
Welcome to...
IT 360 – Fall 2023
Programming for Computer Graphics

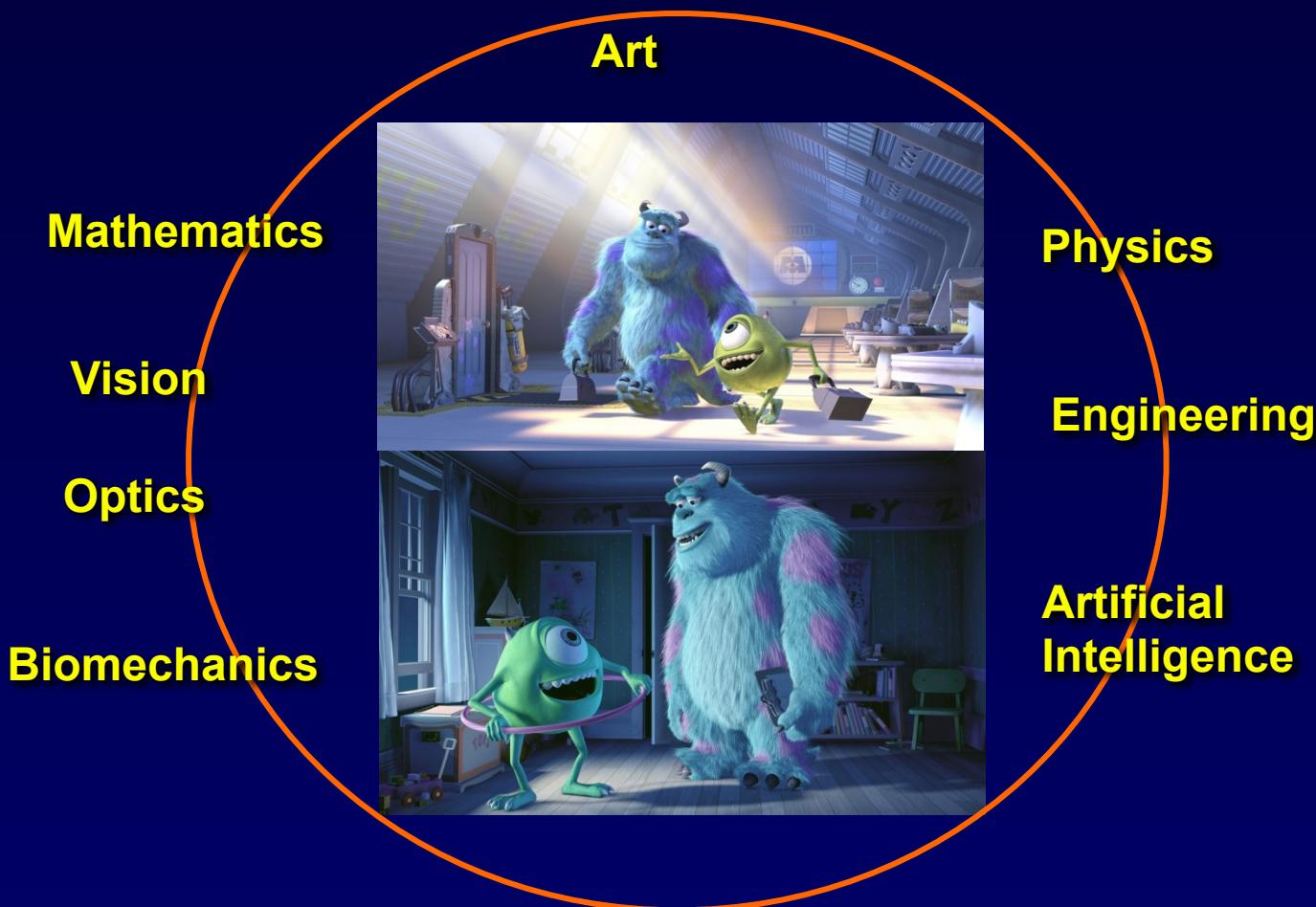
Prof. Tomer Weiss

tweiss@njit.edu

We will start shortly

Computer Graphics

The Art and Science of creating imagery by computer



Class Trailer Time!

- See <https://vimeo.com/444701874>

Logistics

- *Class website:
Canvas*
- *Syllabus
on the website*

Grading

- See *Syllabus*

Logistics

- ***We will share more info/methods of communication if needed***
- ***Email me only for personal questions***
- ***Class questions***

Introduction Time!

- ***My name is:***
(please write name in for attendance records)
- ***Program of study and year:***
- ***What I expect to gain from this class:***

I will start

- *My name is: Tomer Weiss*
- *Program of study and year: Informatics, Professor.
Studying graphics for about 10 years.*
- *What I expect to gain from this class:
Get more of you introduced to the world of computer
graphics and visual computing.*

Applications of CG

Entertainment

- Films
- Computer Games
- Virtual reality

Visualization

- Scientific visualization
- Medical visualization
- Flight simulation
- Architecture

Education, etc.

History

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

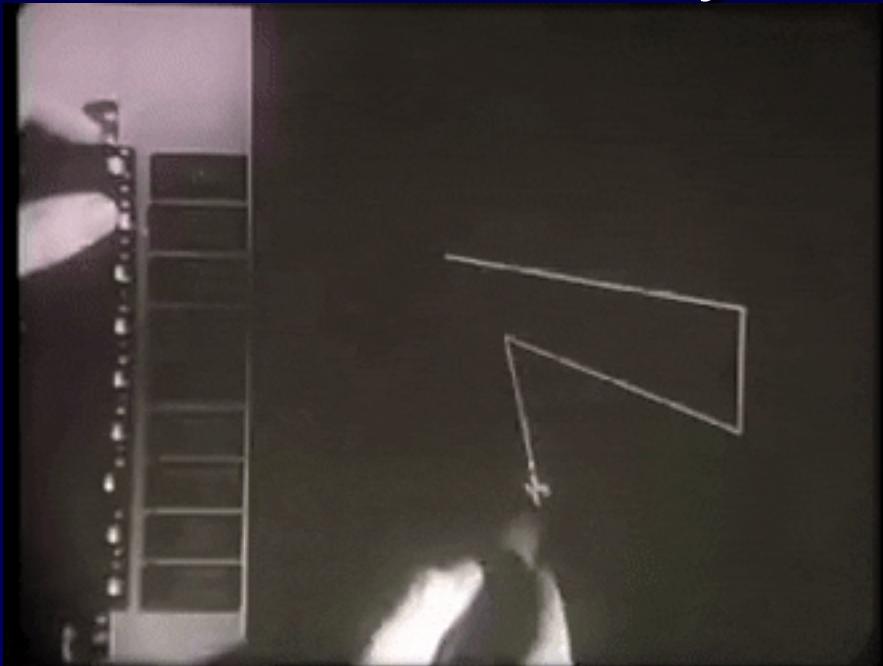
History

- 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*”



Genesis of Computer Graphics and Interactive Techniques

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Quiz

<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.

Quiz

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)

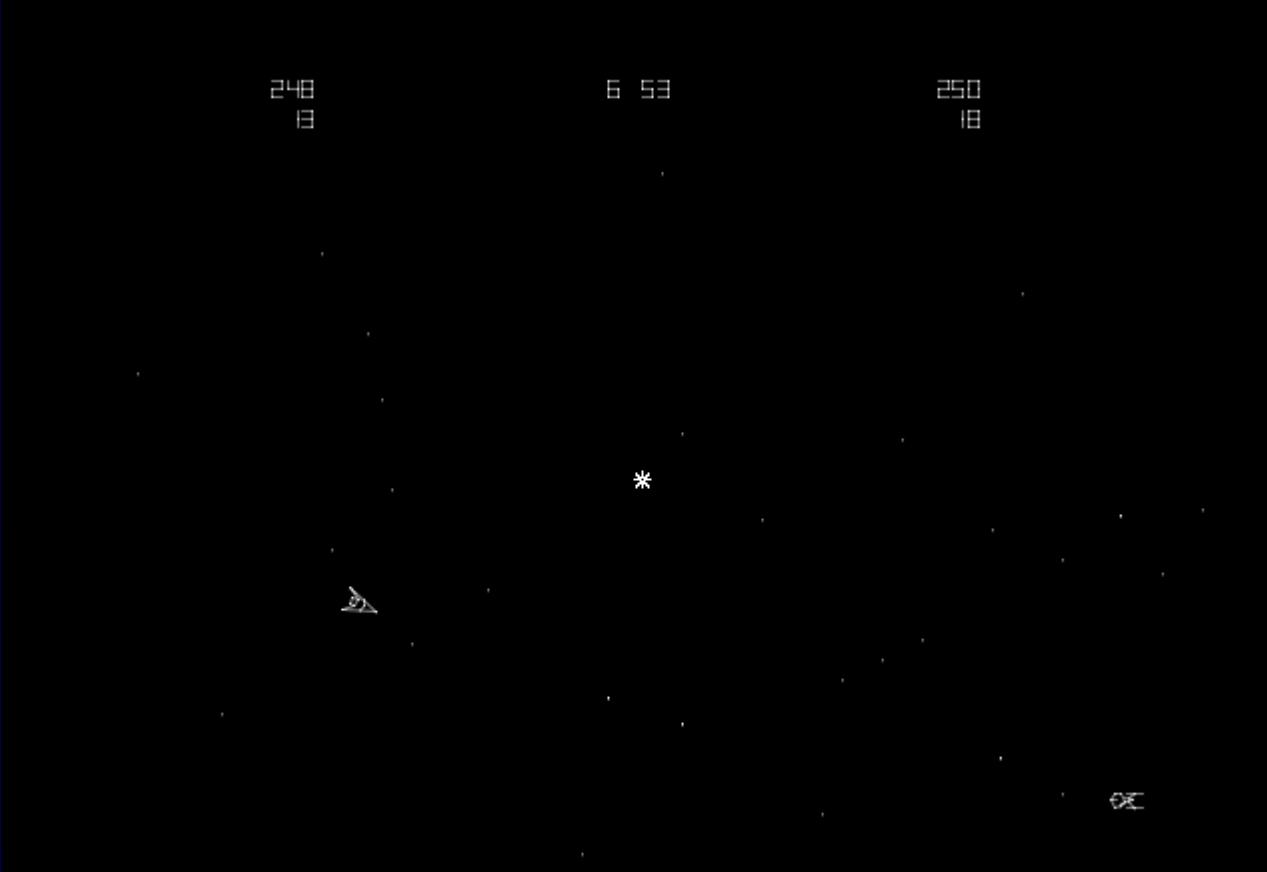
Wii Sports (83M copies)

...

Quiz

7. Which is the newest CG animated movie?
?? (*trick question*)
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?

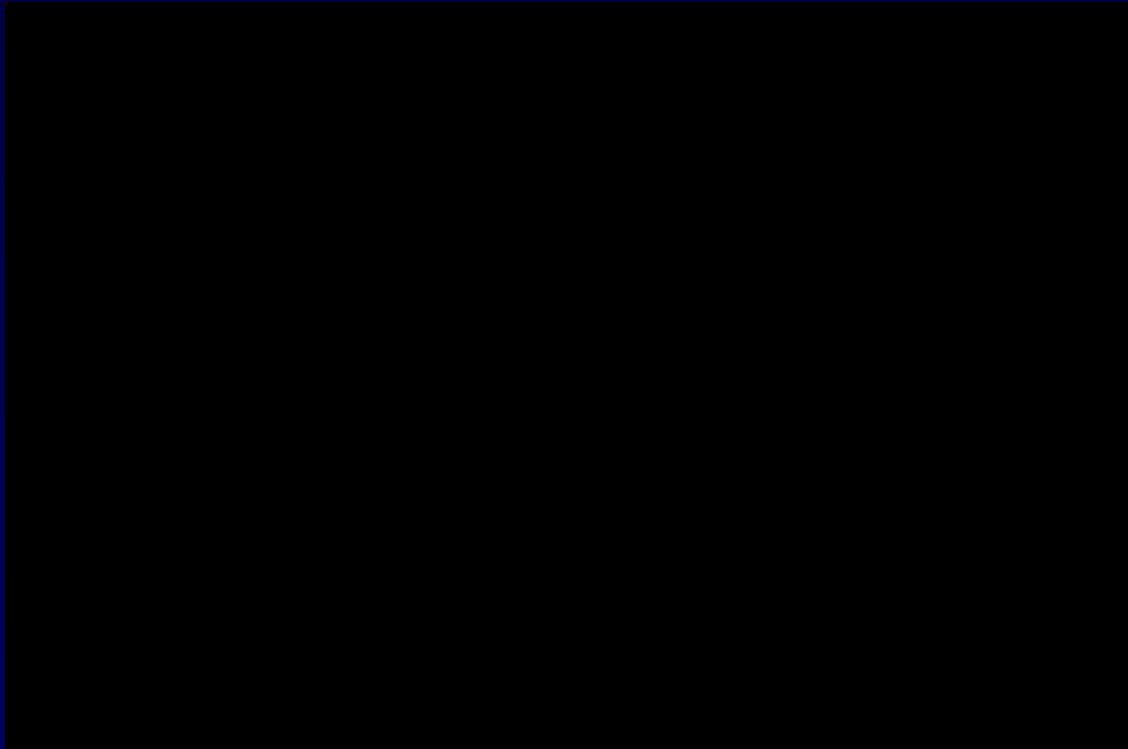
The First Computer Game?



