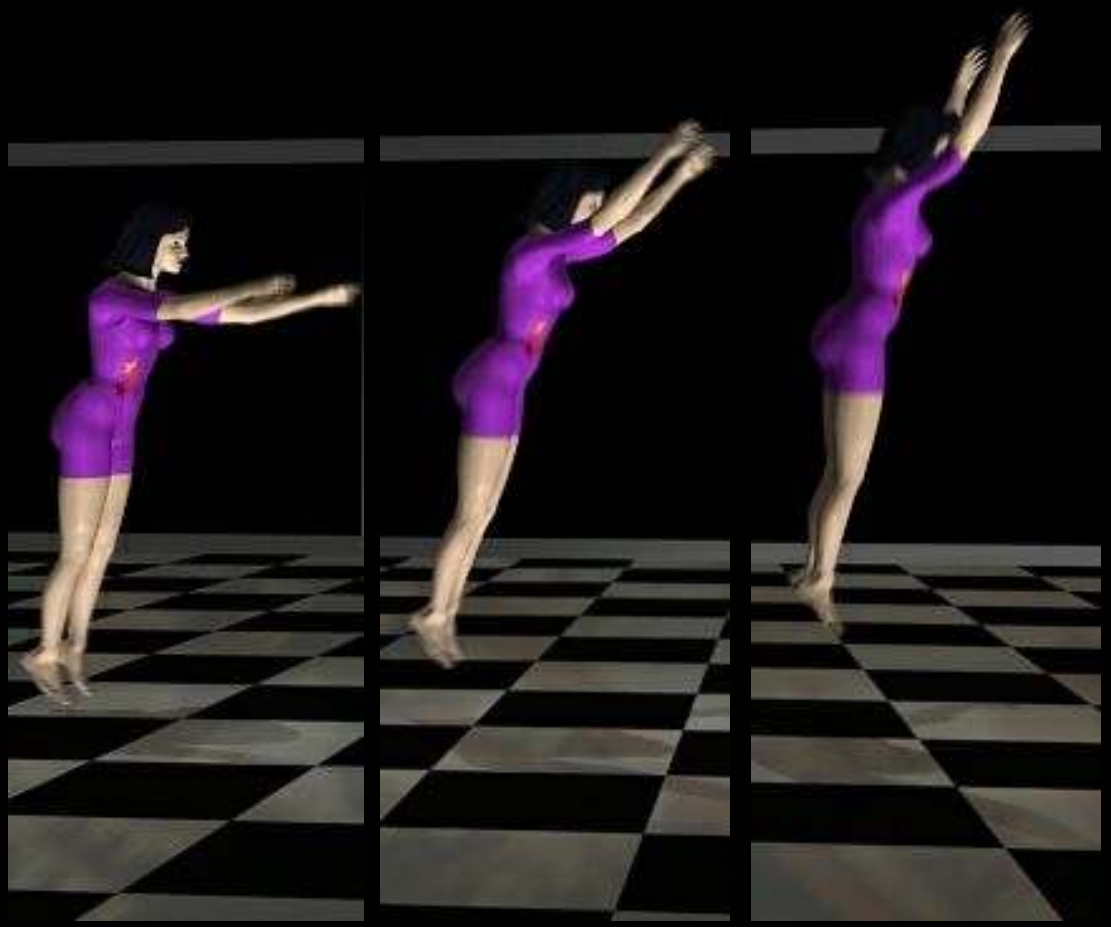
Enright, D., Marschner, S. and Fedkiw, R.,
"Animation and Rendering of Complex Water Surfaces", SIGGRAPH 2002, ACM TOG 21, 736-744 (2002).

Physics for Natural Phenomena

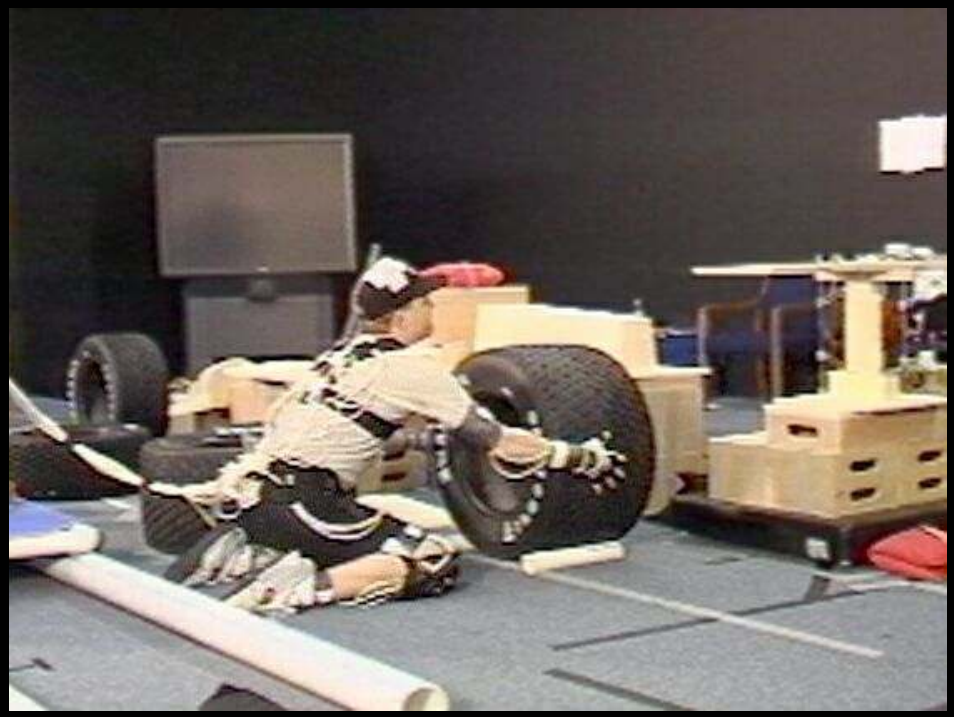
J.F. O'Brien and J.K. Hodgins, (1999)
Graphical Modeling andAnimation of Brittle Fracture.
Proceedings of ACM SIGGRAPH 99.

