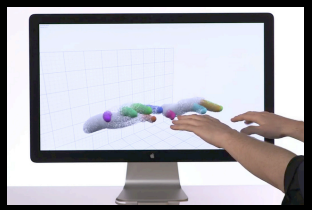
Michael Ball

The Beauty and Joy of Computing

Lecture #4
How It Works : 3D Graphics



LEAP MOTION … WOW!

The Leap Motion ($80) is a new generation of input devices that stands to change the way people interact with 3D data, and provide input to the computer (significant advantages over mouse & tablet)

LEAP MOTION … UGH!

Have they considered the damage they're doing to backs & shoulders by asking users to hold their hands outstretched for hours at a time? No consistent interfaces, it's the wild west of UI.

www.technologyreview.com/news/518721/leap-motions-struggles-reveal-problems-with-3-d-interfaces/

www.leapmotion.com

http://en.wikipedia.org/wiki/3D_computer_graphics

3D Computer Graphics, 10 Miles Up

- Computer Graphics one of the sub-fields of research in Computer Science
- UC Berkeley's Graphics group is ranked in the top 10
- 2D Graphics often called "graphic design"; very different
- Related Fields: Computer Vision

"The Last Guardian" by Johnny Yip (POV-Ray)

3D Graphics Used In…

Film, Television, Print

- Either pure CG (e.g., Pixar) or CG elements added to film plates
- hours / frame

Video Games

- Both "in-engine" graphics + pre-rendered cinematics
- 30 frames / second

"Avatar" (wikipedia)

"Gran Turismo" (us.gran-turismo.com)

events.game-artist.net/scene_from_a_movie/

...although that line is often blurred

events.game-artist.net/scene_from_a_movie/winners.php

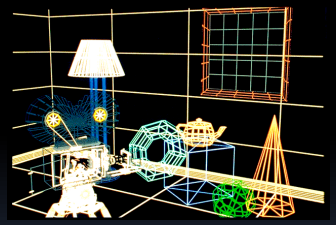
Aside: Scenes from a Movie winner

"Blade Runner" by The Replicants

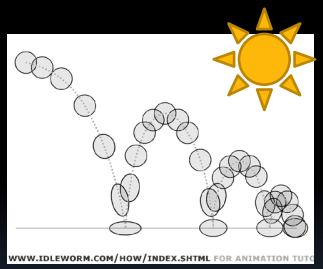
web.engr.oregonstate.edu/~mjb/intro2009/

3D Graphics : How it's done (simplified)

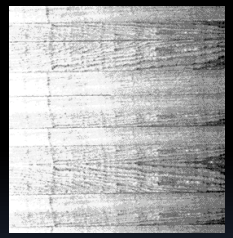
Modeling → Animation → Lighting & Shading → Rendering