Spacewars, PDP-1, MIT, 1961

The First “Computer” Game – 1958 !!

“Tennis for Two”





Metal Gear Solid 4



Games

Focus on interactivity



Movies

To reality and beyond !



Movies

Special effects



Movies

FAKE
JET LI



REAL
JET LI

Digital Compositing



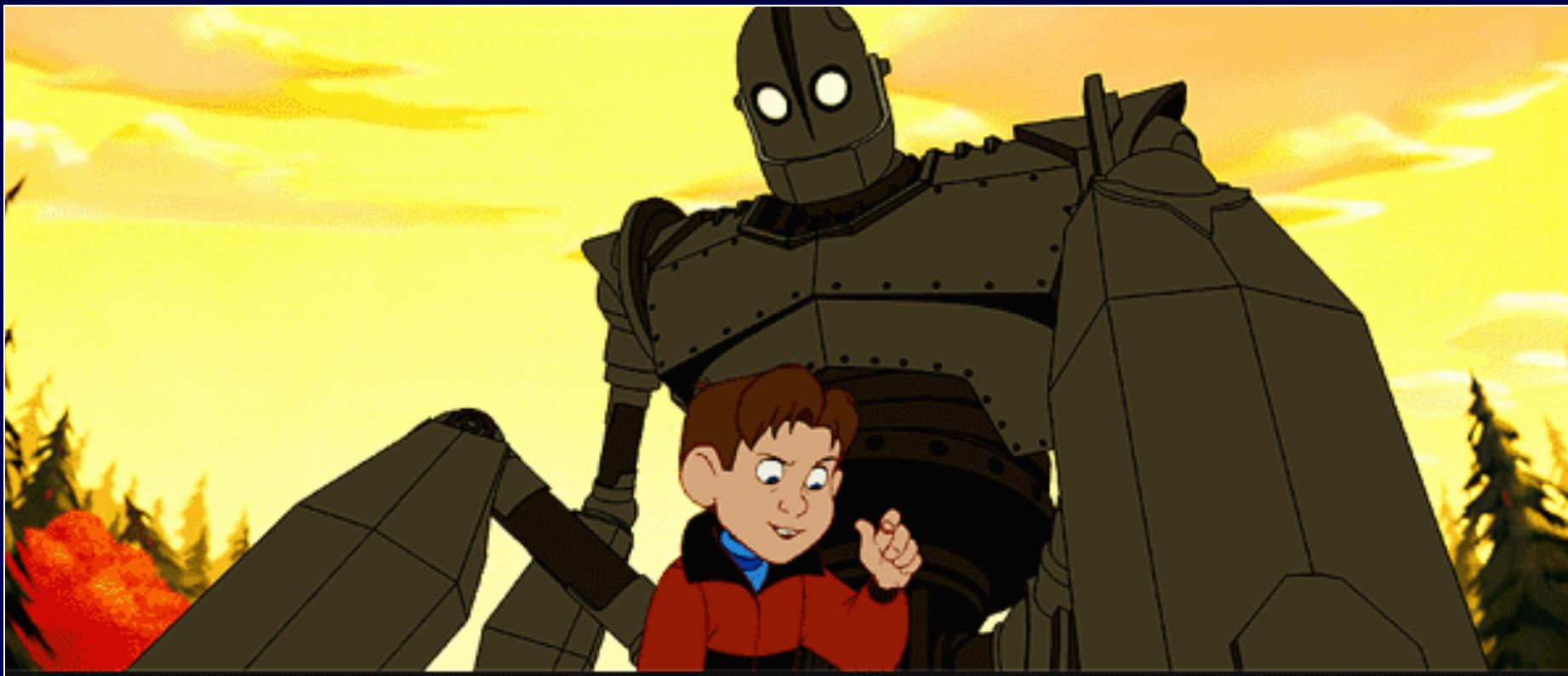


Base Color

Digital Compositing



Cartoons



Computer-Aided Design

Precision modeling

Engineering visualization



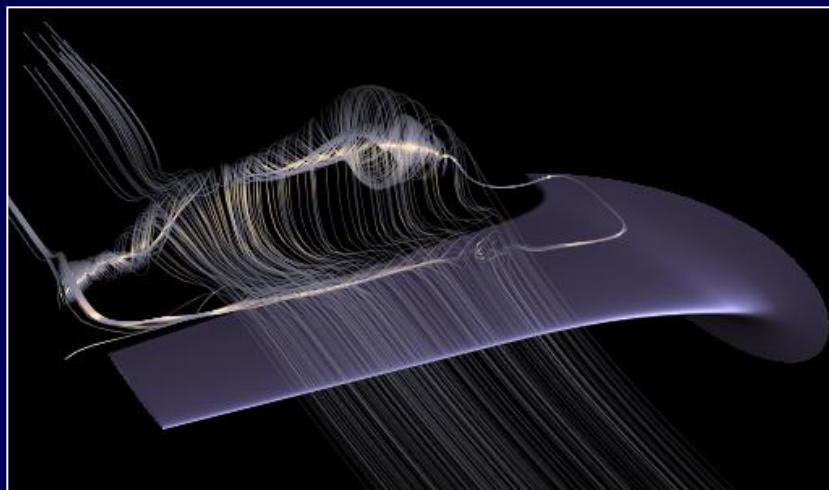
Modeling Clay



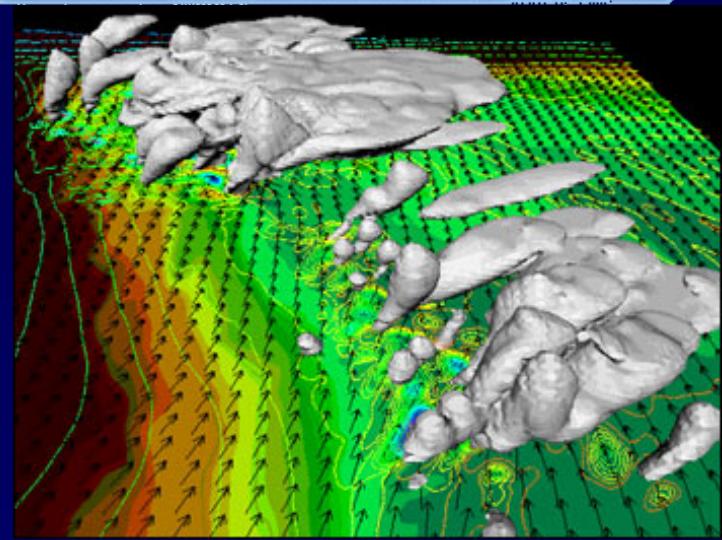
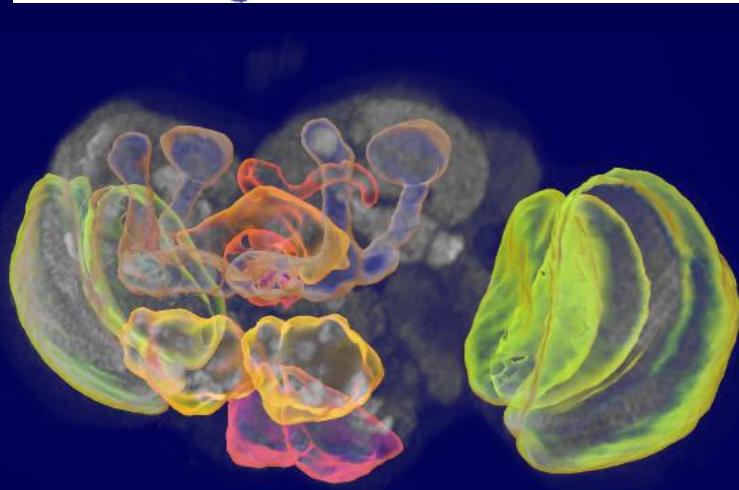
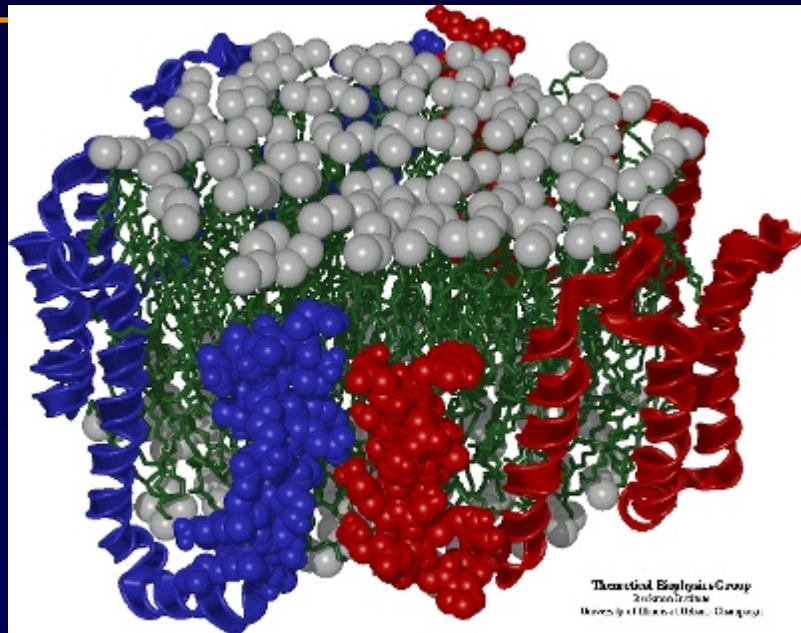
Computer-Aided Design