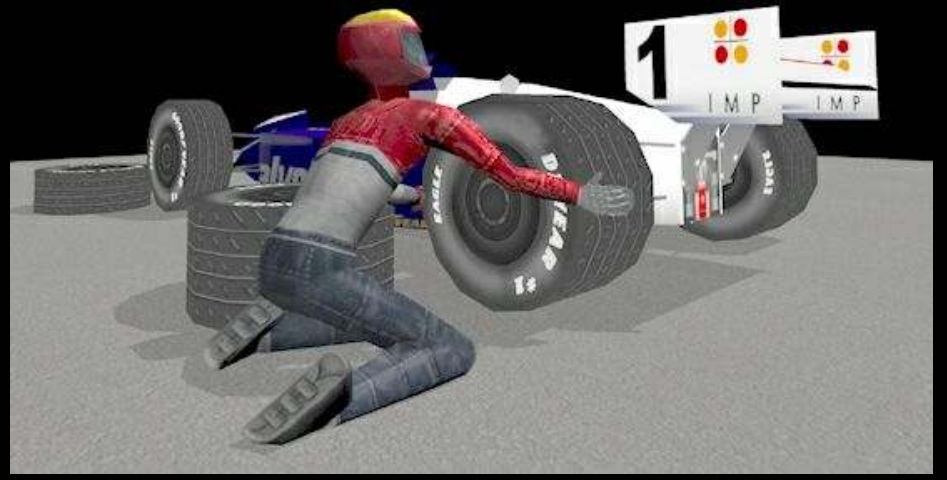


Physics for Characters



Motion Capture





Microsoft’s Motion Capture Group

Motion Capture

Titanic, House of Moves

Motion Capture

Motion Analysis

Rendering

Rendering

- What's an image?
  - distribution of light energy on 2D "film": E(x,y,λ,t) *(λ is wavelength.)*
- How do we represent and store images
  - sampled array of "pixels": p[x,y]
- How to generate images from scenes
  - input: 3D description of scene, camera
  - solve light transport through environment
    - ray tracing
    - radiosity
  - project to camera's viewpoint

Raytracing

May-June 2001 First Place Winner Internet Ray Tracing Competition
warm_up by Norbert Kern

