CS 174A – Fall 2019
Introduction to Computer Graphics

Dr. Asish Law

TAs: Jonathan Mitchell, Yunqi Guo

Instructor & TAs

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Role	Instructor	TA	TA
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Class Location	Kinsey Pavilion 1220B	Royce 362	Dodd 161
Class Hours	TR 4:00 - 5:50 PM	F 10:00 - 11:50 AM	F Noon - 1:50 PM
Office Location	BH 3531A	BH 9432	E-VI 396
Office Hours	TR 3:30 - 4:00 PM TR 6:00 - 6:30 PM	R 10 AM - Noon	T 9 - 11 AM

Contact Protocol

- **We expect you to use the course forum (Piazza)**
- **Good for questions and answers**
  - Dissemination of information, assignments, etc.
- **Try to keep email for class related personal matters**
  - If you ask about assignments, etc. we will likely redirect you to forum

Sign up at the class site on Piazza:

http://piazza.com/ucla/fall2019/cs174a

Let us know your Github account name:

https://forms.gle/6H2Gef41QJ7ykwyM9

Purpose of Class

- ***Learn basic computer graphics and interaction***
- ***Opportunity to use all of your CS skills***
- ***Help each other, learn how to work in a team***
- ***HAVE FUN!***
- ***More detail in syllabus***

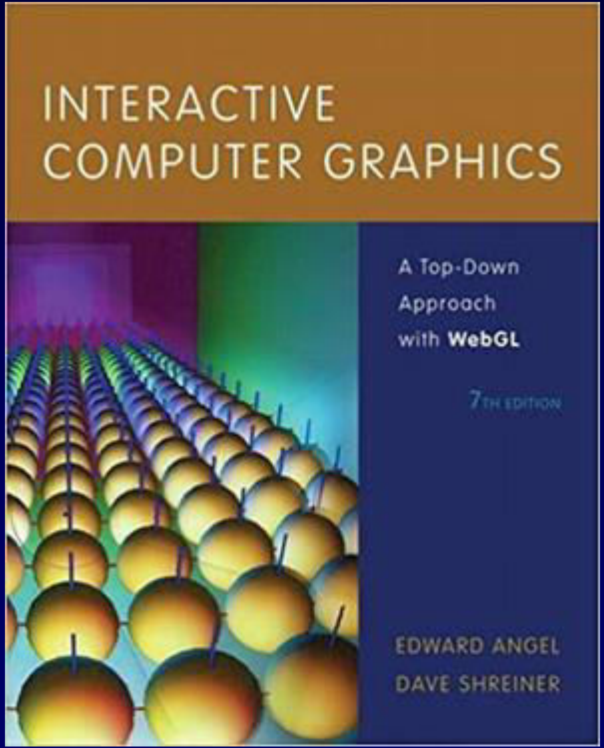
Textbook (Optional)

Interactive Computer Graphics – A Top-Down Approach with WebGL

E-Text only

8th Edition, Angel & Shreiner

ISBN-13: 978-0135258262



Textbook

- ***Textbooks are expensive***
  - Ask on Piazza
- ***Only loosely going to follow this book***
  - Our methodology will diverge quickly
- ***Otherwise this class will mostly follow the usual progression***
  - Many lecture slides have stood the test of time
  - Some we'll skip to make room for hands-on demos

Course Administration

- ***Five project assignments***
  - Last one is an open ended group project
  - Others are to build skills for that one
- ***Grading breakdown (1000 pts):***
  - 4 projects (0+50+50+50): 150 pts
  - Team project: 600 pts
  - Midterm: 100 pts
  - Final: 150 pts

Course Administration (contd.)

- ***More Points***
  - Class participation (50 pts)
  - Interaction with classmates on Piazza (50 pts)
  - Super impressive final project (50 pts)
  - Bonus questions on midterm and final exams (50 pts)

Course Administration (contd.)

- *Curving final grades up or down is not ruled out, if needed to move the distribution so that grades are not too uniform or too low*
- *Besides that, final grades will be awarded as follows:*

D-: 500+, D: 550+, D+: 600+, C-: 650+, C: 700+, C+: 750+, B-: 800+, B: 850+, B+: 900+, A-: 950+, A: 1000+, A+: 1100+

Programming Assignments

- *JavaScript, HTML/CSS, Git are used in this class*
- *If you don’t know these, you will by the end*
- *You’ll even see TAs use them on the screen*
- *Learn to use debuggers (we will not debug for you)*

Programming Assignments

- *Production software off limits - let’s make our own*
- *Libraries - only our small helper code is permitted for most assignments*
- *For team project, outside code won't count towards grade or impressiveness*

Team Project (600 points)

- *Team sizes 3-4*
- *Expectations scale with size*
- *Instructor grading: 200 pts*
- *TA grading: 200 pts*
- *Team grading: 100 pts*
- *Class grading: 100 pts*

Team Project

- ***You get to make something!***
- ***Show it to your mom***
- ***Be proud of it***
- ***Put it on your resume***
  - But it was a team effort?
  - So far that's been the effective part!
- ***Link to examples from earlier quarters***

Individual Project Examples

- ***Done by one person***
- ***Done using only:***
  - Plain JavaScript
  - Low level math
  - Pixel operations
  - Some 2D image files
  - An understanding of 3D techniques

TA Sections

- *Primarily to discuss JavaScript, Github, project, etc.*
- *Occasionally for more detail (linear algebra)*
- *Deeper dives into specific topics from class*
- *Q&A, homework help*

Mathematics of Computer Graphics

- ***Linear (vector/matrix) algebra***
- ***Coordinate systems***
- ***Geometry***
    - Points, lines, planes
- ***Affine transformations***
- ***Projection transformations***
- ***More geometry***
    - Curves, surfaces

Typical Comments From Prior 174A Course Offerings

- Lots of math!
- A lot of material
- Fast pace
- A lot of programming
- Challenging final exam

Remember:

- Come to class
- Manage your course load
- Do individual work
- Start assignments early
- Get help early (on Piazza and in TA sessions)

Remember

- ***If you:***
  - Do the Assignments
  - Take the Exams
  - Complete the Term Project
  - …you should be able to do just fine

- ***Extra stuff is for those of you who***
  - Want to challenge yourself (or show off)
  - Have some extra fun
  - Something cool to show during interviews…

Detailed Class Schedule

Week #	Date	Topics	Projects (due on Sundays)
Week 1	09/26/19	Class / project overview, state of graphics field, graphics history, graphics program anatomy	
Week 2	10/01/19	Linear Algebra Review, Vector math	
	10/03/19	Vertex Arrays, Indexing, Polygons, Interpolation	A1: Set up and use Chrome Developer Tools (due 10/6)
Week 3	10/08/19	Flat vs Smooth Shading	
	10/10/19	Matrix transformations, Hierarchies, Viewing	
Week 4	10/15/19	Matrix transformation order	
	10/17/19	Projections, View Volumes, Smooth Motion in Scenes Shaders, Interpolation, Lighting	A2: Tilting Boxes (due 10/20)

Computer Graphics

The Art and Science of creating imagery by computer

Art

Mathematics

Vision

Optics

Biomechanics

Physics

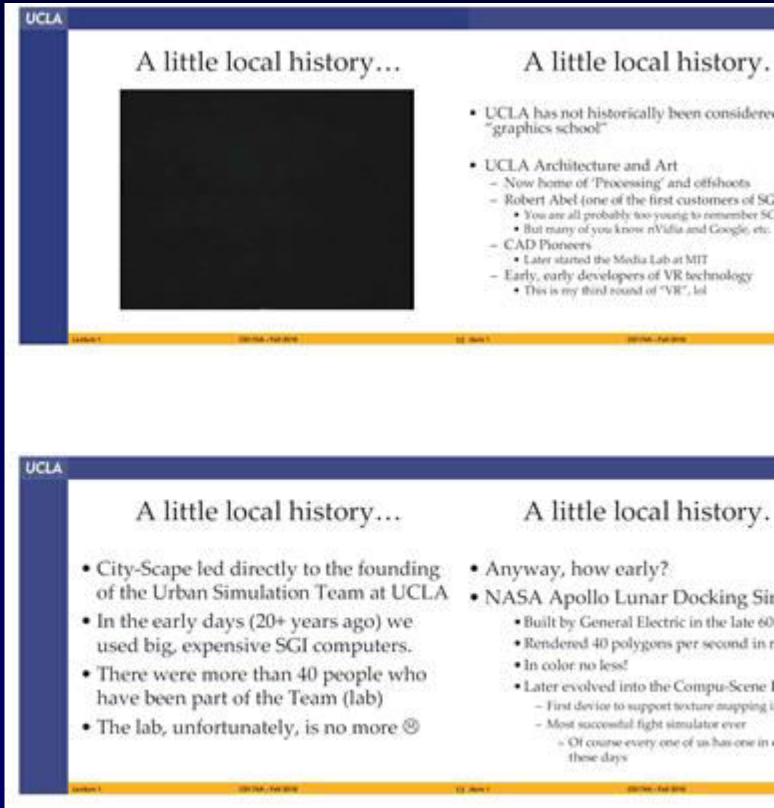
Engineering

Artificial Intelligence

Applications of CG

- ***Entertainment***
  - Films
  - Computer games
  - Virtual reality
- ***Visualization***
  - Scientific visualization
  - Medical visualization
  - Flight simulation
  - Architecture
- ***Education, etc.***