It's not just about visualization

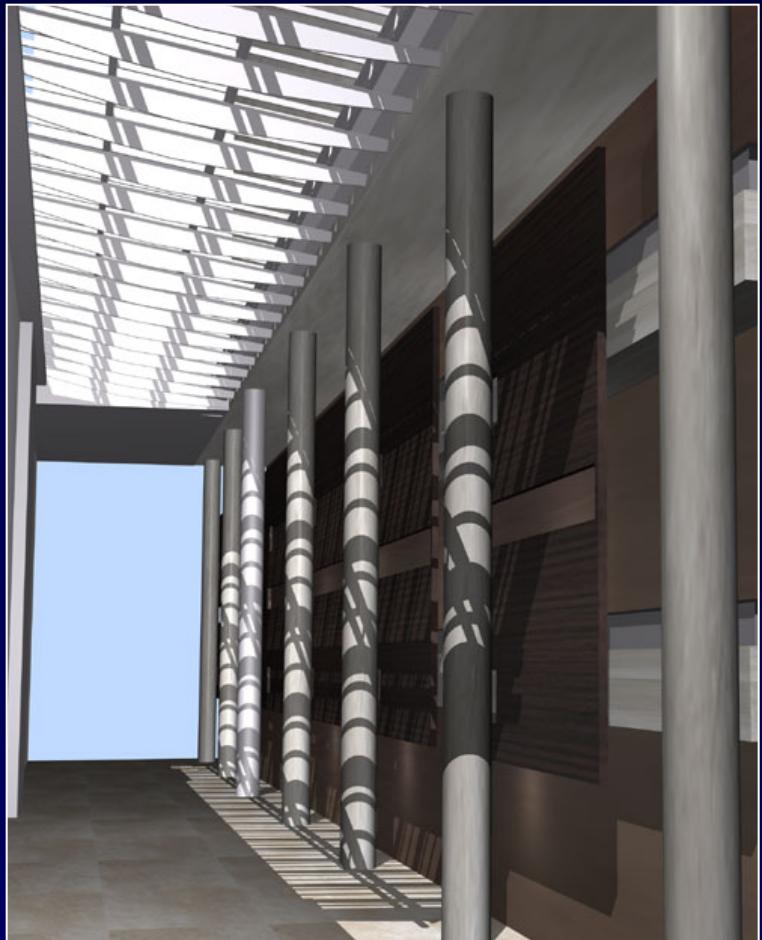
- Simulation is also useful



Visualization: Scientific



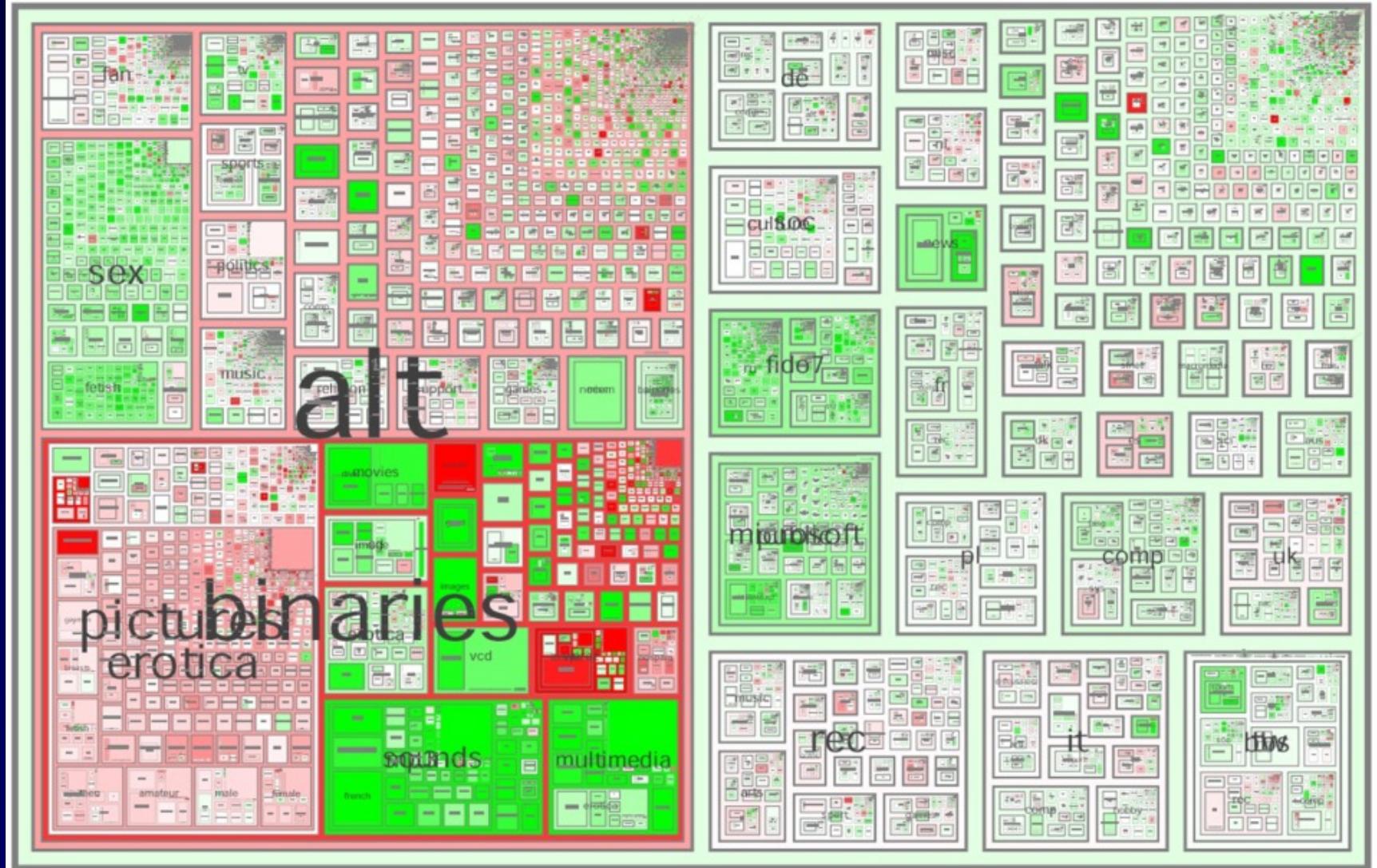
Visualization: Architectural



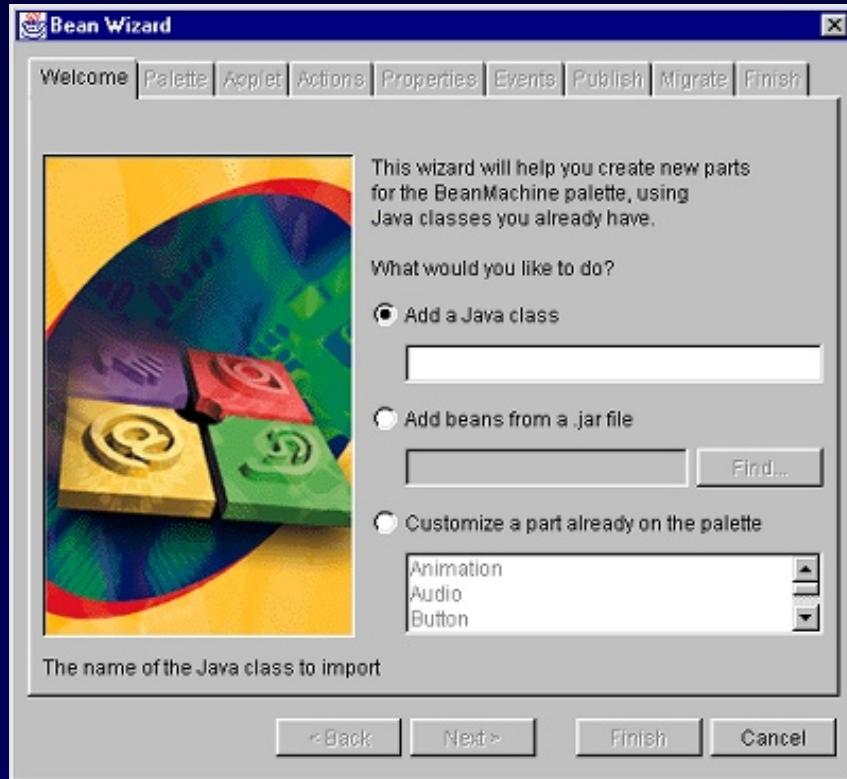
<http://www.diamondschmitt.com/>

Visualization: Info

Smith and Fiore



Graphical User Interfaces



Steven Schkolne

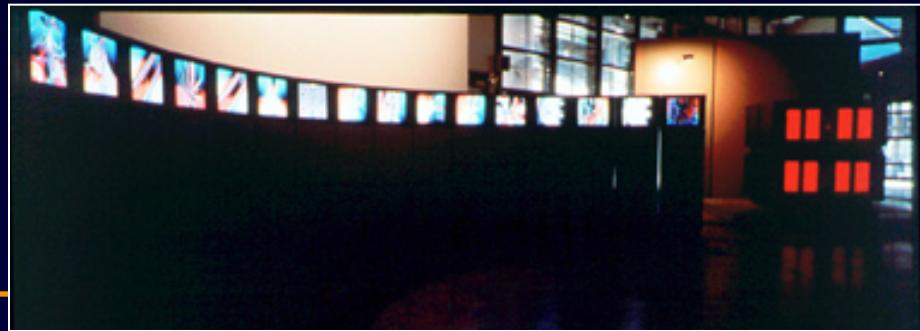
WIMP

Art

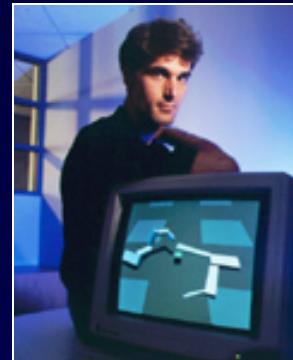
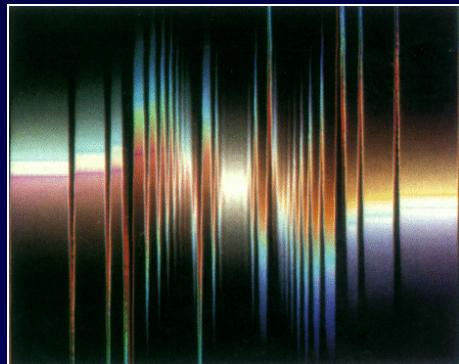
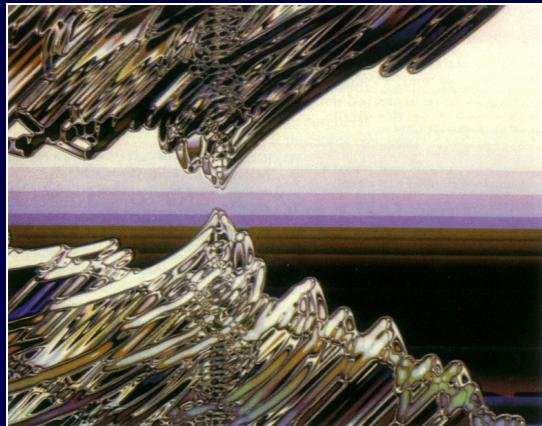


Steven Schkolne

Digital Art



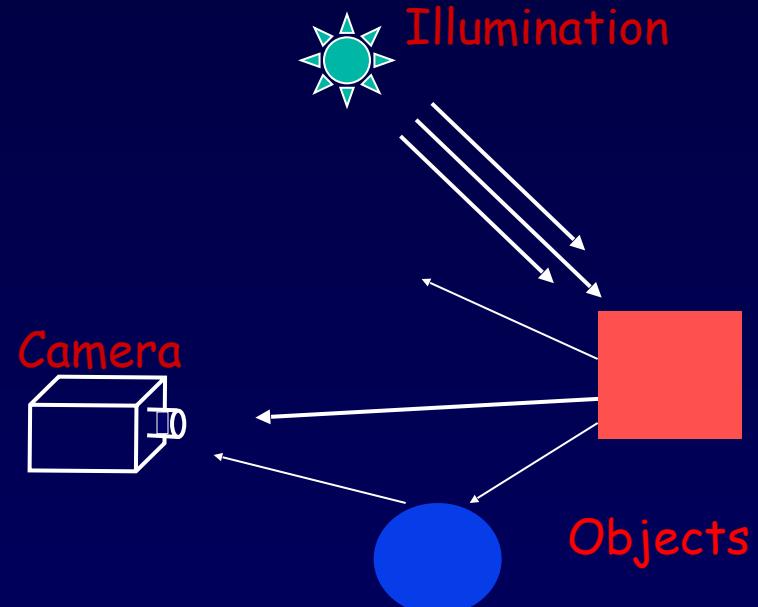
Genetically evolved



**5 Minute Break
Back at ...**

What is an Image / Video?

- Array of pixels (one or **more** numbers)
- A video is a time sequence of images
- How they are formed:
 - *Objects in the world (static or dynamic)*
 - *Illumination (light sources)*
 - *Imaging device (eye, camera)*
- We want to synthesize images/videos