Radiosity

Lightscape, Autodesk

Image-based Rendering

Mike Harris

Martin Løvvold

Caligari, True Space

Real-time Global Illumination

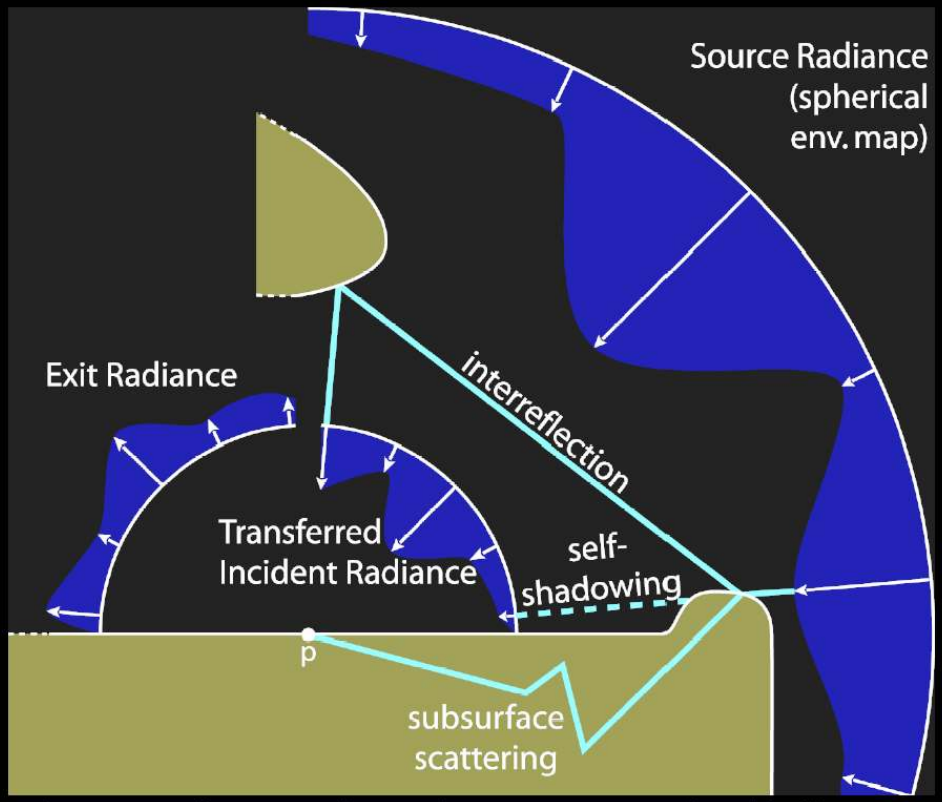
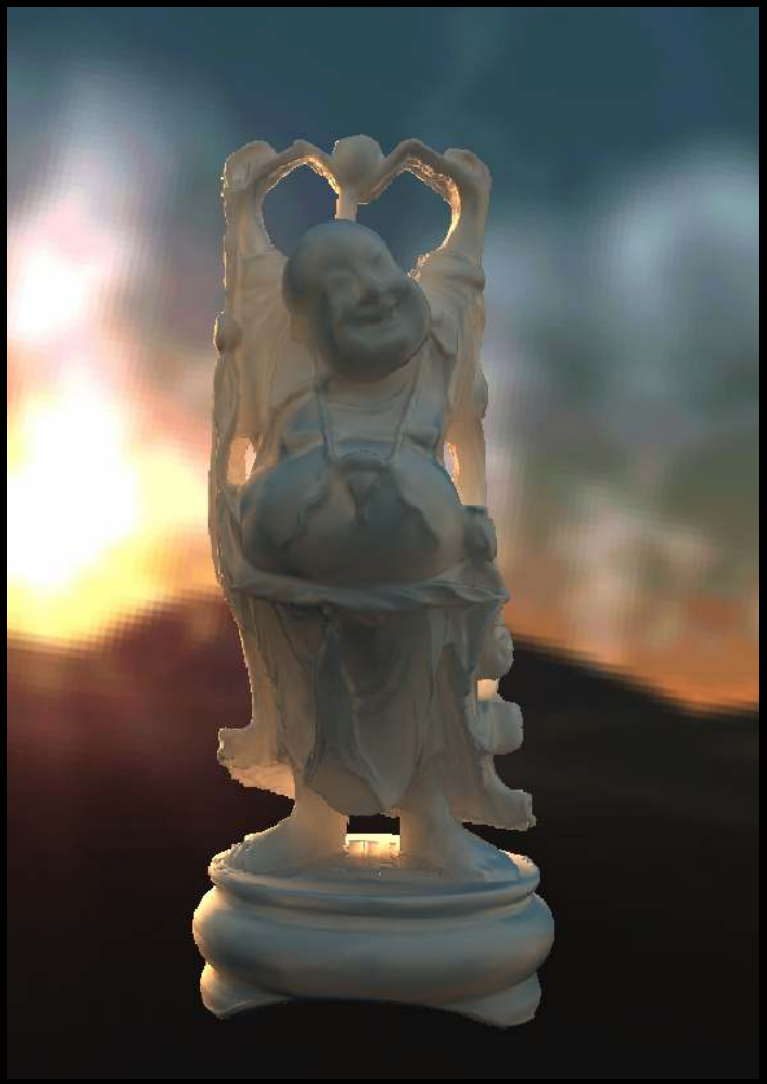


Figure 1: Radiance transfer at p from source to transferred incident to exit.



Sloan et al., SIGGRAPH 2003

Hot Application Areas

- Special effects
- Feature animation
- PC graphics boards
- Video games, location-based entertainment
- Medical training
- Visualization (science, architecture, space)
- The web

Hot Research Topics

- Modeling
  - getting models from the real world
  - multi-resolution
- Animation
  - physically based simulation
  - multimodal interaction
  - motion capture
- Rendering:
  - more realistic: image-based modeling
  - less realistic: impressionist, pen & ink

Starting out Simple

- The field didn't start out with all this difficult stuff…
- First there were wireframes. Then faceted and smooth shading. Advanced ideas such as radiosity and physically based animation came later.
- Gradually the idea of “physically based” took hold.
- The simpler models and methods are still very much in use, because they're well understood, they're amenable to hardware implementations, and fast.
- In this class, we concentrate on the simple stuff, but sprinkle in some advanced topics here and there.

See you Thursday!