Motivation/local history



History

- 2000 B.C.
  - *orthographic projection*
- 1400s
  - *Perspective: Italian Renaissance*
- 1600s
  - *coordinate systems: Descartes*
  - *optics: Huygens*
  - *optics, calculus, physics: Newton*

History

- *1897 oscilloscope: Braun*
- *1950-1970*
  - computers with vector displays
- *1966*
  - first true raster display
- *1993*
  - 1200x1200, 500k triangles/sec, 36-bit color, stereo, texture mapping… all at 60Hz
- *1995*
  - feature-length CG films
- *Today…still rapidly evolving*

Genesis of Computer Graphics and Interactive Techniques

- ***A PhD project at MIT in the early 1960s***
- ***Ivan E. Sutherland, 1963***
  - "Sketchpad, a man-machine graphical communication system"

Trivia

https://design.osu.edu/carlson/history/timeline.html

When was the term “Computer Graphics” first stated?

William Fetter of Boeing coins the term "computer graphics" for his human factors cockpit drawings 1960

1. When was the Graphical User Interface developed?

   GUI developed by Xerox (Alan Kay) 1969

2. When was Tron released?

   Disney contracts Abel, III, MAGI and DE to create computer graphics for the movie Tron released in 1981

Trivia

4. Which is the first **animated** movie to employ CG?

   "The Great Mouse Detective" (1986) was the first animated film to be aided by CG

5. When was the game "Doom" released?

   1993

6. Which is the best selling game of all time?

   http://en.wikipedia.org/wiki/List_of_best-selling_video_games

Tetris	*(170M copies)*
Minecraft	*(154M copies)*
Grand Theft Auto V	*(100M copies)*

Trivia

7. Which is the newest CG animated movie?

   Abominable

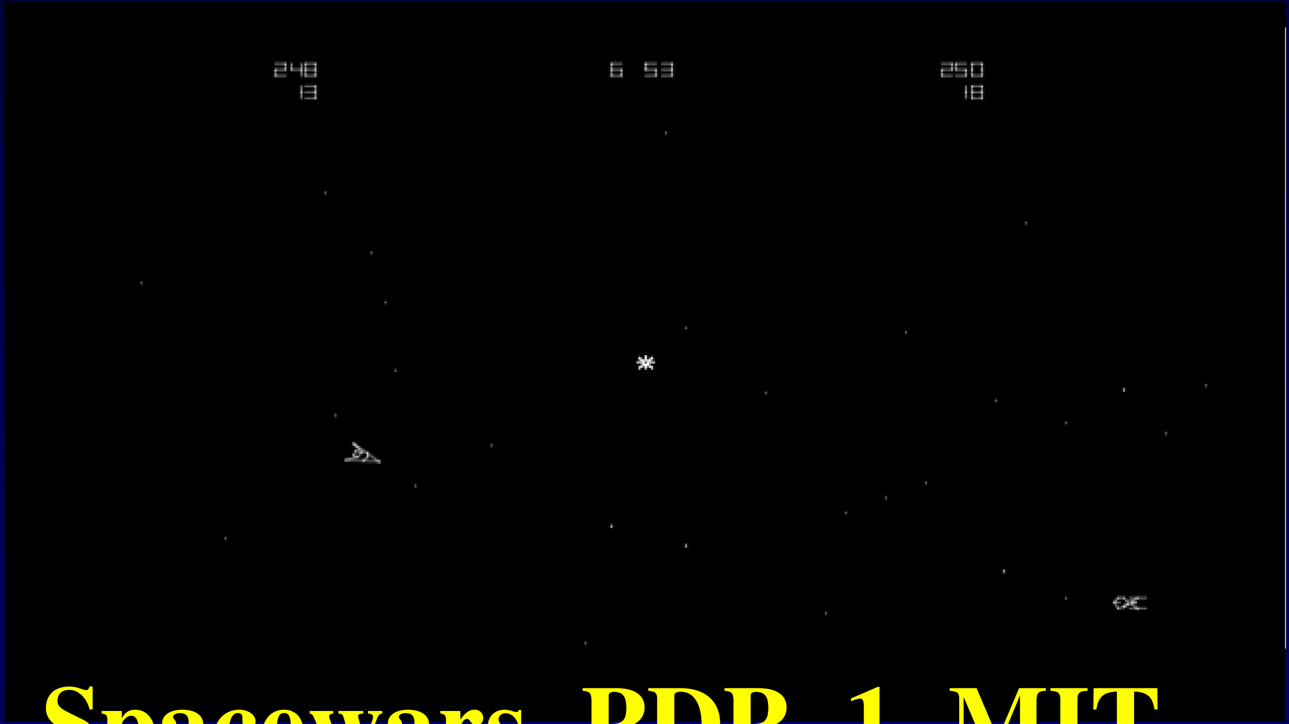
8. Which is bigger in terms of gross revenue, the game industry or the (Hollywood) movie industry?

   The game industry

9. Which is your favorite animated movie?

   Tangled, Moana, Frozen, Incredibles

The First Computer Game?



Spacewars, PDP–1, MIT, 1961

1972

The <u>First</u> “Computer” Game – 1958 !!

“Tennis for Two”

Metal Gear Solid 4

Games

Focus on interactivity

Movies

To reality and beyond !

Movies

Toy Story 1 (1995)

Toy Story 4 (2019)

Movies

Special effects

Movies

Digital Compositing


CG Axe
Base Color

Digital Compositing

Cartoons

Computer-Aided Design

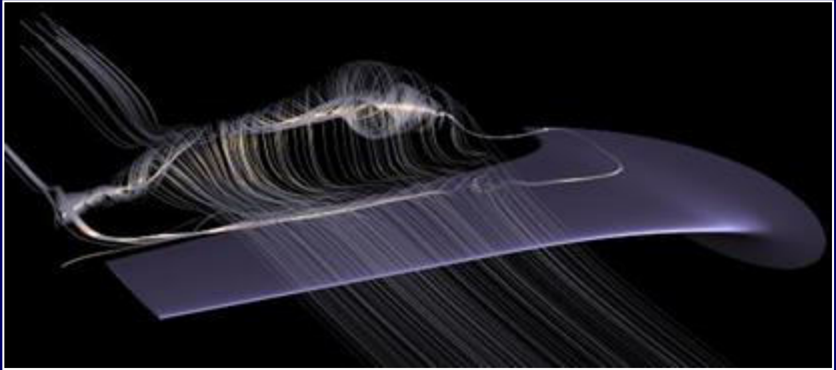
Precision modeling

Engineering

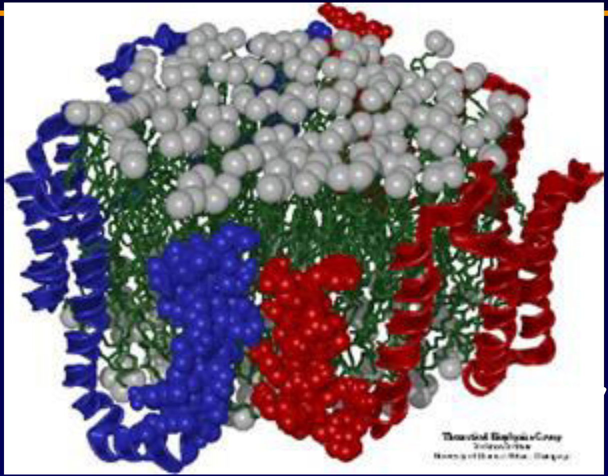
Modeling Clay

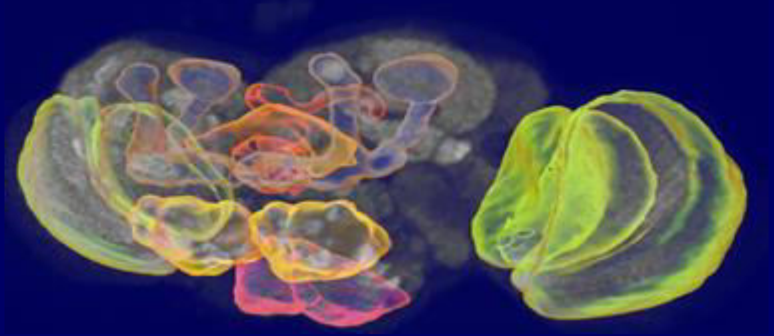
Computer-Aided Design

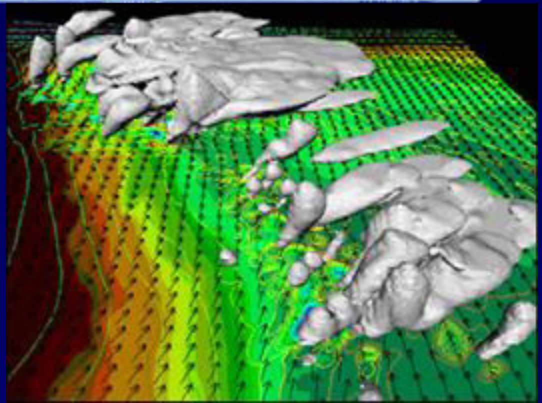
- ***It's not just about visualization***
  - Simulation is also useful