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

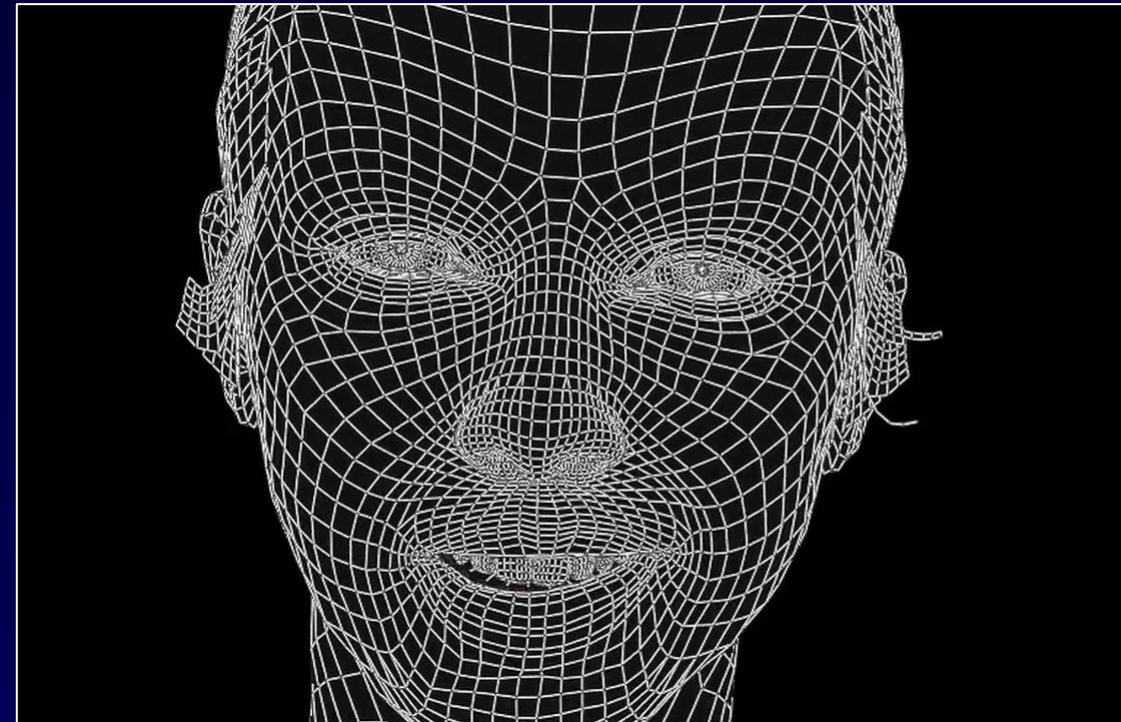
Primitives

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

Attributes

- Color, texture maps
- Lighting properties

Geometric transformations

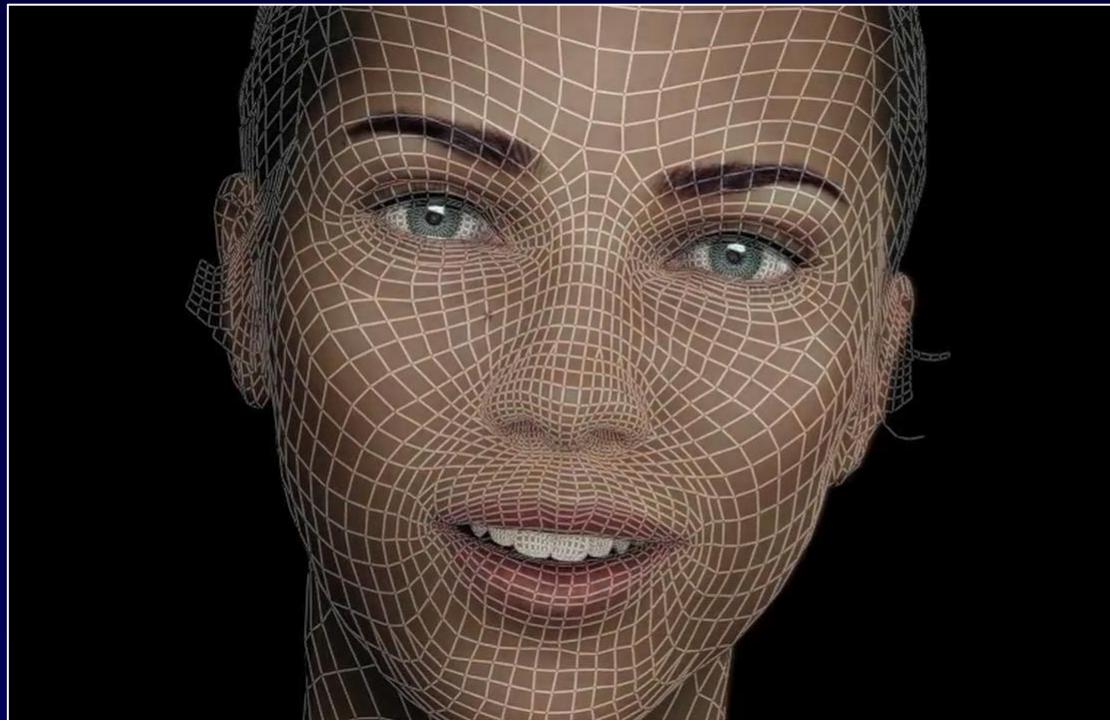


Rendering

Visibility

Simulating light propagation

- Reflection
- Asborption
- Scattering
- Emission
- Interference



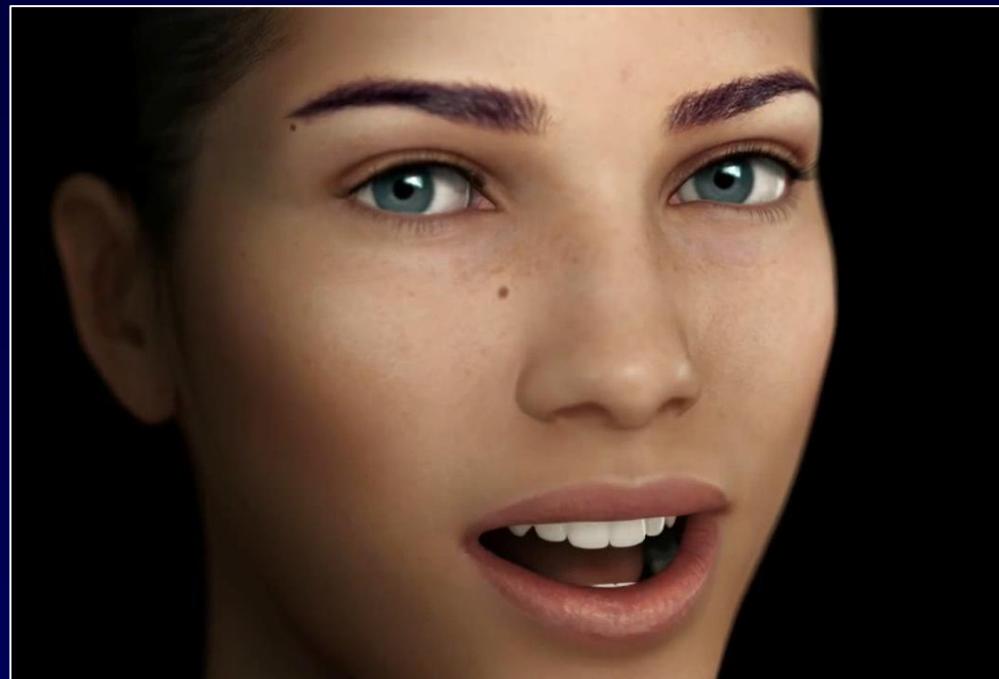
Animation

Keyframe animation

Motion capture

Procedural animation

- Physics-based animation
- Behavioral animation



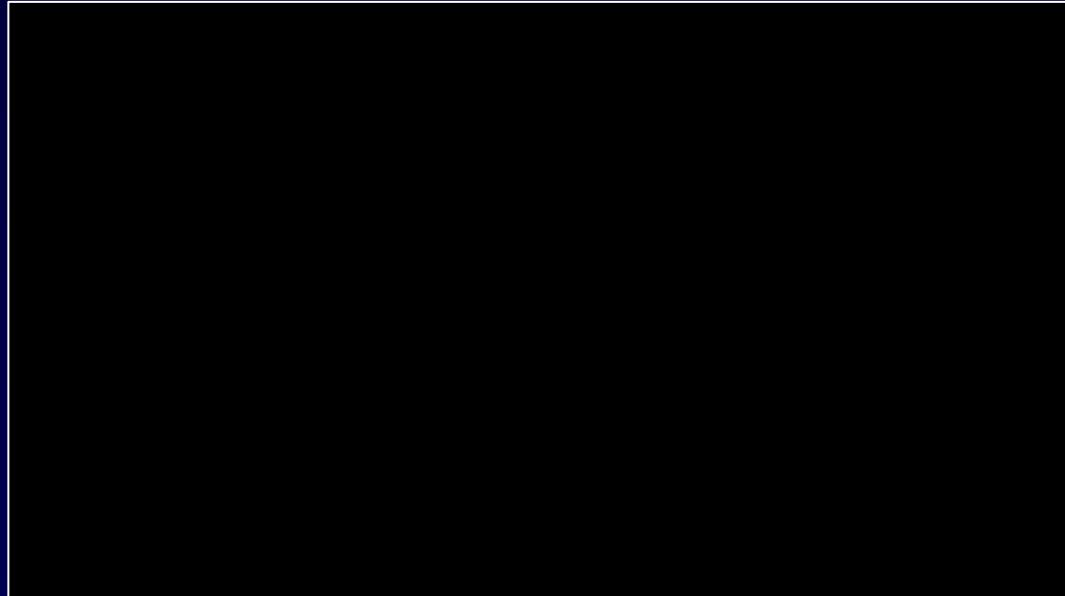
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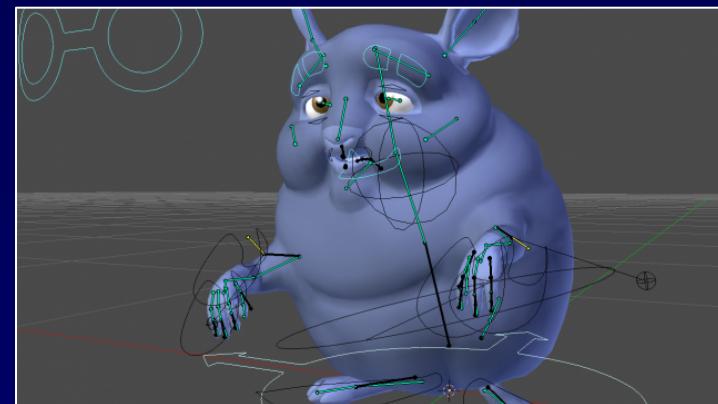
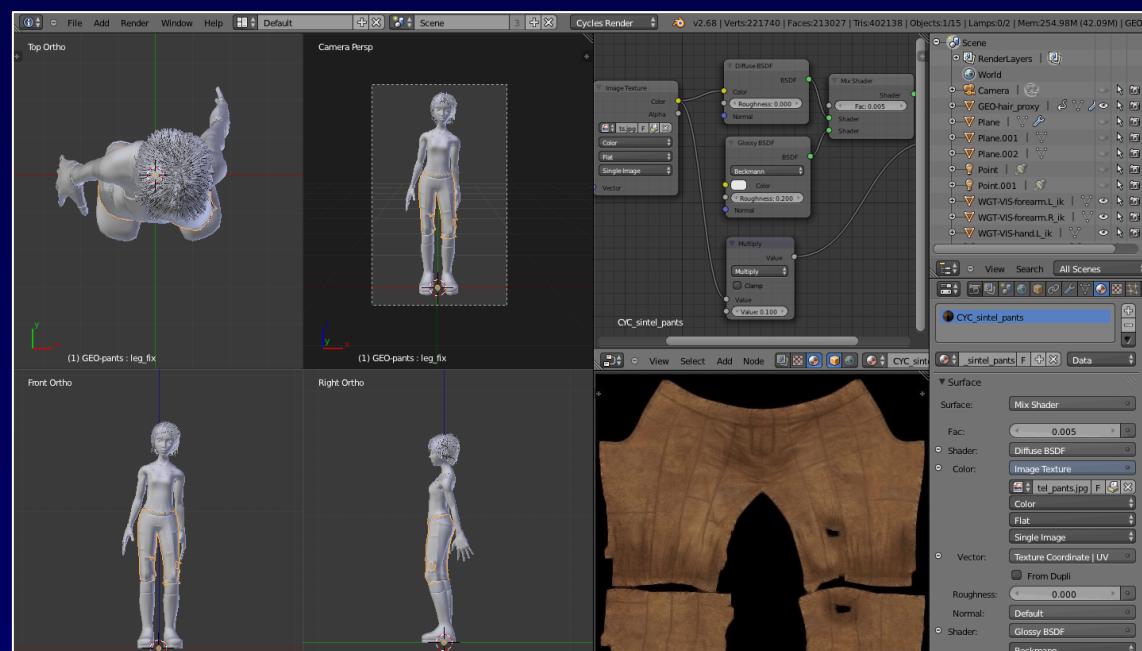
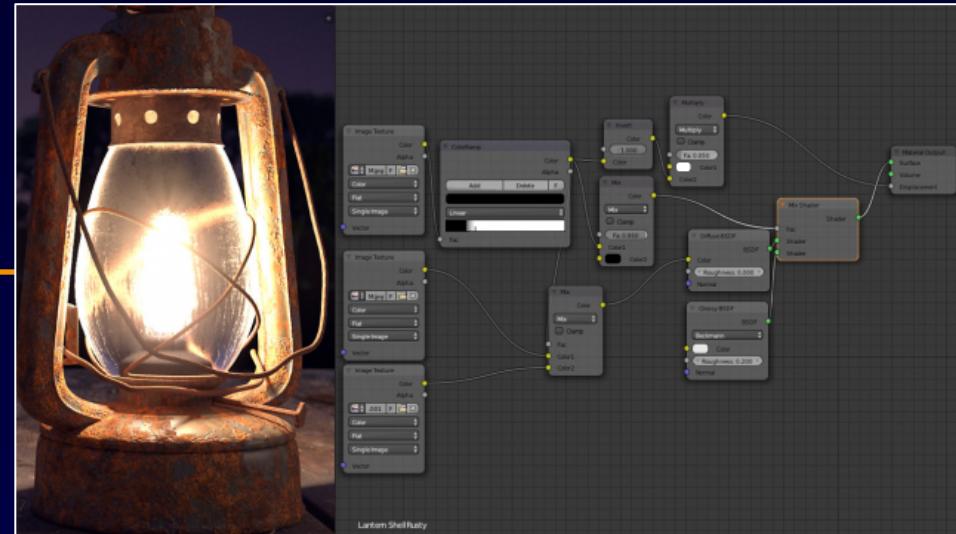