"Shutterbug Rendering Progression" by Pixar



"Squash & Stretch" by idleworm.com



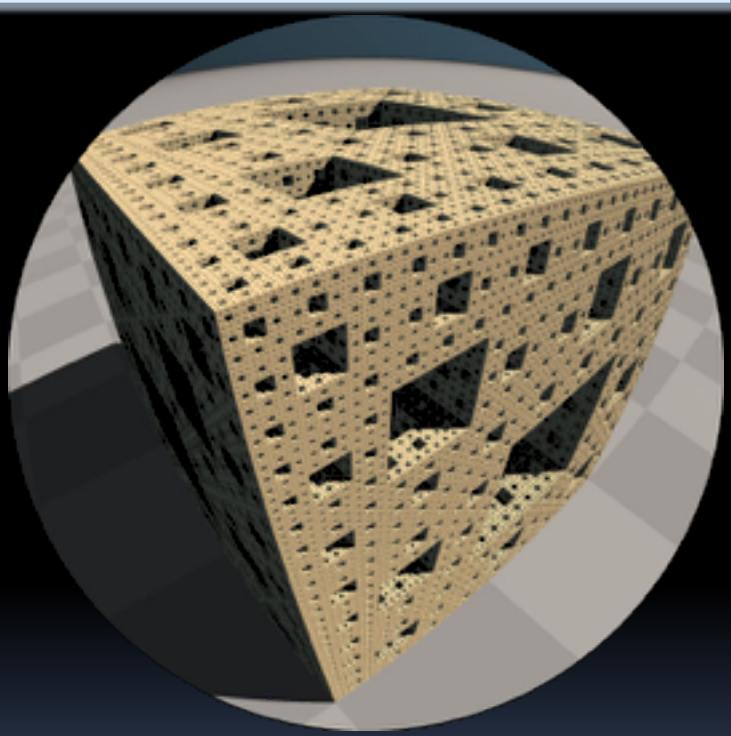
"Procedural Wood" by Pixar

"Shutterbug Rendering Progression" by Pixar

Modeling

www.youtube.com/watch?v=FOOynE1F4P4
www.cyberware.com

- **Could come from**
  - 3D Scanners
  - Interactive modeling
  - Model libraries
  - Procedural techniques
- **This also involves**
  - Attaching animation variables to model, allowing animator to control a very complex model w/a few controls
  - Representation: Lots of options, math



"Menger Cube" by UCB Alum David Wallace (now at LucasFilm)

Animation

web.engr.oregonstate.edu/~mjb/intro2009/
en.wikipedia.org/wiki/Motion_capture
www.youtube.com/watch?v=1wK1Ixr-UmM

- **Could come from**
  - Interactive key-framing
  - Procedural motion
  - Motion capture
    - This has put some animators out of a job
    - Used in Avatar, LotR, …
  - Physics
  - Evolution, Rule systems
- **Emotions conveyed!**
  - Humans are very good at reading bad motion

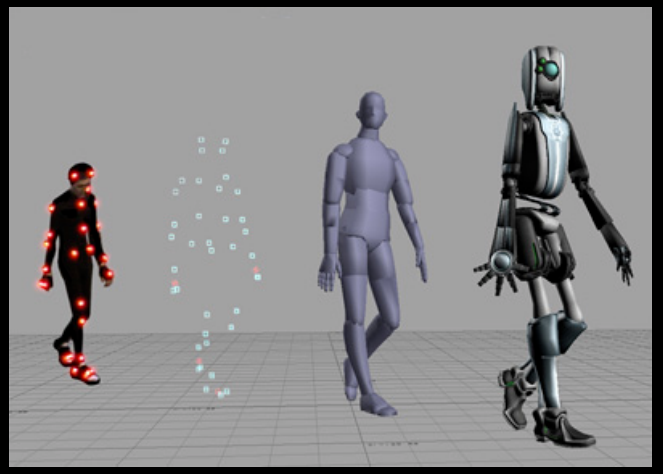
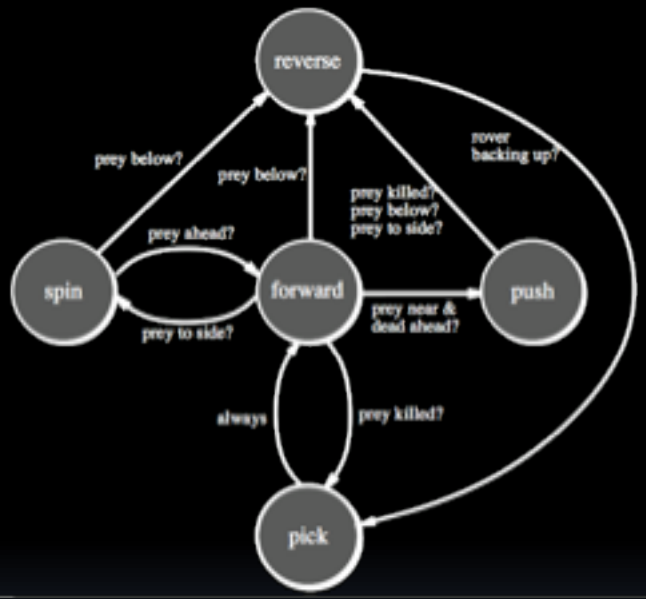


Image by Hipocrite (wikipedia)

www.kuffner.org/james/software/dynamics/mirtich/

Creature War … Animation automatic!

- **Brian Mirtich, 1996 UCB Ph.D.**
  - Thesis: "Impulse -based Dynamic Simulation of Rigid Body Systems"
  - Very cool work!
- **"Creature War" demo**
  - His purpose: show off his simulator
  - Great example of rule-drive motion!