Visualization: Scientific







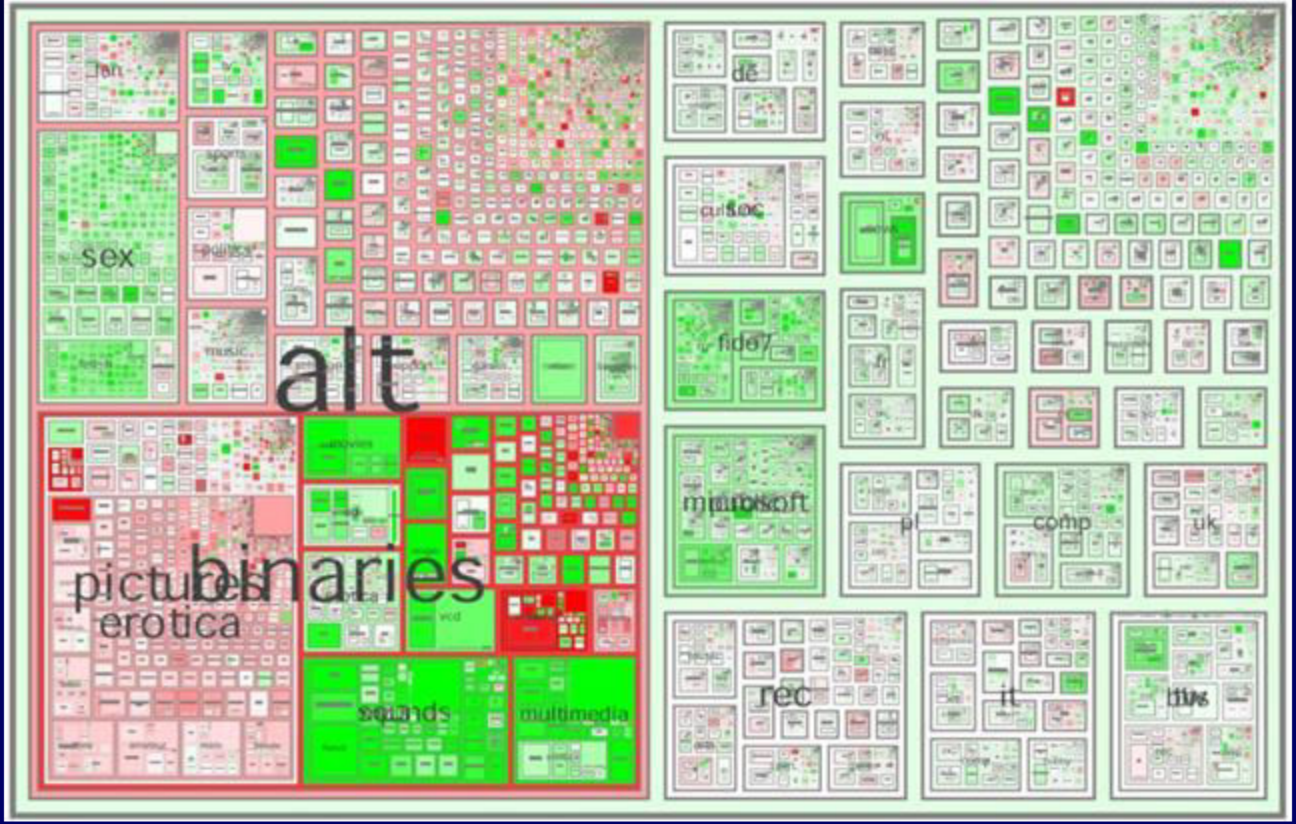
Visualization: Architectural

[redacted]

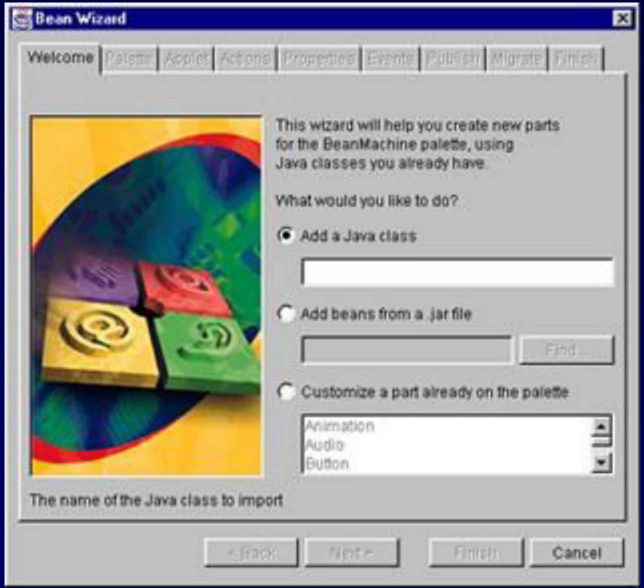
http://www.diamondschmitt.com/

Visualization: Info

Smith and Fiore



Graphical User Interfaces



WIMP

Steven Schkolne

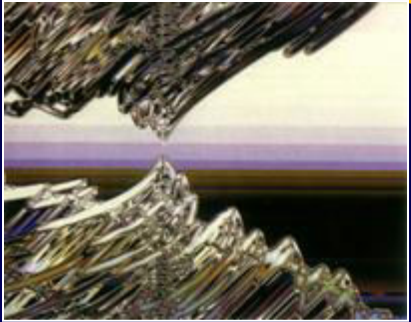
Art

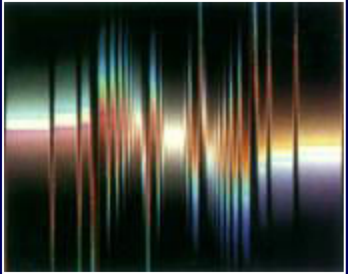
Steven Schkolne

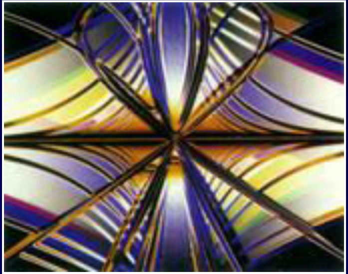
Digital Art

Genetically evolved

Carl Sims







Digital Art

By Jason Salavon

The Top-Grossing Film of All Time “Titanic”

^2nd

Basic Elements

Modeling

Animation

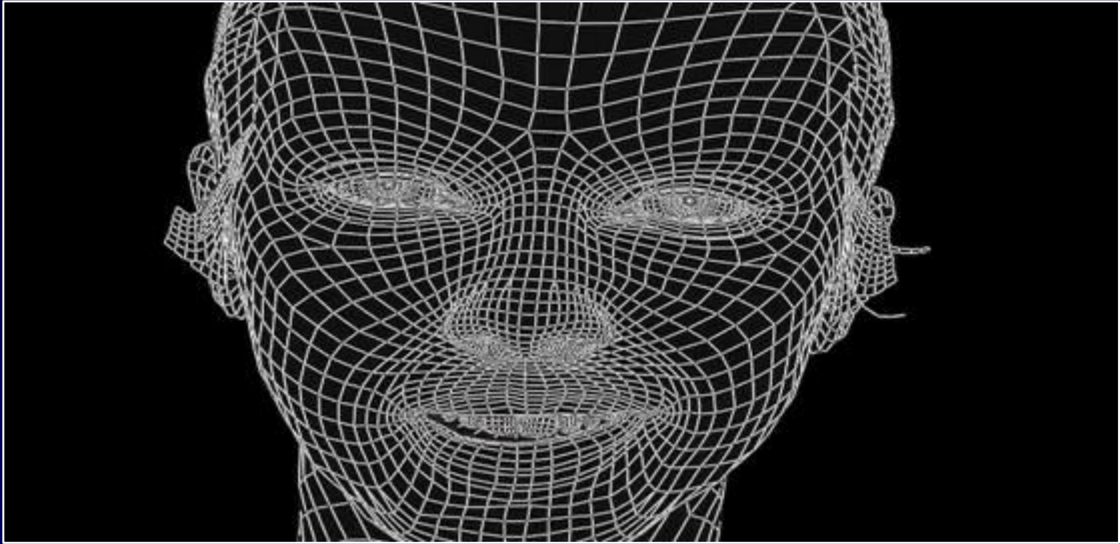
Rendering

Interaction

Basic Elements

- ***Modeling***
  - How do we model (mathematically represent) objects?
  - How do we construct models of specific objects?
- ***Animation***
  - How do we represent the motions of objects?
  - How do we give animators control of this motion?
- ***Rendering***
  - How do we simulate the real-world behavior of light?
  - How do we simulate the formation of images?
- ***Interaction***
  - How do we enable humans and computers to interact?
  - How do we design human-computer interfaces?