Ed

Interaction

Input/Output Devices Tools

- Modeling, animation, and rendering



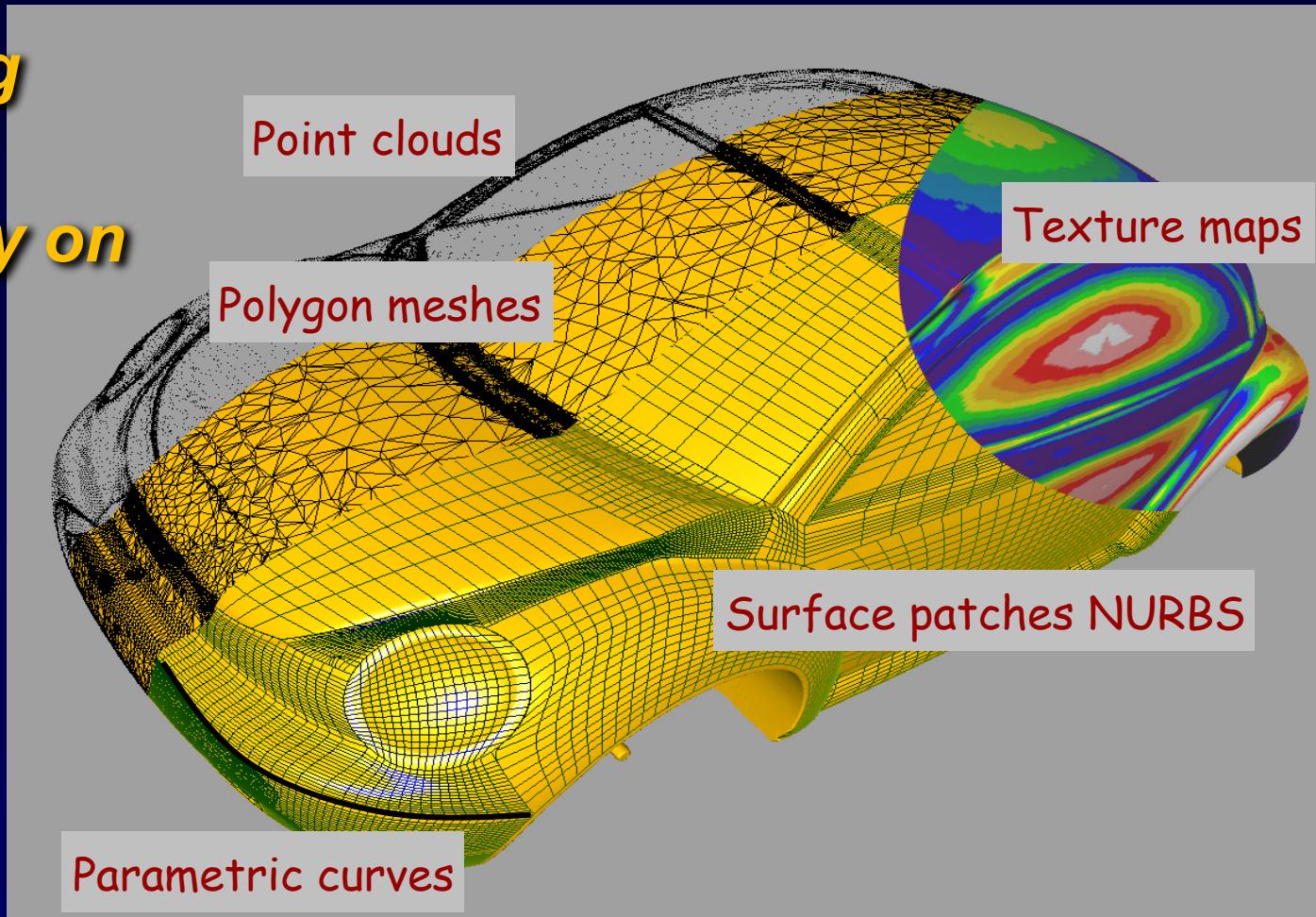
Elements of CG

The graphics pipeline



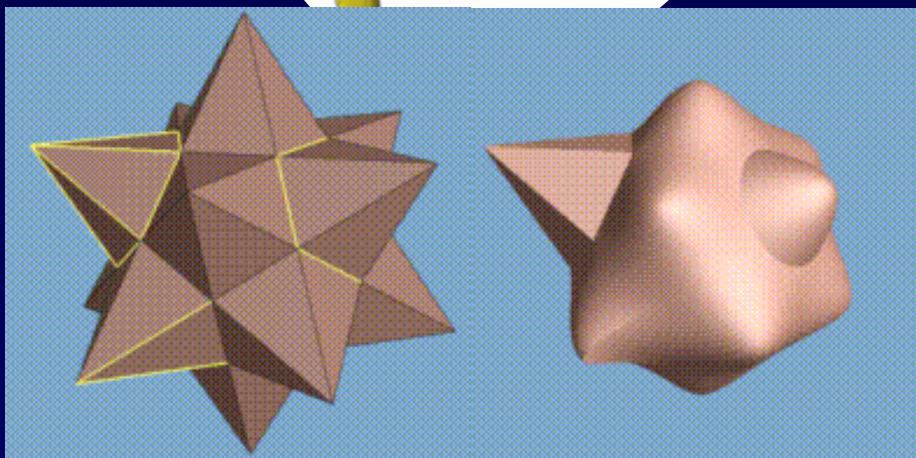
Modeling

*Representing
objects
geometrically on
a computer*

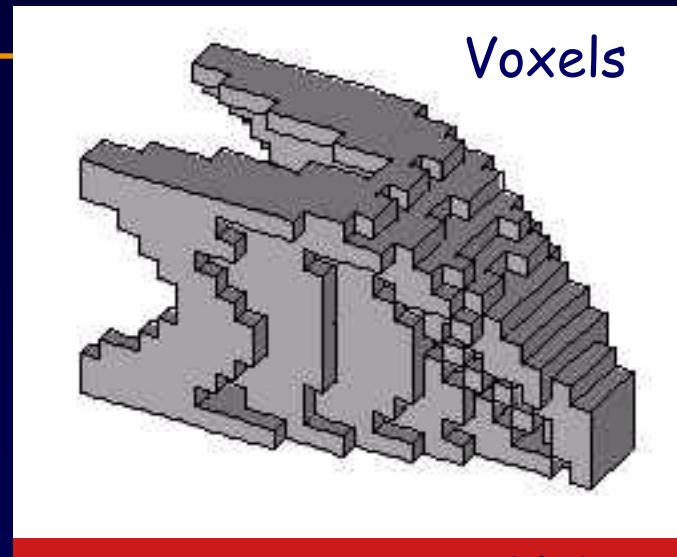


Other Modeling Data Structures

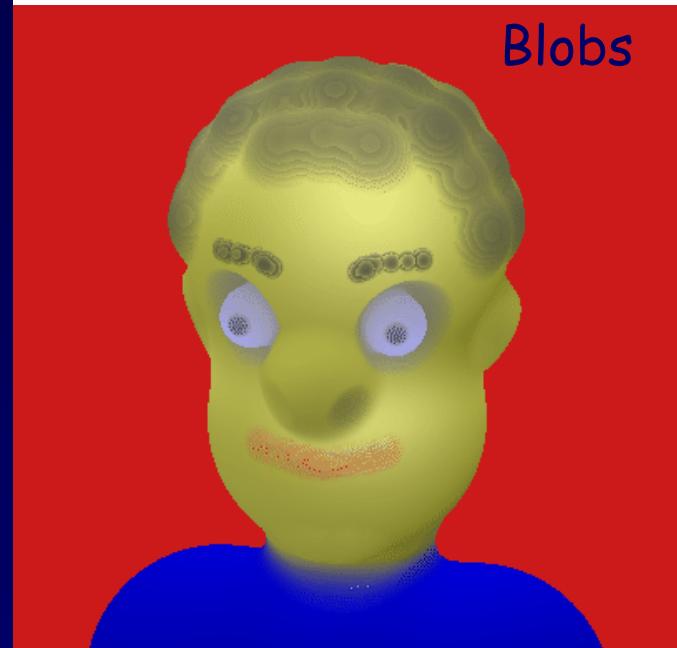
*Alternative
representations*



Subdivision surfaces

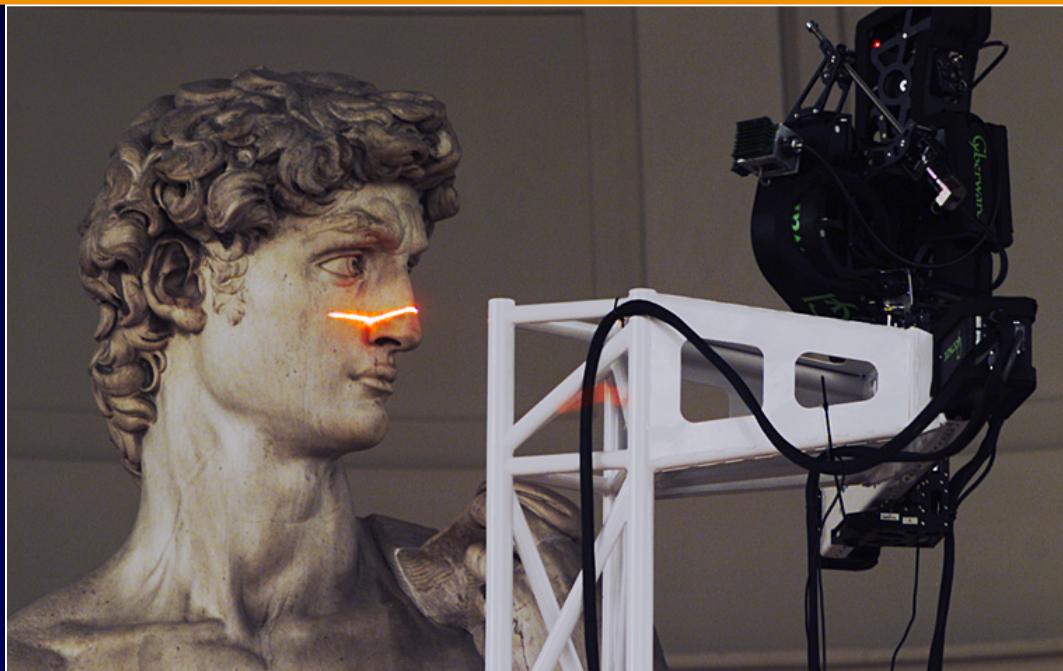


Voxels



Blobs

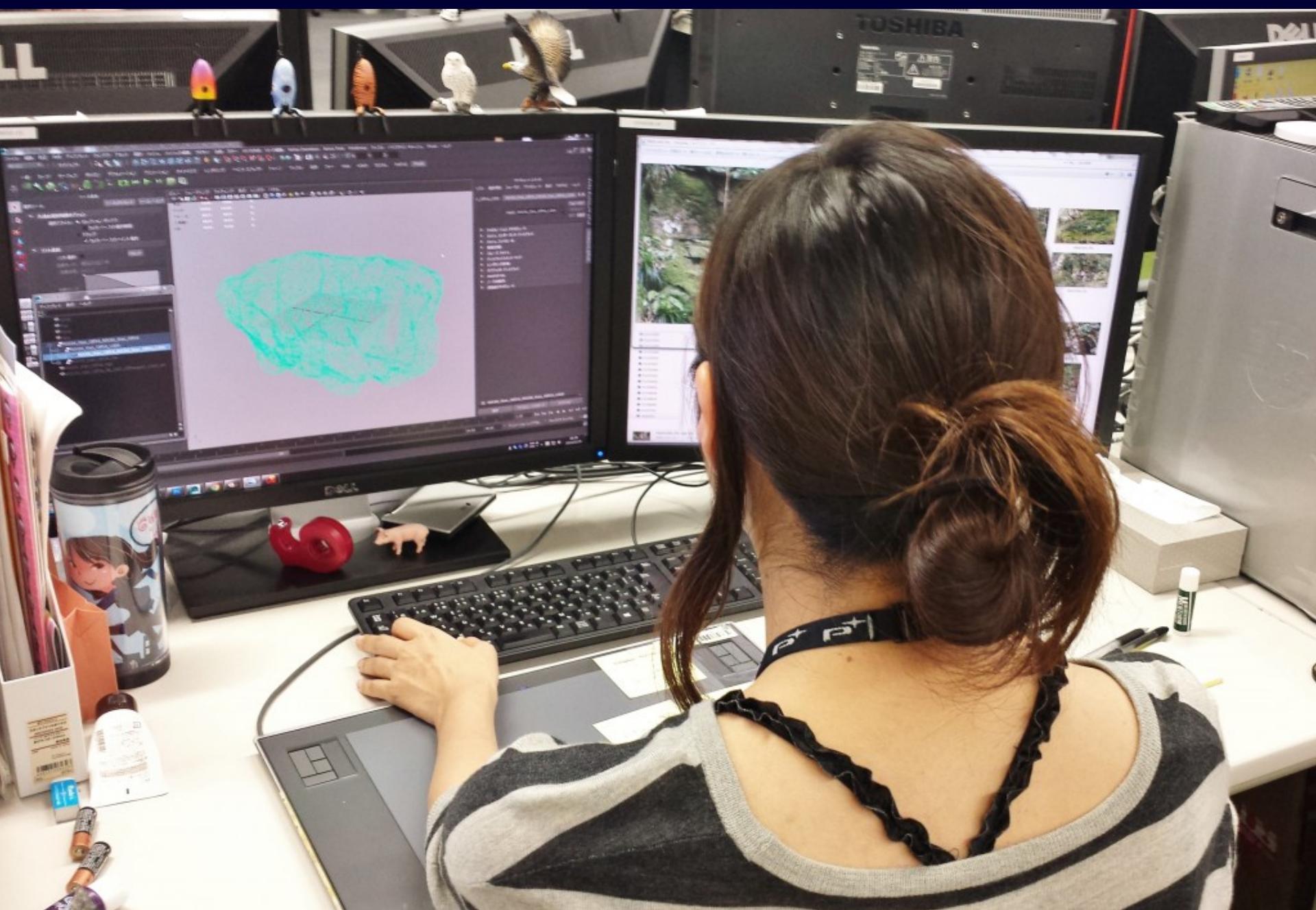
Input: Scanning Shapes



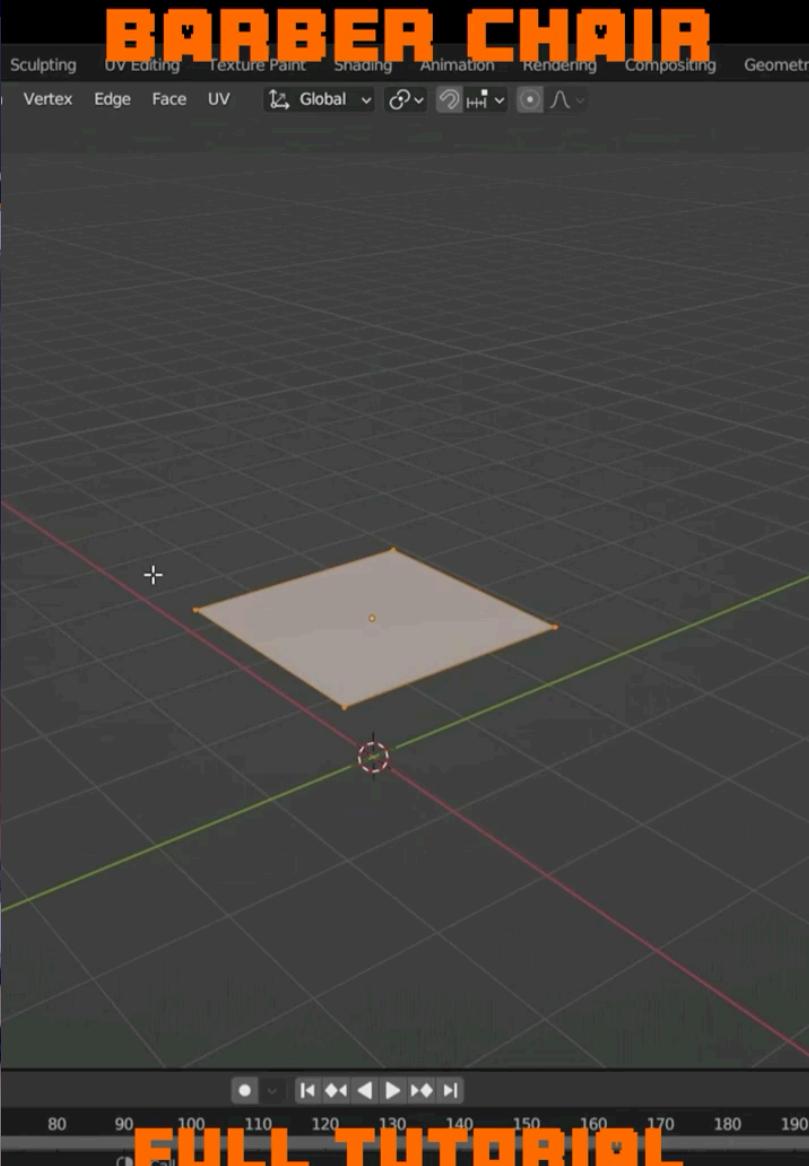
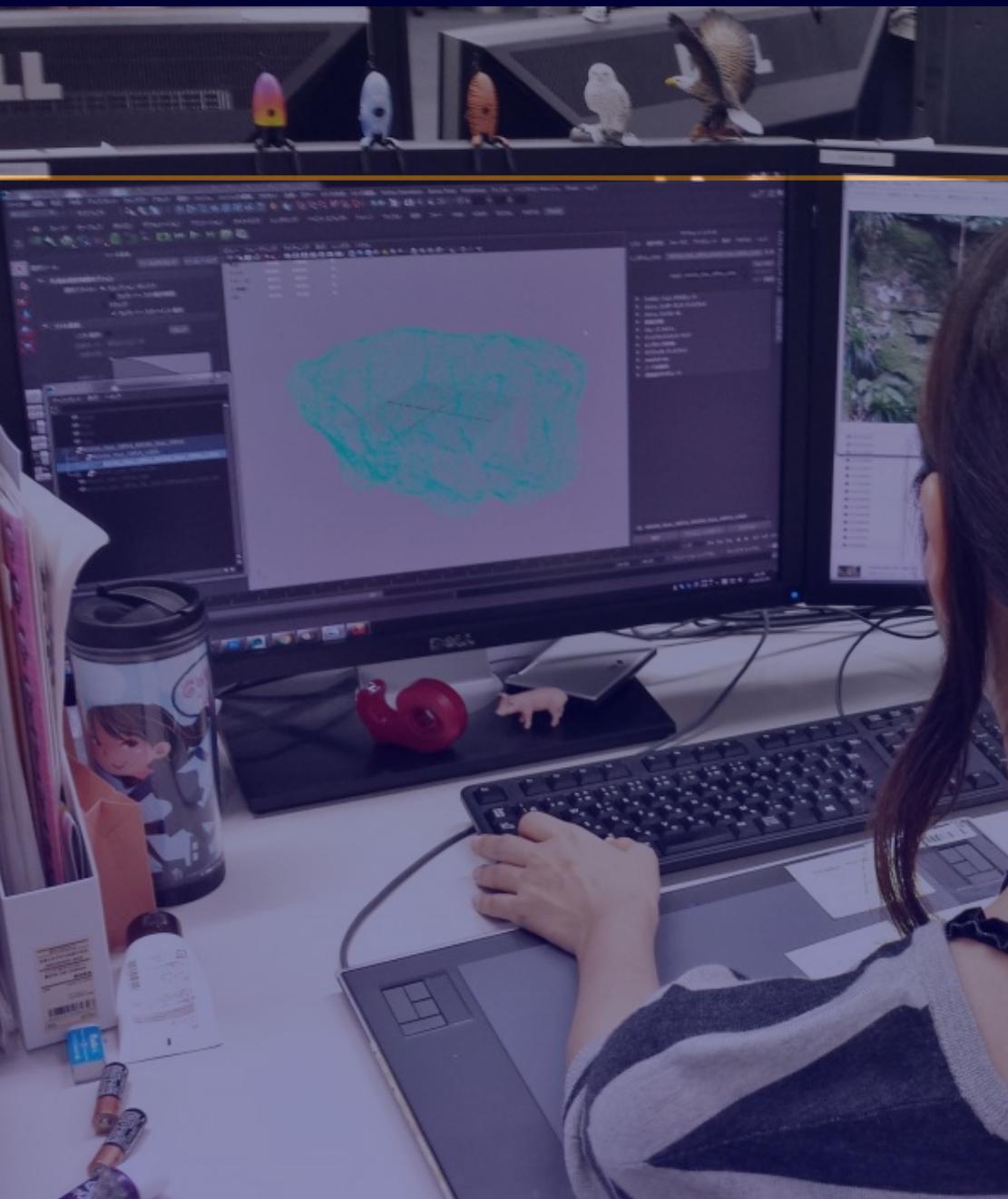