Creature "rules"

Genetic Algorithms

web.genarts.com/karl/

- Karl Sims blew away his colleagues with his 1994 seminal work on evolved creatures

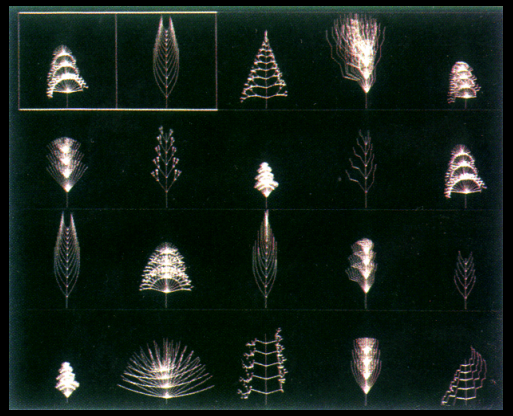


Photo by Hank Morgan

evolved virtual creatures

hof.povray.org/2b.html

Lighting and Shading (and Camera…)

- **Just like in a movie…**
  - Artist sets up lights in the shot for mood
  - Teams of artists apply hand-drawn and procedural textures, called "shaders"
    - There are layers of them
  - The virtual 3D camera (and its movement) set
- **But "render!" instead of "action!"…**

"Harvest Time" by Gilles Tran (POV-RAY)

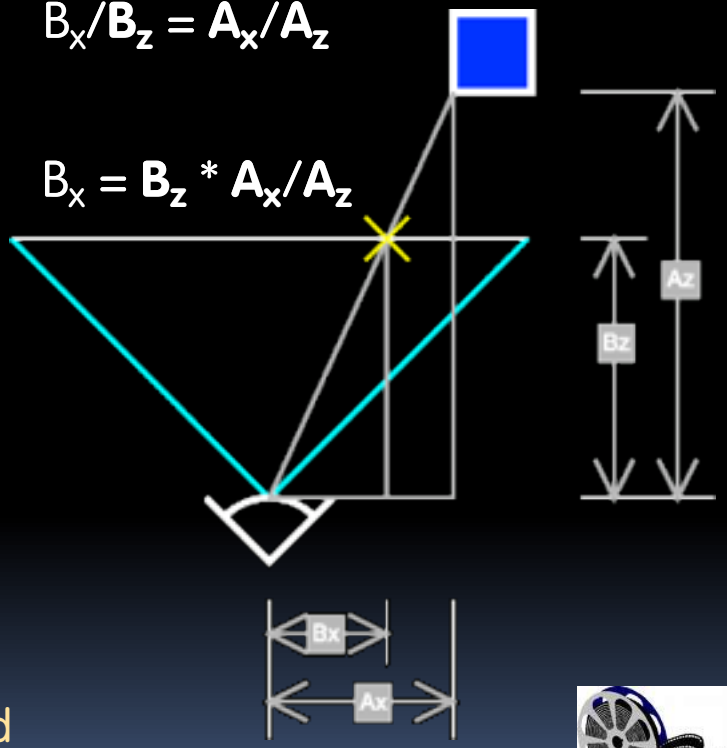
http://en.wikipedia.org/wiki/3D_projection

3D Projection Basics (in Rendering)

- **For each frame…**
  - Take 3D geometry (and lights and surface shaders) and figure out what color each 2D pixel should be
- **The math is simply similar triangles**
- **There are lots of algorithms to do this**
  - "Expensive" = slower, but quality usually higher
  - Classic example of "speed vs accuracy"