Modeling



Primitives

- 3D points
- 3D lines and curves
- Surfaces (BREPs): polygons, patches
- Volumetric representations
- Image-based representations

Attributes

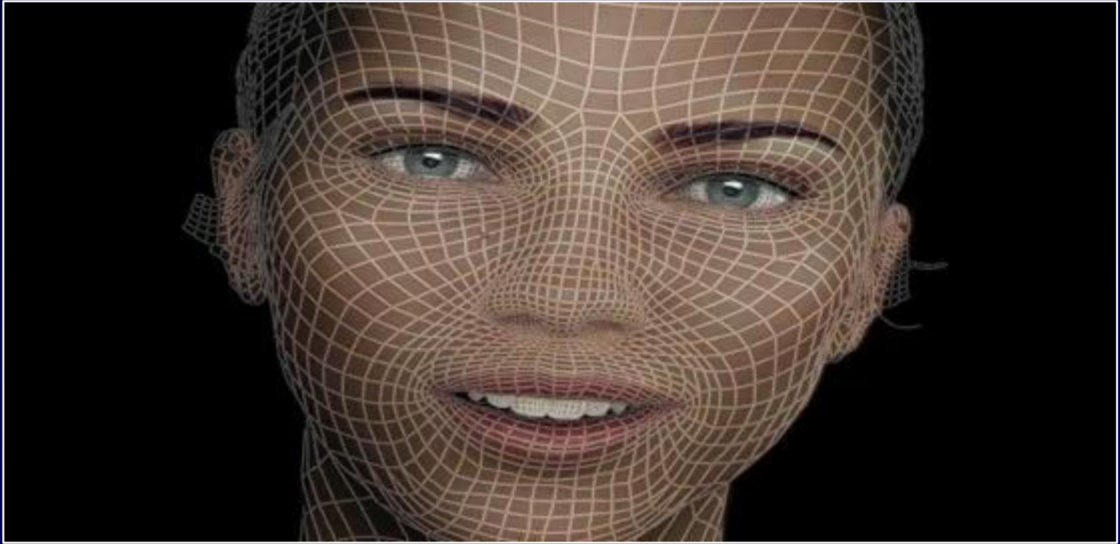
- Color, texture maps

Rendering

Visibility

Simulating light propagation

- Reflection
- Asborption
- Scattering
- Emission



Animation

Keyframe animation

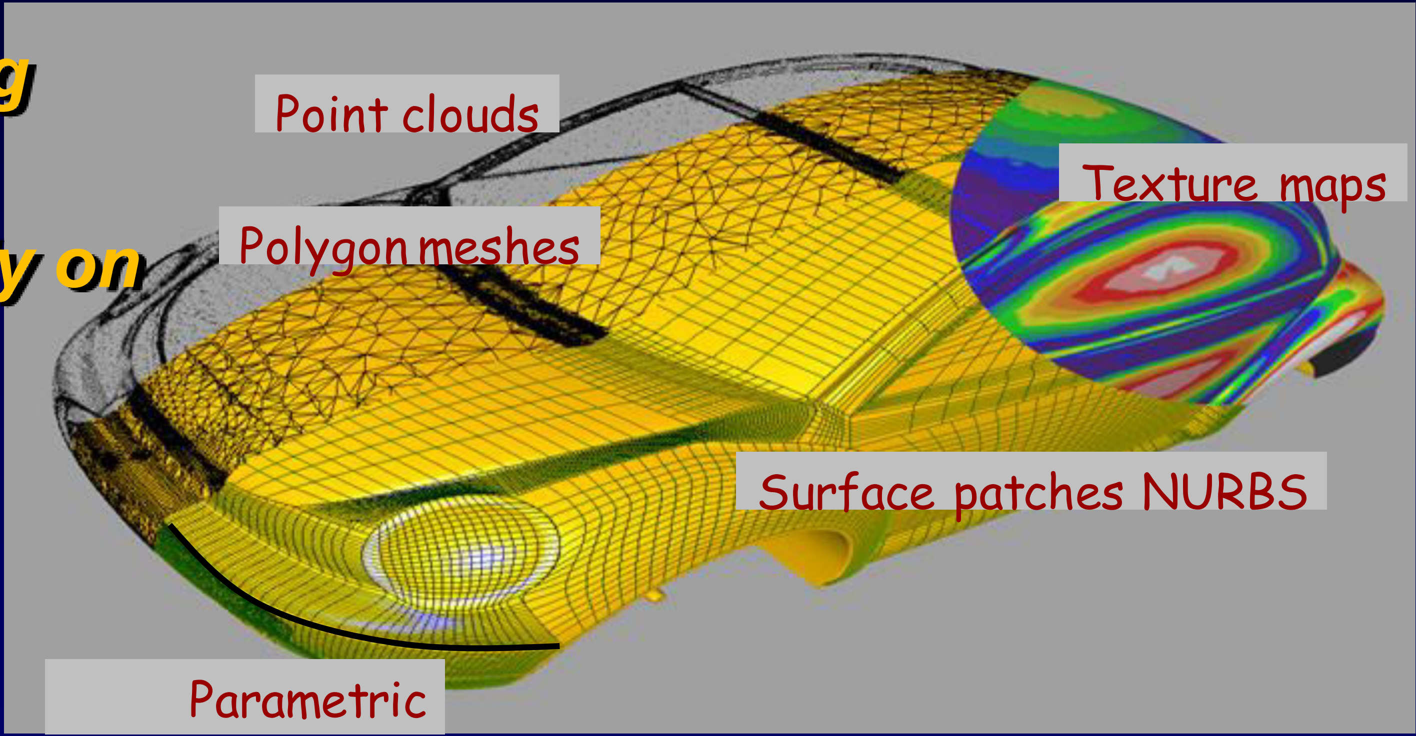
Motion capture

Procedural animation

- Physics-based animation
- Behavioral animation
- Emotion-based animation

Modeling

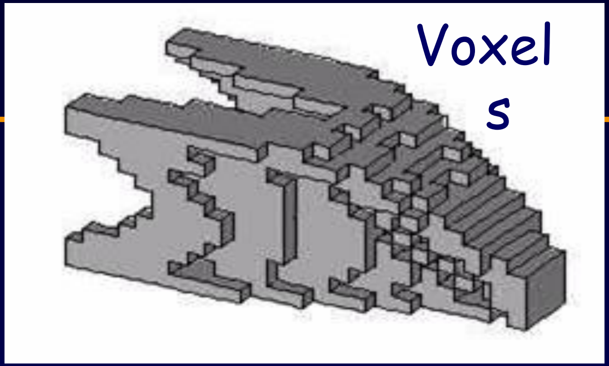
Representing objects geometrically on a computer