Digital Michaelangelo Project



Input: Manual Creation



Input: Manual Creation



FULL TUTORIAL
ON MY CHANNEL!

Modeling: Procedural with an Algorithm



Rendering

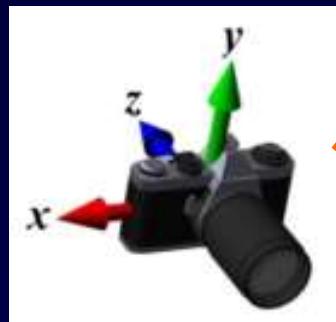
Key elements



Rendering

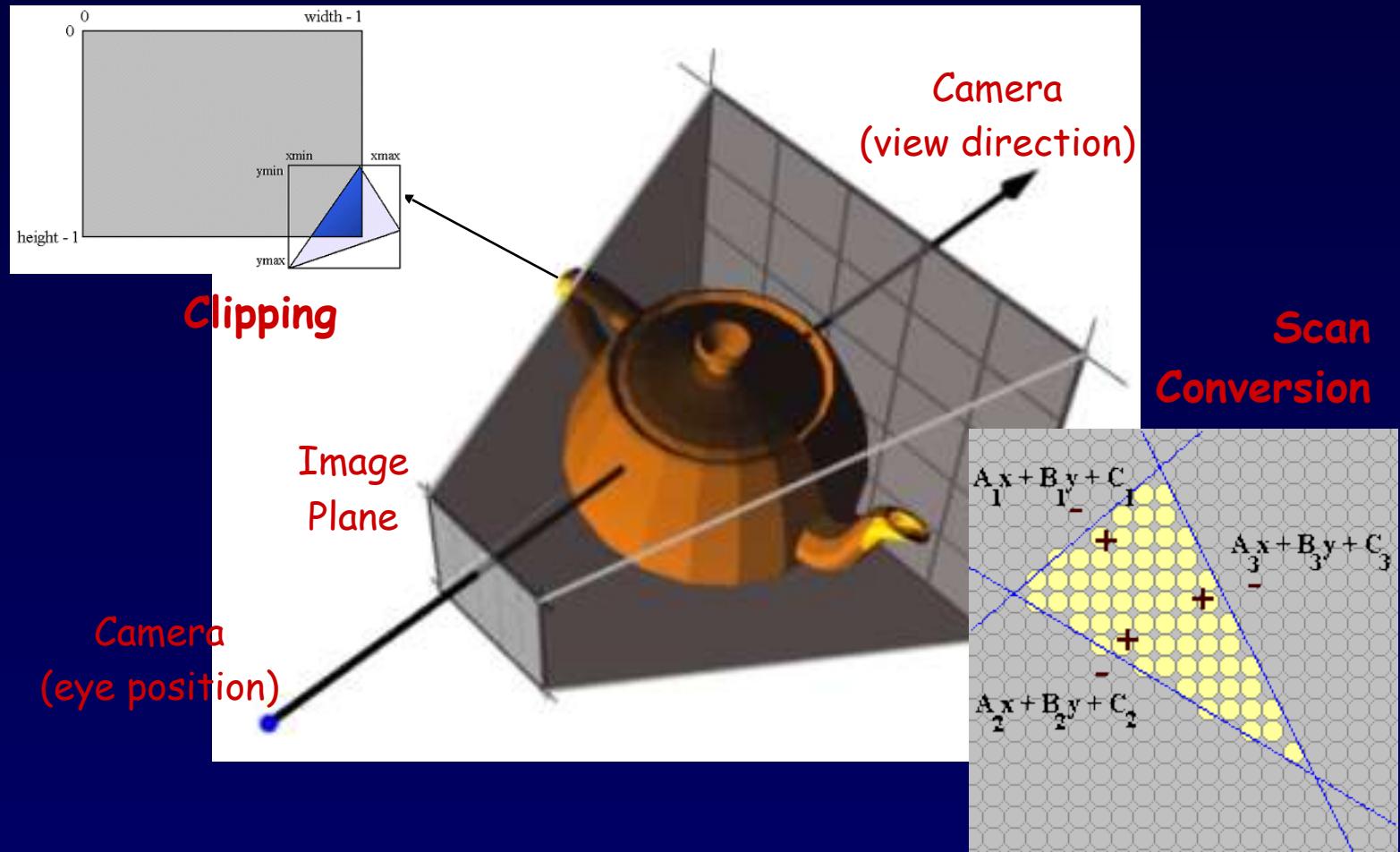


Camera Model



Rendering

Draw visible surfaces onto display



Reflectance Modeling



Complex Reflectance



<http://stemkoski.github.io/Three.js/Reflection.html>

Subsurface Scattering

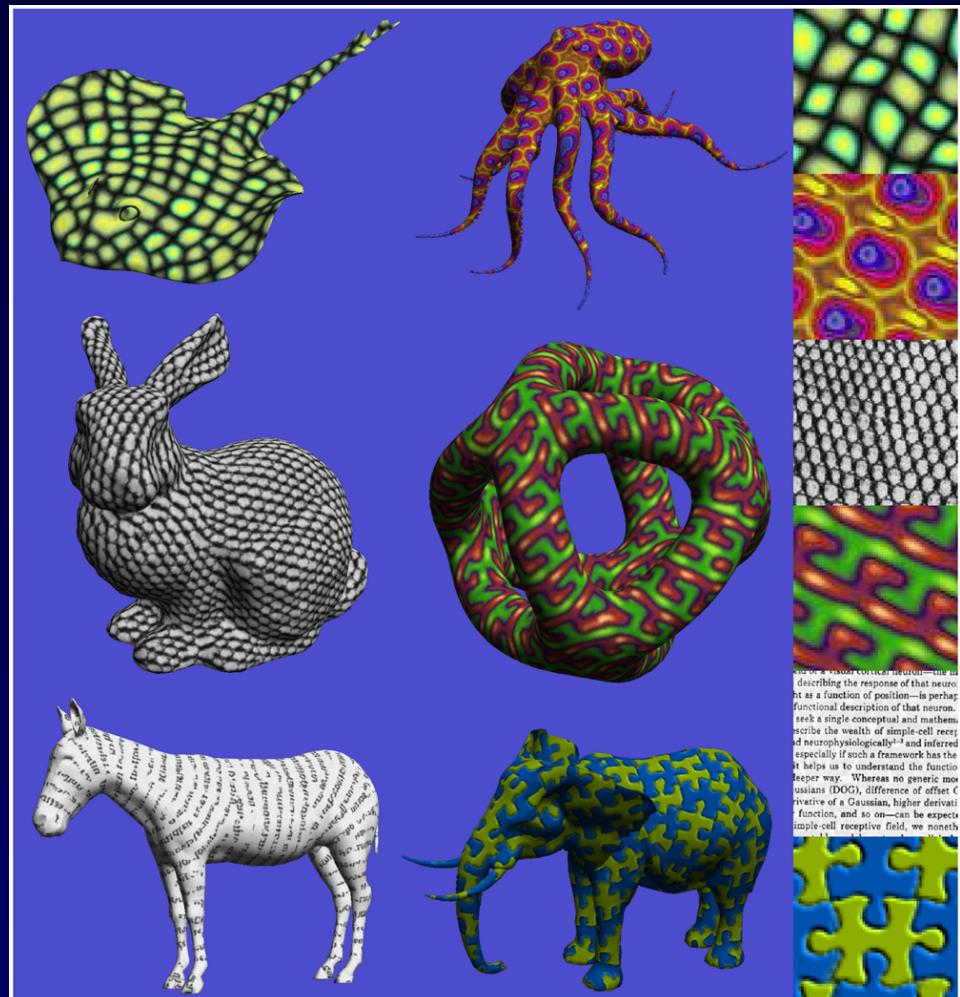
Translucency and varied levels of light penetration can be created using subsurface scattering effects