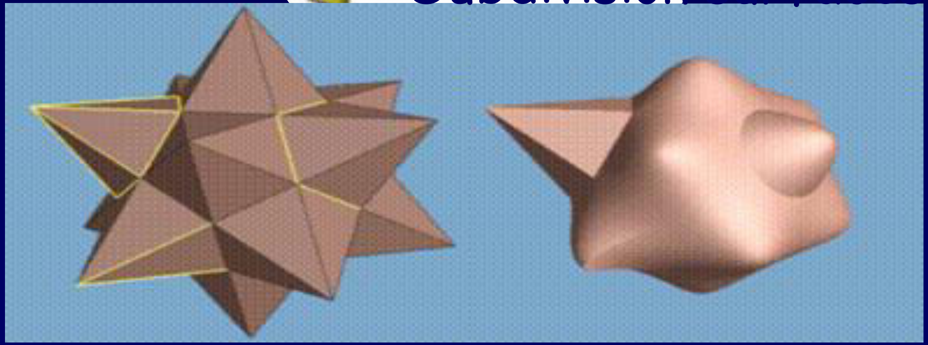
curves

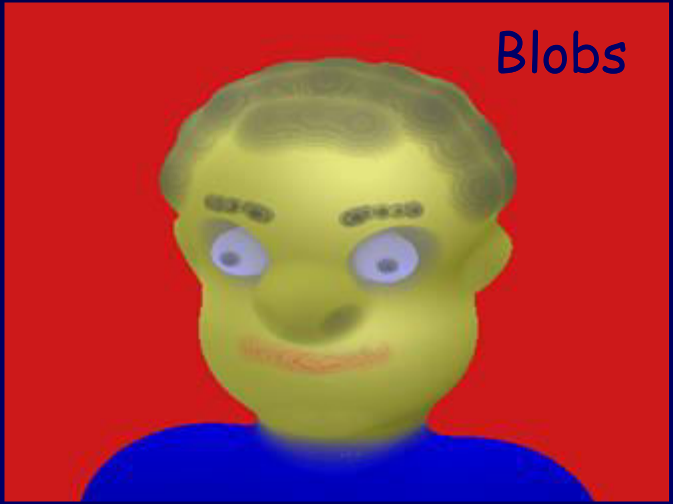
Modeling

Alternative representations



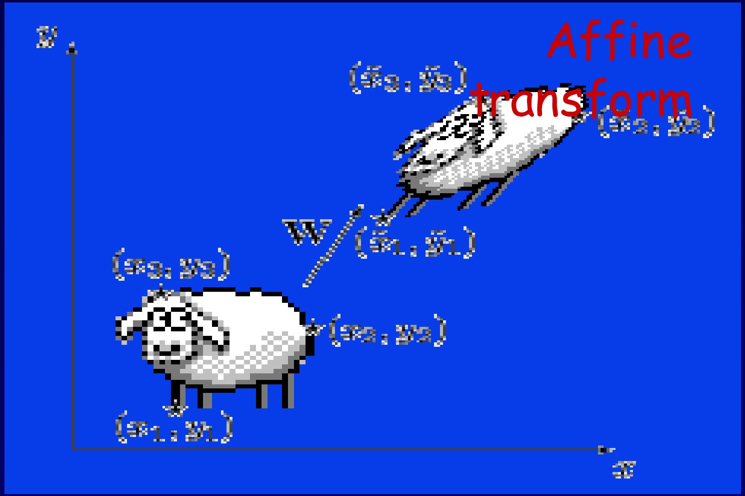
Subdivision surfaces

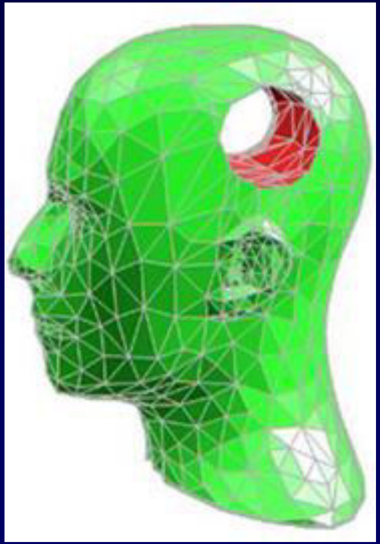




Modeling

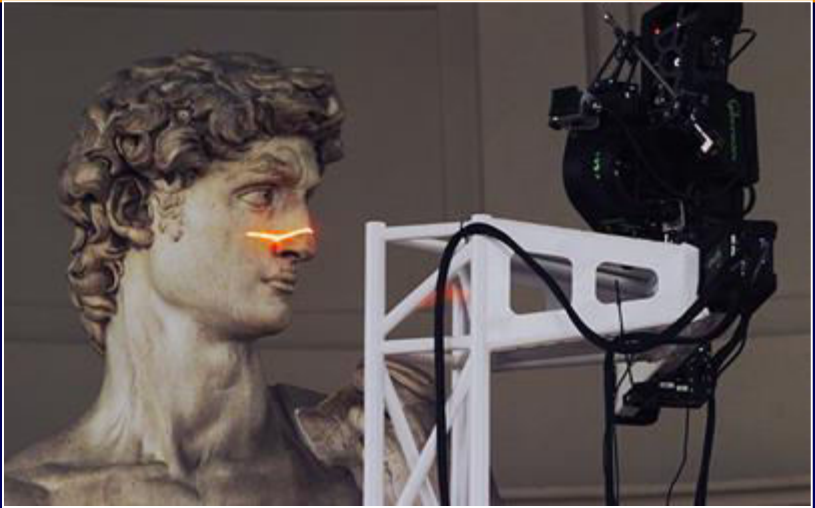
Altering geometric models





Ying, Kristjansson, Biermann, Zorin

Scanning Shapes



Digital Michaelangelo Project

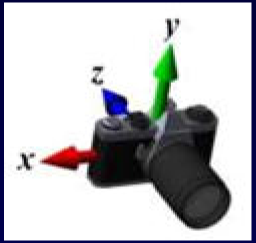
Plant Modeling

Plant Modeling

Rendering

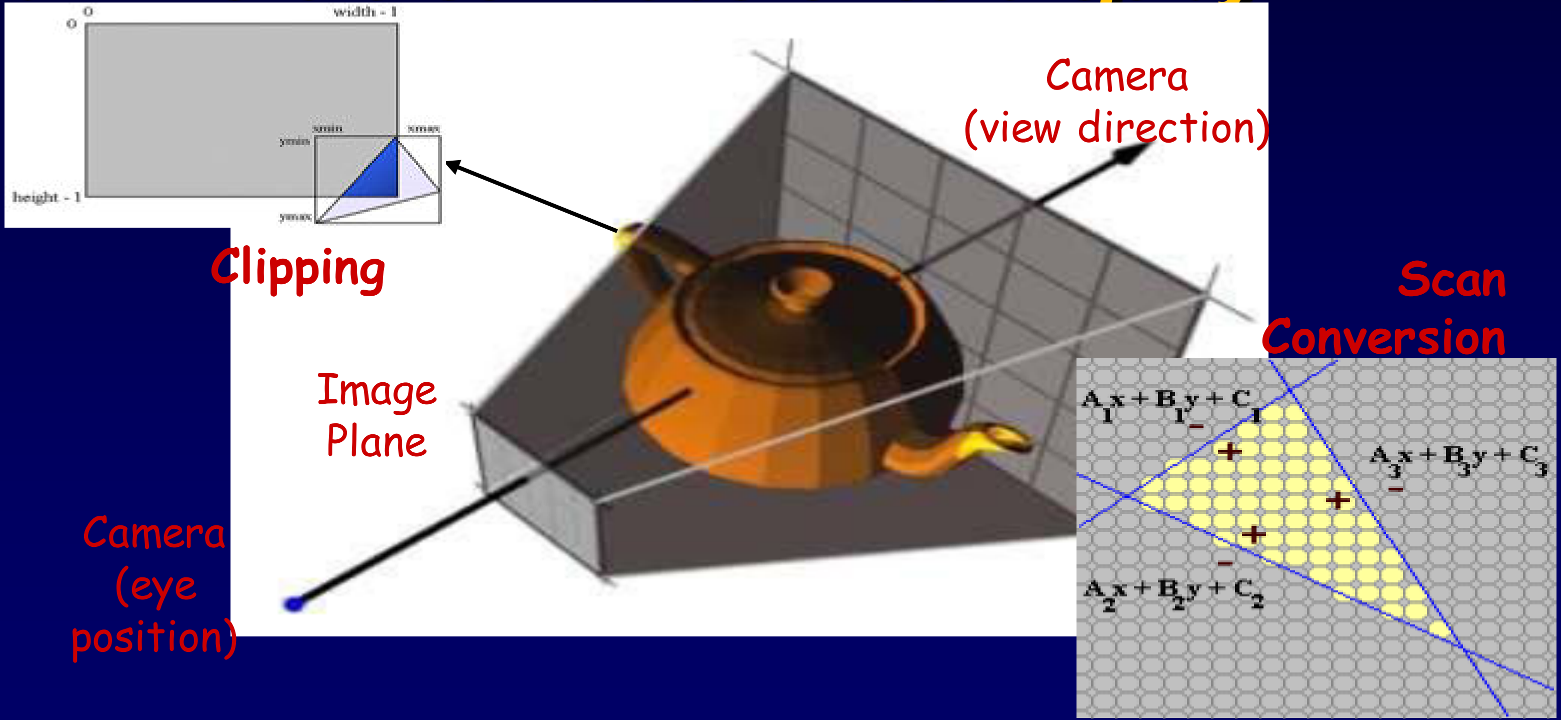
Key elements

Camera Model



Rendering

Draw visible surfaces onto display

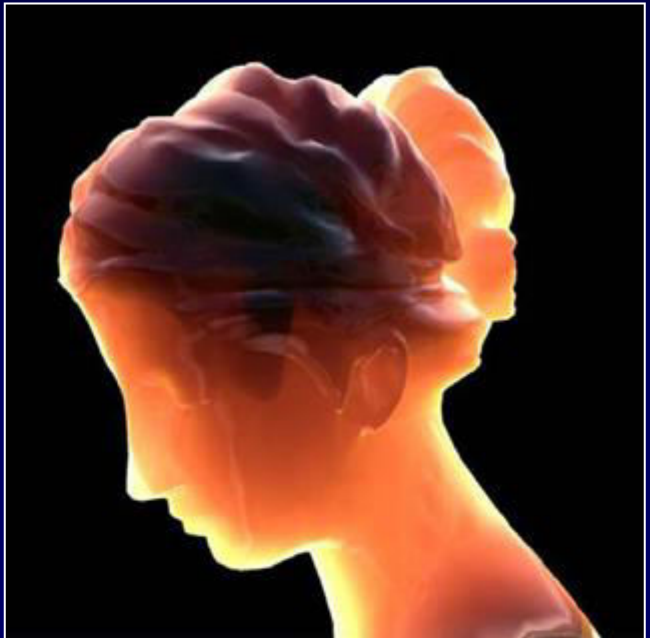


Reflectance Modeling

Complex Reflectance

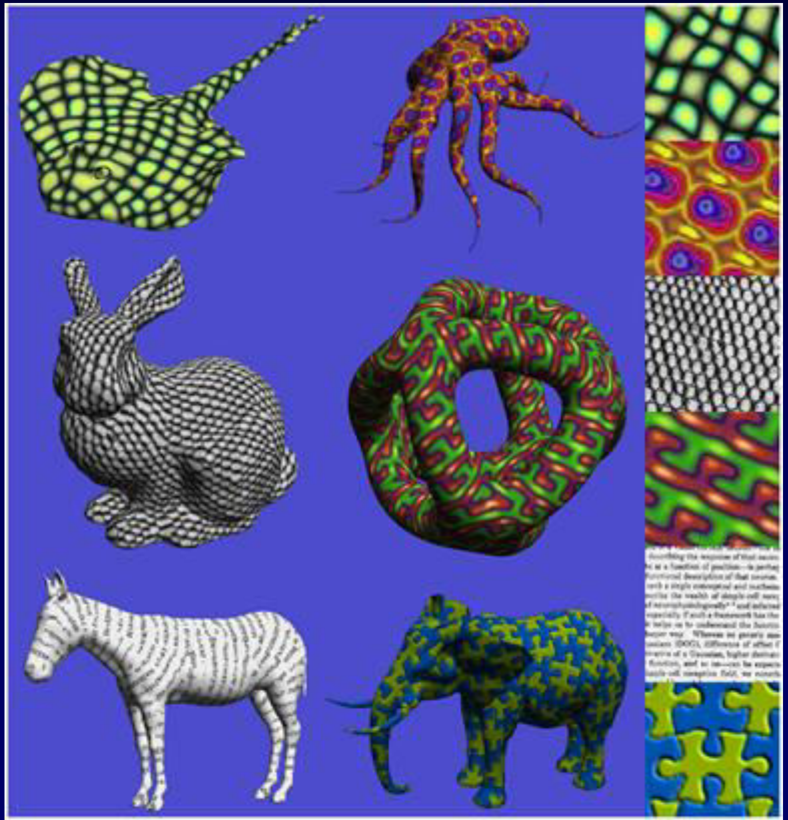
Subsurface Scattering

Translucency and varied levels of light penetration can be created using subsurface scattering effects



Texture

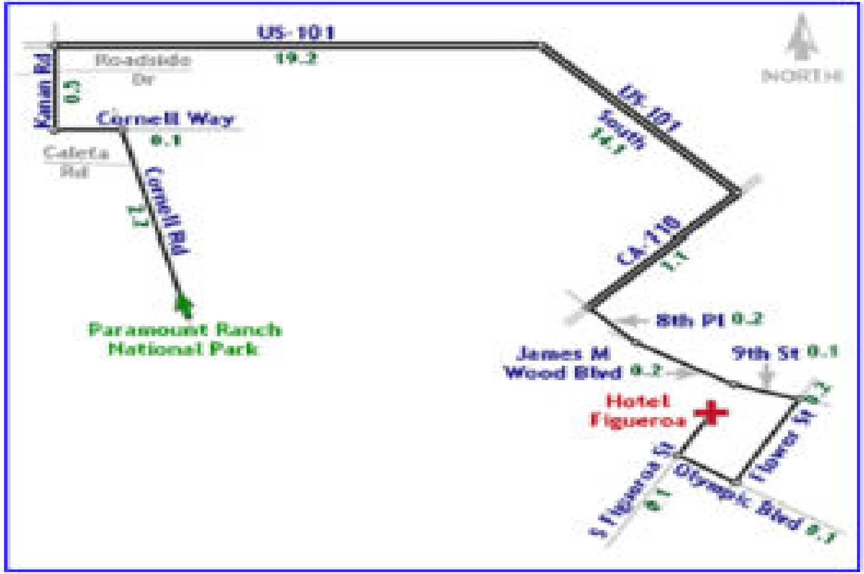
Multilevel texture synthesis



Non-Photorealistic Rendering

Aaron Hertzmann

Rendering: Information



Animation

Keyframe animation

Keyframing

Animation

Pixar: "Luxo Jr." (1986)

A baby lamp finds a ball to play with and it's all fun and games until the ball bursts. Just when the elder Luxo thinks his kid will settle down for a bit, Luxo Jr. finds another ball—ten times larger.

Luxo Jr. has a great dad in the larger lamp. Even though he is a bit unpredictable, the elder Luxo gives him room to grow and explore. And the tiny light has no problem with that.

When John Lasseter was learning how to make models, he chose the nearest, easiest subject: an architect's lamp sitting on his desk. He started moving it around in the animation system like it was alive and it eventually became another short film by Pixar that was nominated for an Academy Award®.

Animation

Motion capture

Animating Golem in LOTR

Animation

The Animatrix –

"Final Flight of the Osiris"

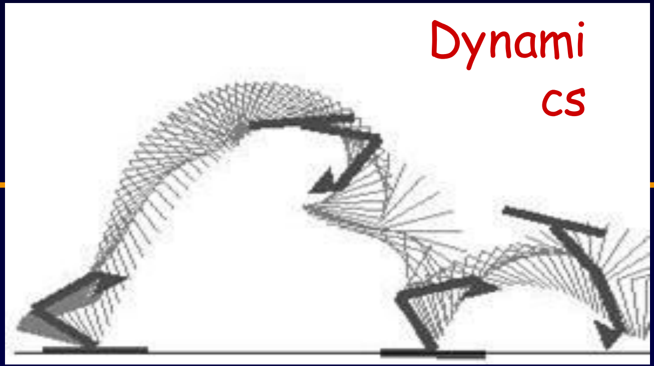
Animation

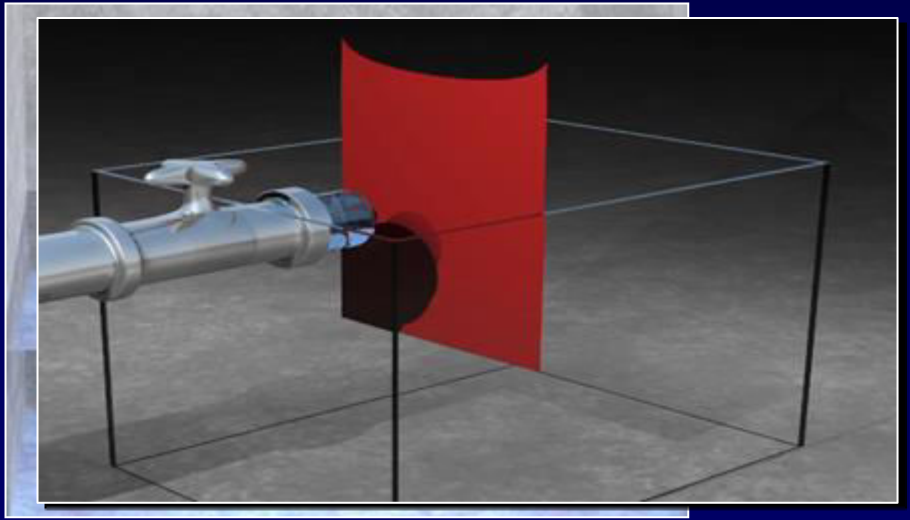
Example: “Geri’s Game” - Pixar

Cloth Simulation

Animation

Physics-based animation





Fluid Simulation

Modeling

- Incompressibility
- Viscocity

Navier-Stokes Equations

$$\nabla \cdot \mathbf{u} = 0$$

$$\frac{\partial \mathbf{u}}{\partial t} = \nu \nabla \cdot (\nabla \mathbf{u}) - (\mathbf{u} \cdot \nabla)\mathbf{u} - \frac{1}{\rho}\nabla p + \mathbf{g}$$

$\mathbf{u}$: fluid velocity field

$\mathbf{g}$: gravity

p: pressure

ν : viscosity

ρ : density

Level Sets

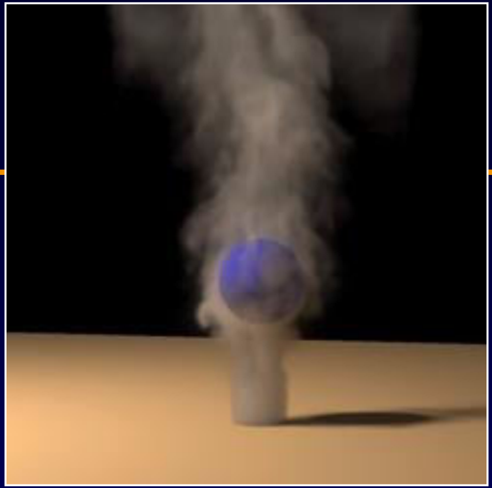
Smoke Simulation

Assumptions

- No viscosity

Rendering

- Photon maps
- Multiple scattering



$$\nabla \cdot \mathbf{u} = 0$$

$$\frac{\partial \mathbf{u}}{\partial t} = (\mathbf{u} \cdot \nabla)\mathbf{u} - \frac{1}{\rho}\nabla p + \mathbf{f}$$