threejs.org/examples/webgl_materials_subsurface_scattering.html

Texture

Multilevel texture synthesis



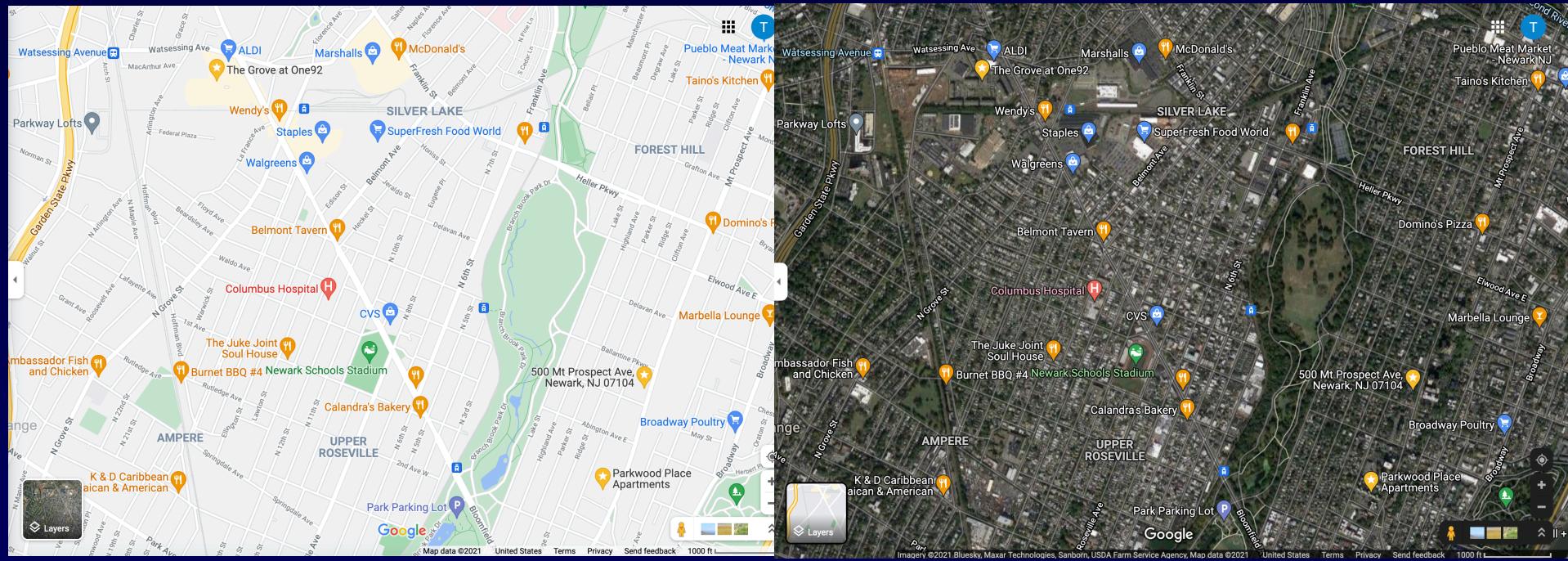
...and a neuron's receptive field—describing the response of that neuron as a function of position—is perhaps the functional description of that neuron. If we seek a single functional and thematic metric for the wealth of visual-cell receptive fields neurobiologically¹ and interested especially if such a framework has the potential to help us to understand the function better way. Whereas no generic measures (DOG), difference of offset C derivatives of a Gaussian, higher derivative function, and so on—can be expected to completely cover all the neurons in a simple cell receptive field, we nonetheless

Non-Photorealistic Rendering



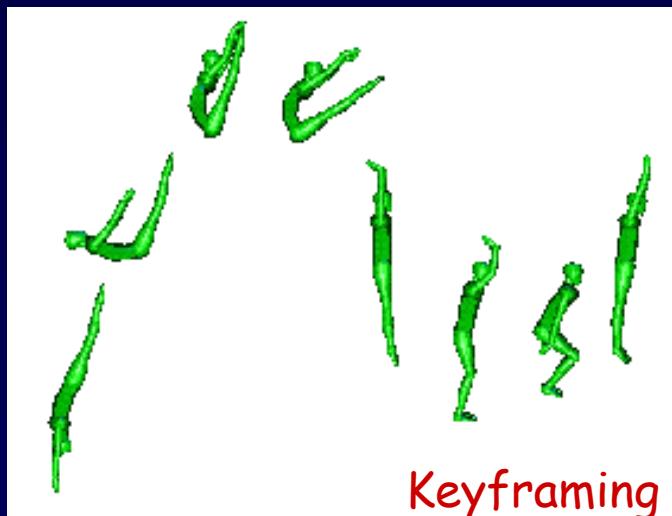
Aaron Hertzmann

Rendering: Information



Animation

Keyframe animation

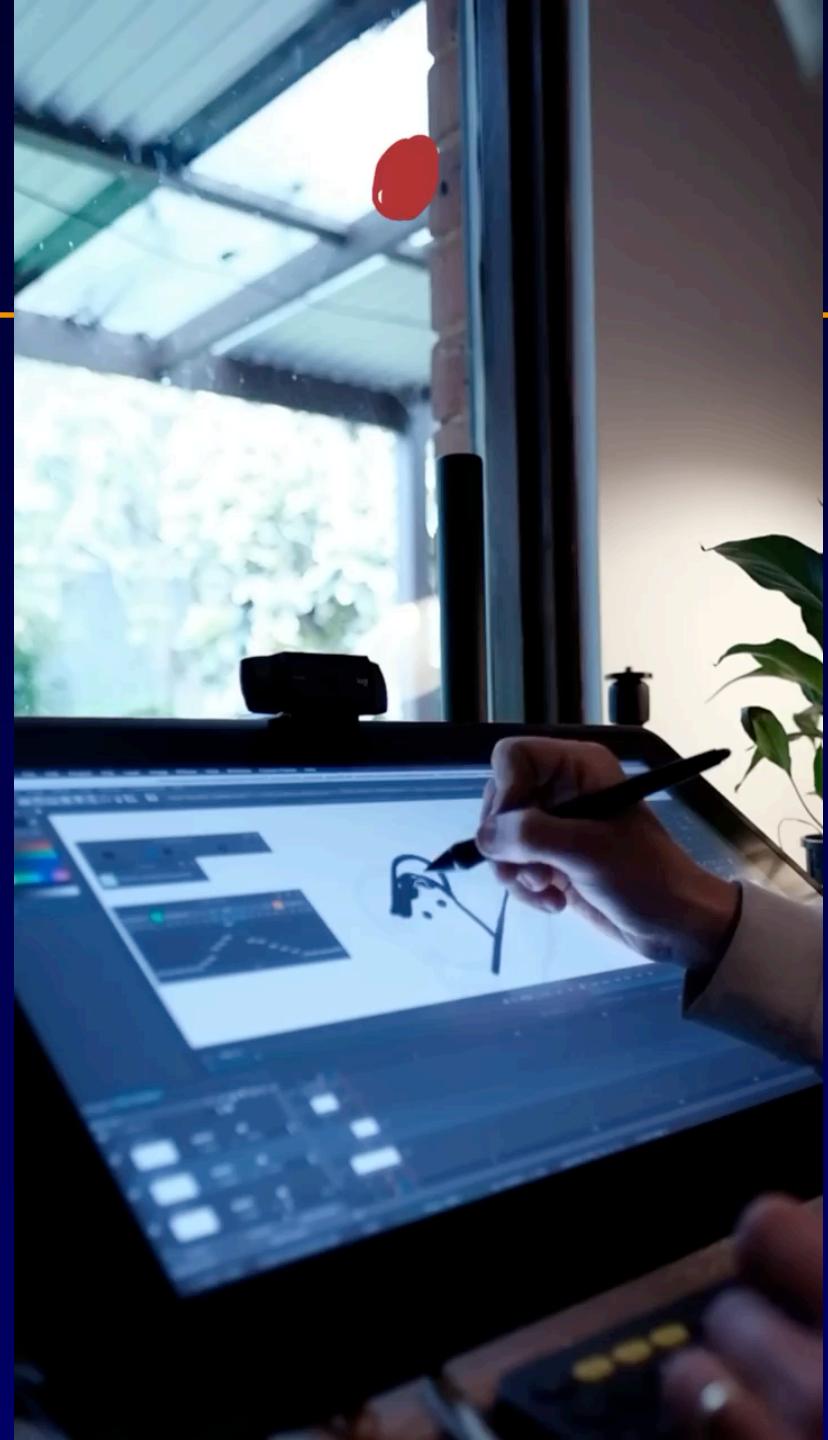


Animation

Keyframe animation



Keyframing



Animation: Keyframing

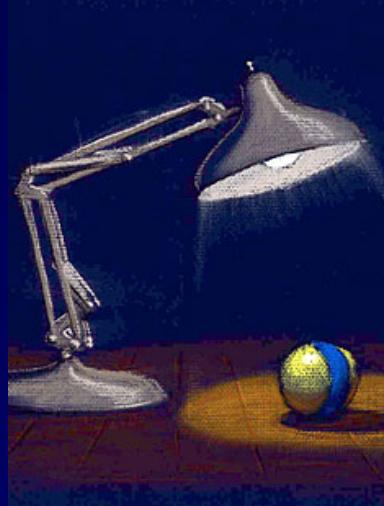
Pixar: “Luxo Jr.” (1986)



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



(c) MMIII New Line Productions, Inc. All Rights Reserved.



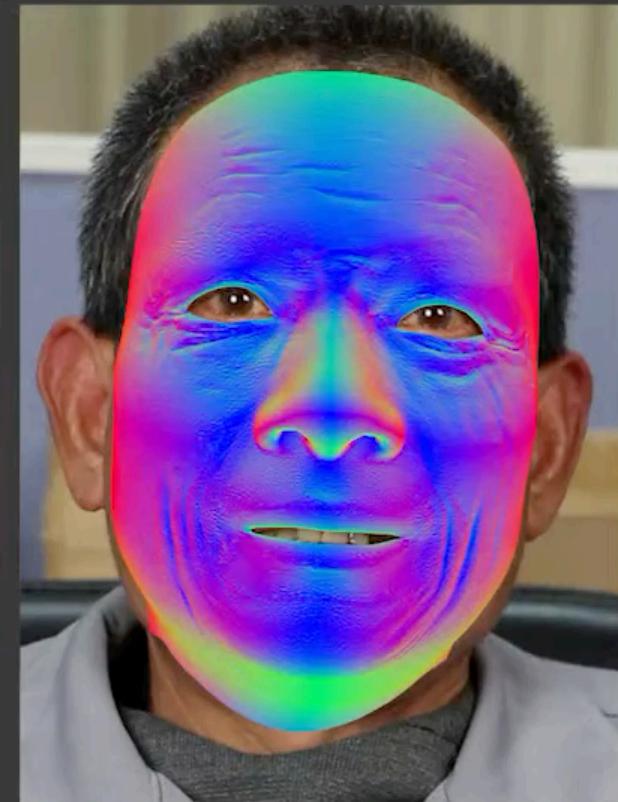
Motion Capture



Video



Shaded Mesh



Mesh Normal

Animating Golem in LOTR



Animation via Physics: Cloth Simulation



Cloth Simulation

Interactive Cloth Simulation

Everything you see was recorded in
realtime with live user interaction.