$\mathbf{u}$: smoke velocity field

$\mathbf{f}$: external forces

p: pressure

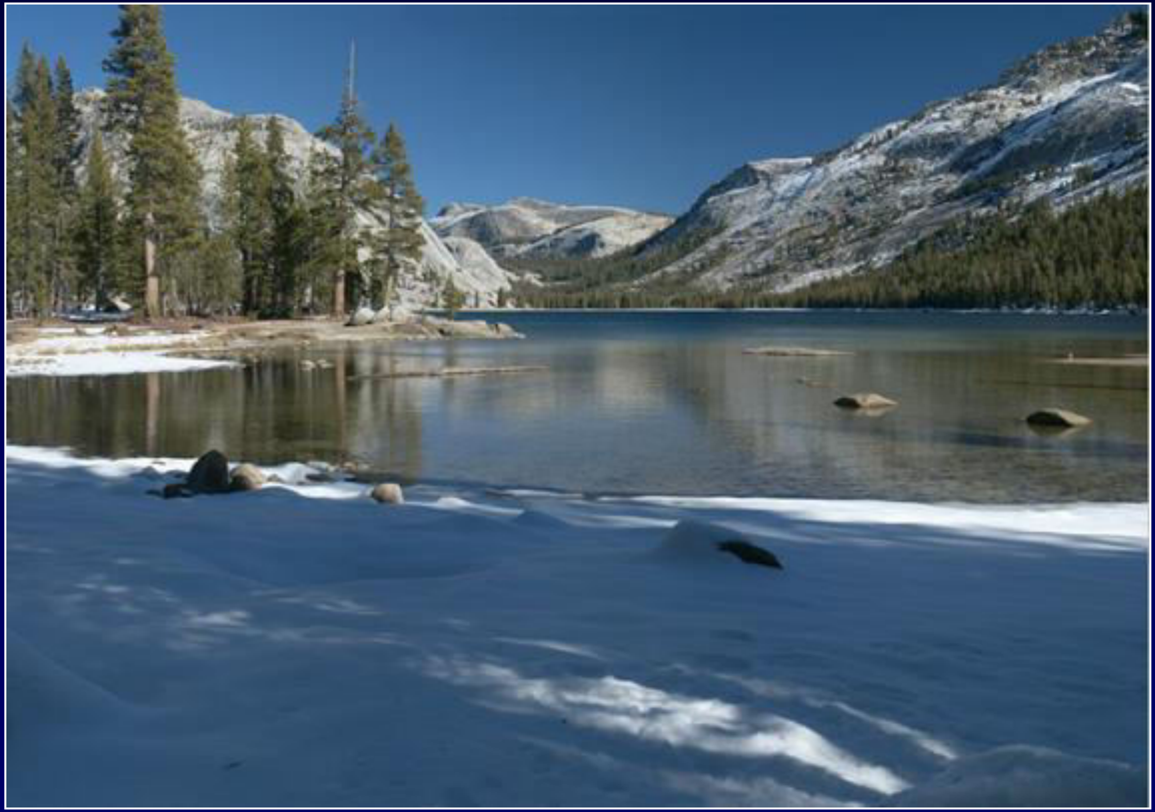
ρ : density

Animation

Ethology

Behavioral animation

Reality is *Very* Complex

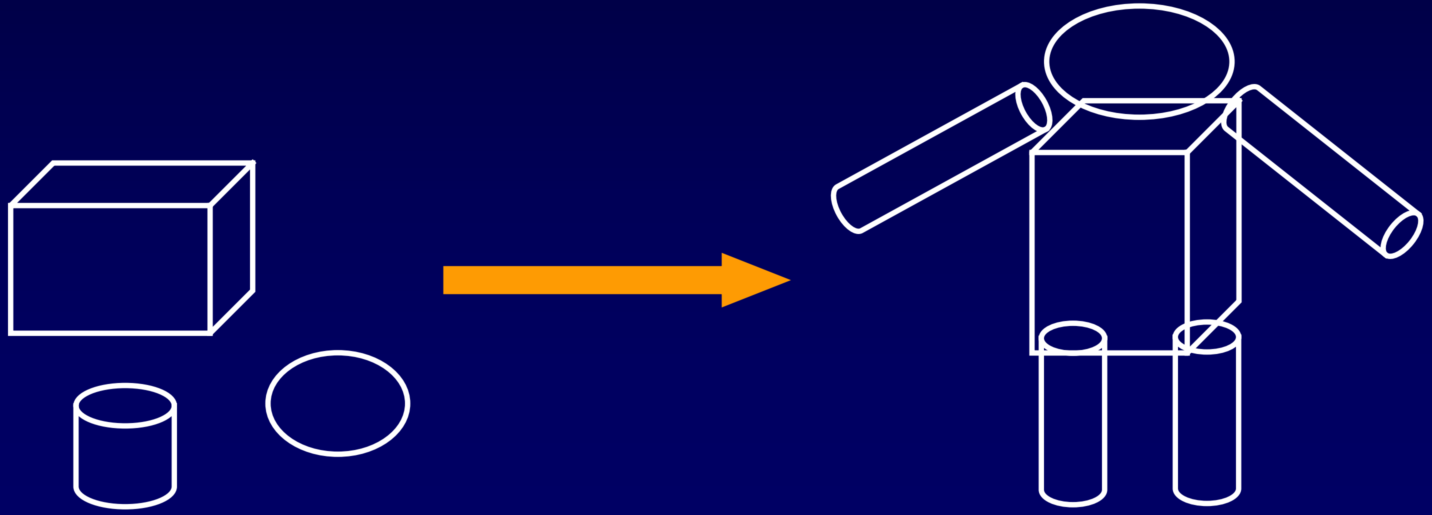


Reality is *Very* Complex

Reality is *Very* Complex

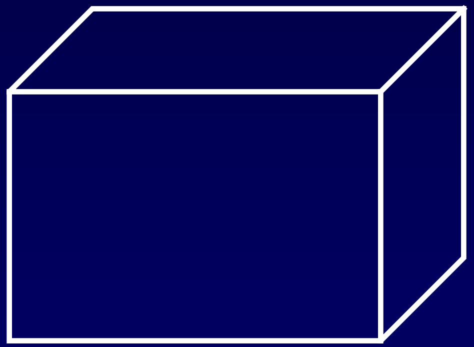
Modeling Transformations

Assembly

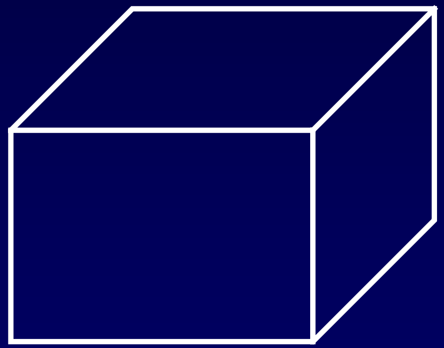


Viewing

Orthographic

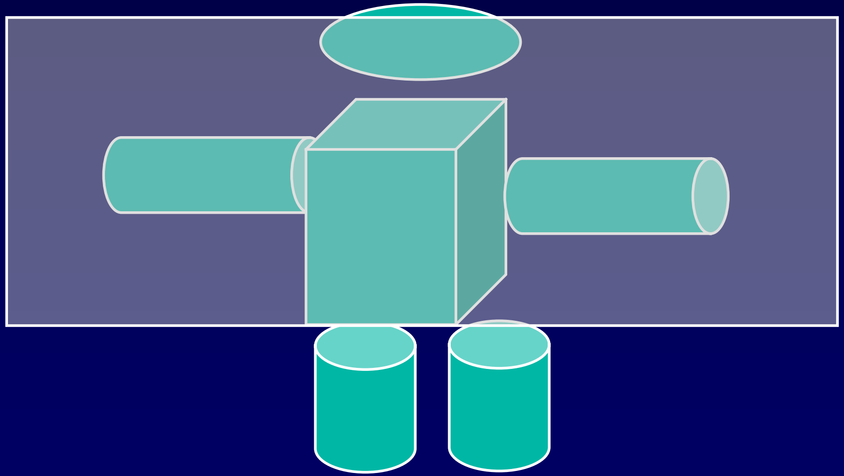


Perspective



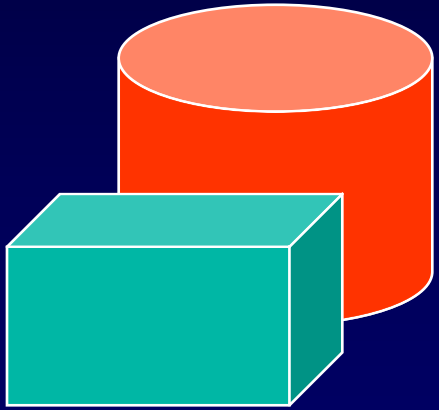
Clipping

Remove what is not visible



Visibility

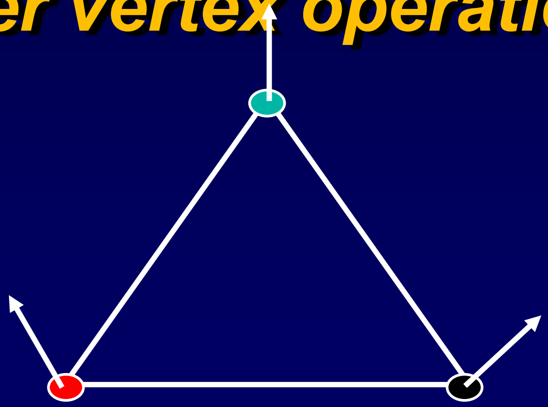
Resolve occlusions (efficiently)