Explosion Simulation

Shockwave/House Interaction

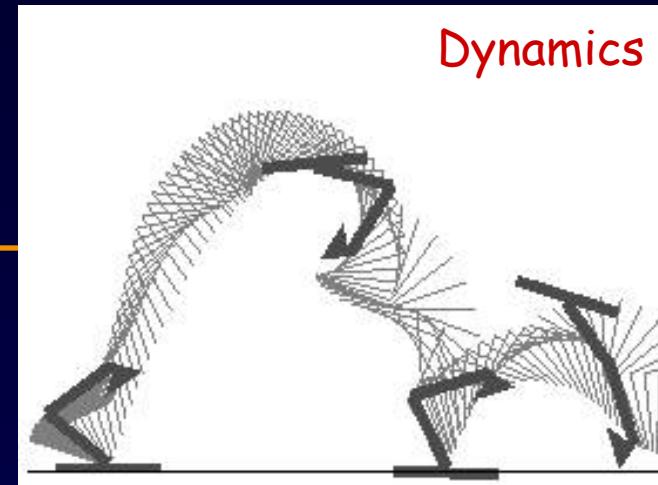
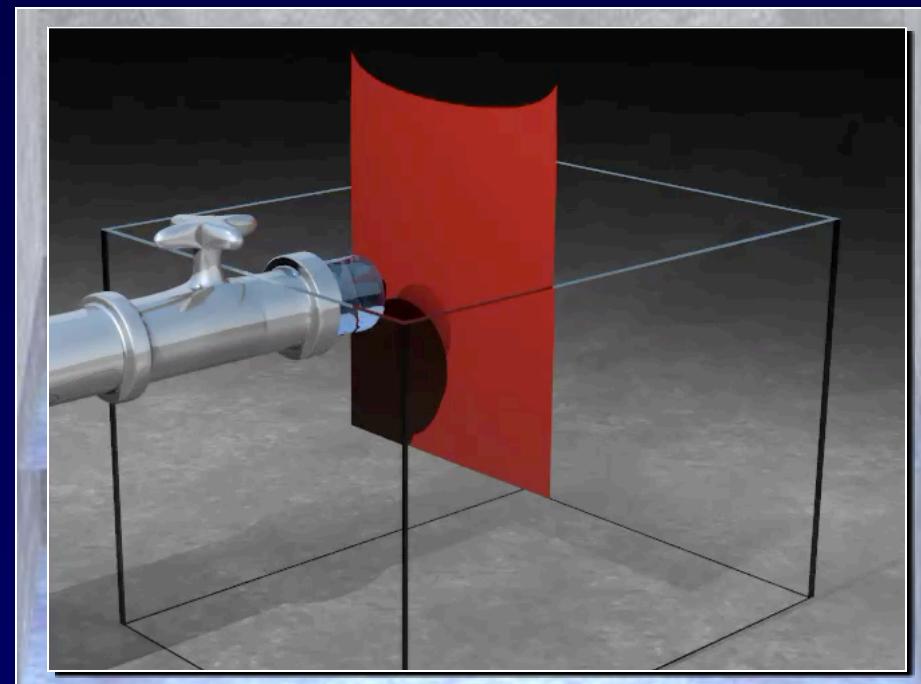
408 concrete blocks

Grid size: **100x100x100**

Simulation frames per second: 0.310

Animation

Physics-based animation



Fluid Simulation

Modeling

- Incompressibility
- Viscosity

Navier-Stokes Equations

Level Sets

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

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

\mathbf{u} : fluid velocity field

\mathbf{g} : gravity

p : pressure

ν : viscosity

ρ : density



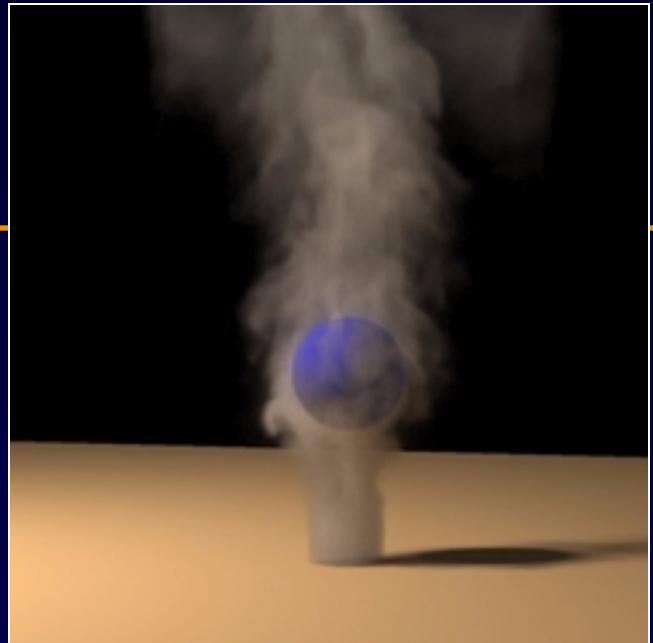
Smoke Simulation

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

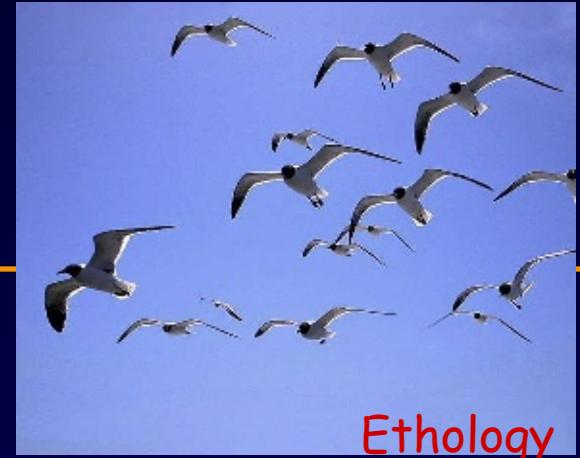
\mathbf{f} : external forces

p : pressure

ρ : density

Animation

Behavioral animation



Ethology

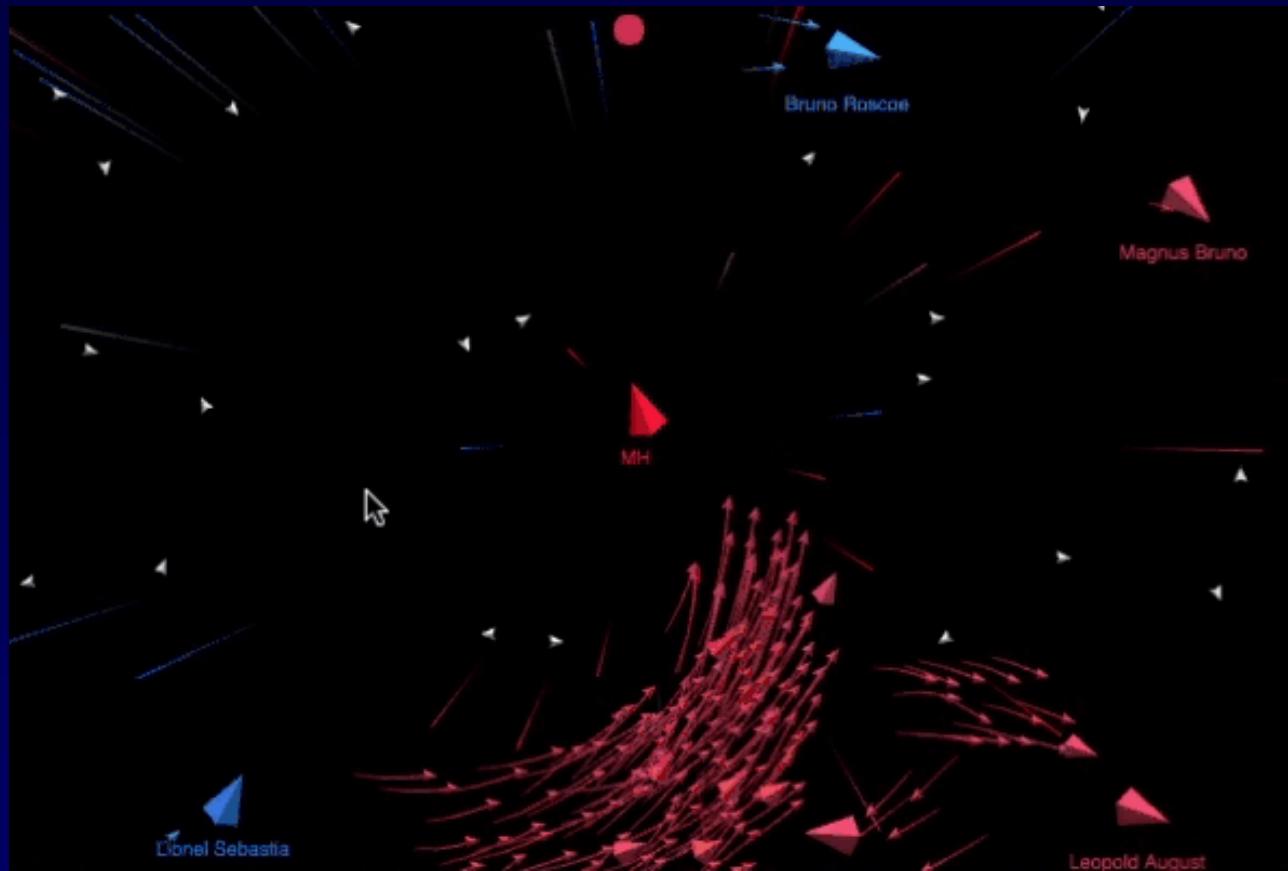


Animation

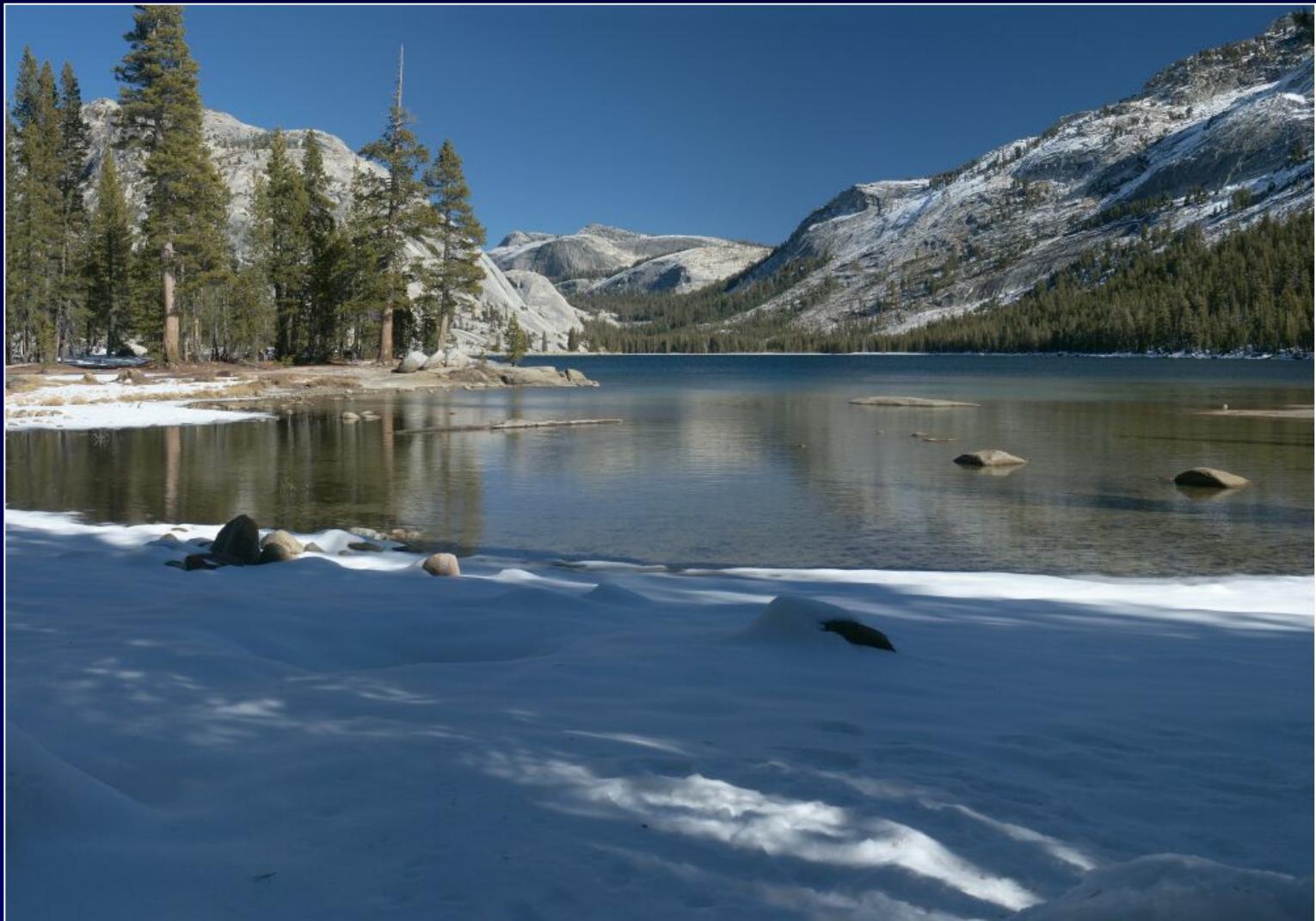
Behavioral animation



Ethology



Reality is *Very* Complex



Reality is *Very* Complex



Reality is *Very* Complex



Scheduled Break

- *Till in 7:15pm*

Great! But what are we going to do?

Learn the mathematical foundations of graphics

Apply them in programming projects



Summary of the Syllabus

- + *Mathematics of computer graphics*
- + *Rendering*
- + *Modeling*
- + *Animation*
- *Interaction*
- *Hardware*

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 Course Offerings

- Lots of math!
- A lot of material
- Fast pace
- A lot of programming
- Tough
- Challenging
- Great animation shows at the start of each lecture!

- Please post copies of the lecture slides prior to each lecture?
 - *NO, I won't do that, because...*



Advice

- Attend lectures and discussion sessions
 - *You will perform better on this course if you do (trust me)*
 - *The lecture slides will be a good start*
- Start the assignments EARLY
 - *Get HELP from us with the assignments EARLY!*
- Do NOT do more on the assignments than you are required, unless you are done with the required part of the assignment
 - *You will NOT get more points for additional work*
- Refresh your knowledge of linear algebra and geometry, and keep up with the math

Important Issues to Remember

- Lectures normally begin ~5 min late
- We will take a breaks sometimes
- Manage your course load
- No plagiarism (of course)