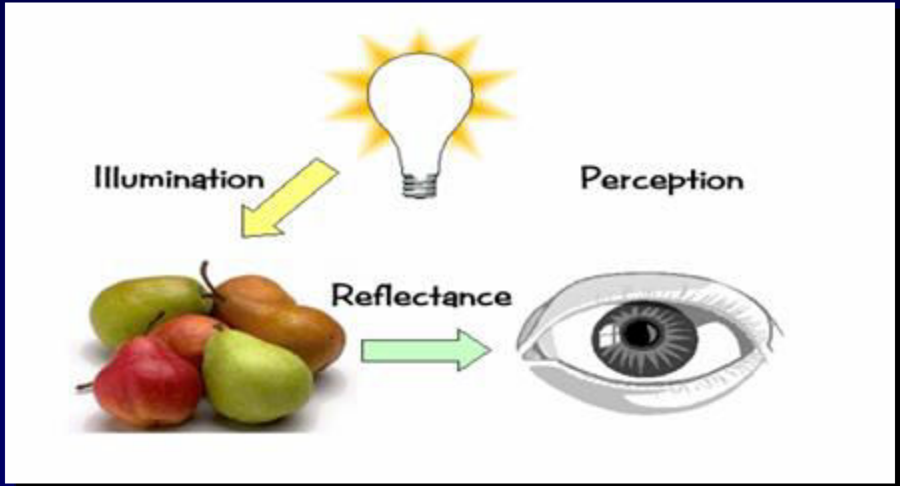


Illumination

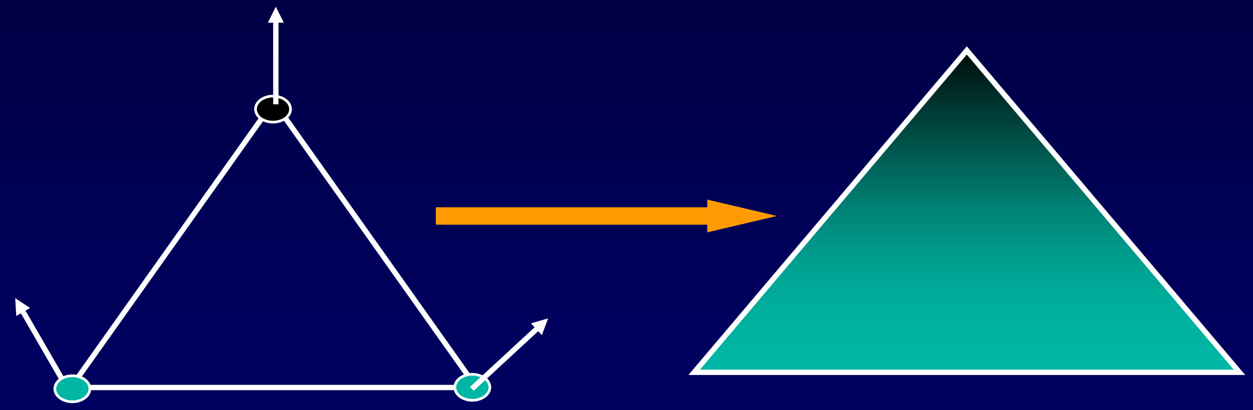
Compute normals and color at vertices

Per vertex operations



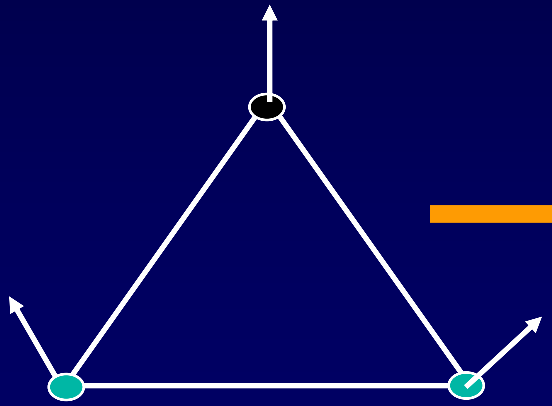


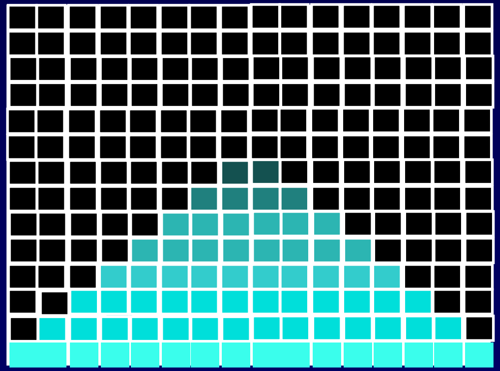
Shading



Rasterization

Convert to colored pixels





Texture Mapping

Other Issues

Shadows

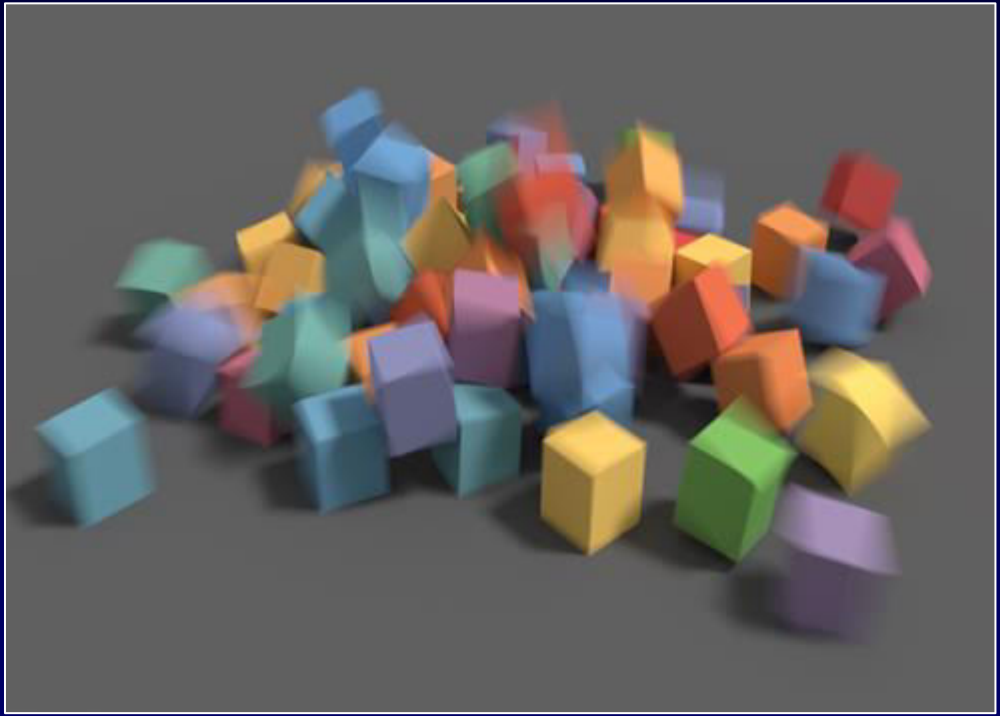
Participating media

Subsurface scattering

Motion blur

Camera models

Etc.



A Final Result

What is Academic about all this?

- *The full collection of techniques and “hacks” known to the industry? No*
- *The history of the techniques? No*
- *The skill of getting code working? No*

- *Well-understood math concepts that separate graphics from other programming? That’s better*
- *Tying into graphics research sometimes*

TA Session This Week

Following topics are on TA Session agenda:

- ***Walkthrough of Piazza and how the class intends to use it***
- ***Walkthrough of Github***
- ***Discuss first project assignment*** ***https://classroom.github.com/a/PiJBdIUg***
- ***Introduction to JavaScript and WebGL***
- ***Grading criteria for projects***
- ***Intro to linear algebra and matrices***