$B_x/B_z = A_x/A_z$

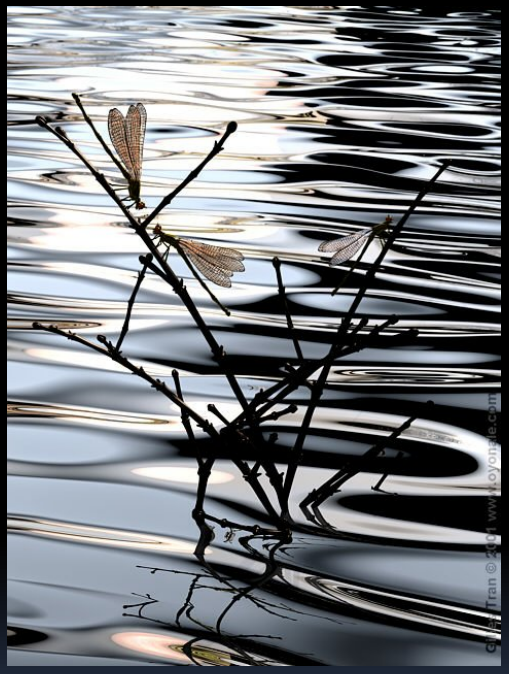
$B_x = B_z * A_x/A_z$



en.wikipedia.org/wiki/Global_illumination

Rendering : Global Illumination

- **What's our goal?**
  - Find rendering algorithms that simulate what real light does in real world
  - "Photo-realism"
- **Limitations**
  - There are way too many photons to simulate all of them at once!
  - Every technique is a different way to simulate the real world
  - Each has costs & benefits
- **Direct vs Global Illumination**



"The Lovers" by Gilles Tran. (POV-Ray)

Cornell Box

www.graphics.cornell.edu/online/box/compare.html

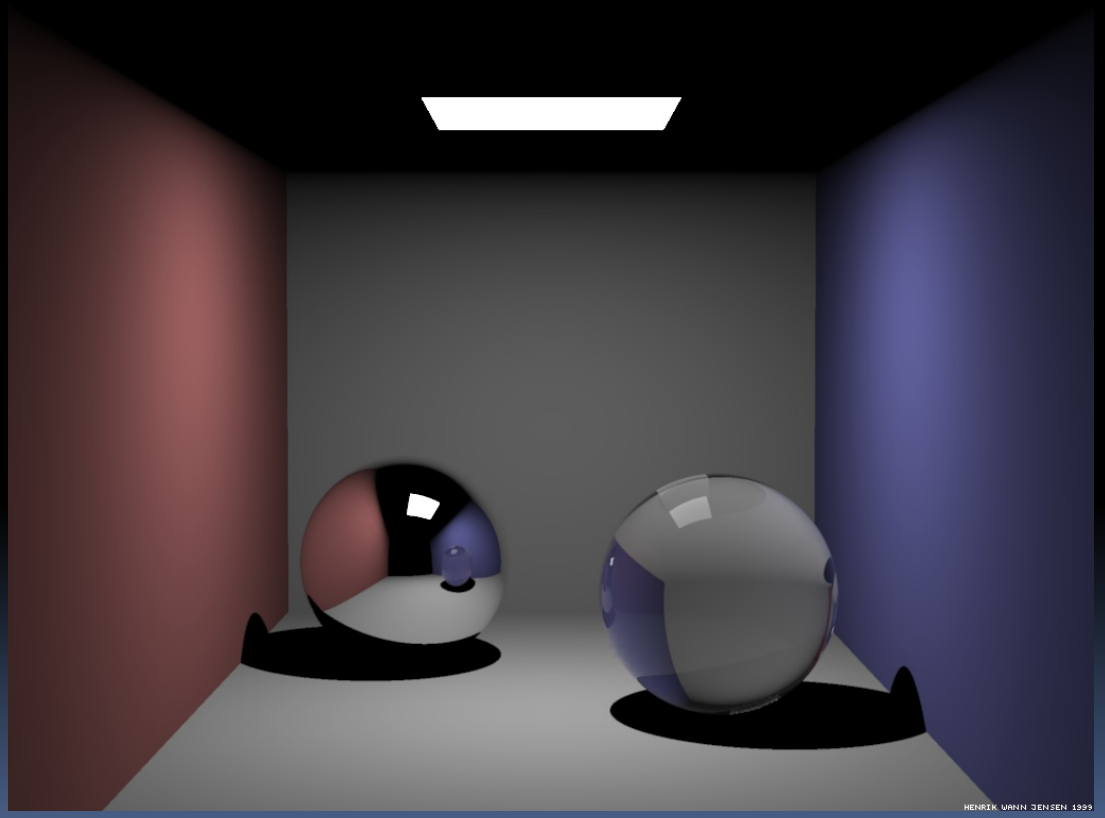
"The Cornell Box experiments have come to symbolize our approach to physically based rendering. The Cornell box is a simple physical environment for which we have measured the lighting, geometry, and material reflectance properties. Synthetic images of this environment are then created, and compared to images captured with a calibrated CCD camera. In this way, we can confirm the accuracy of our simulations."

Photograph

Rendering

Direct Illumination Image

Image courtesy Henrik Jensen @ UCSD



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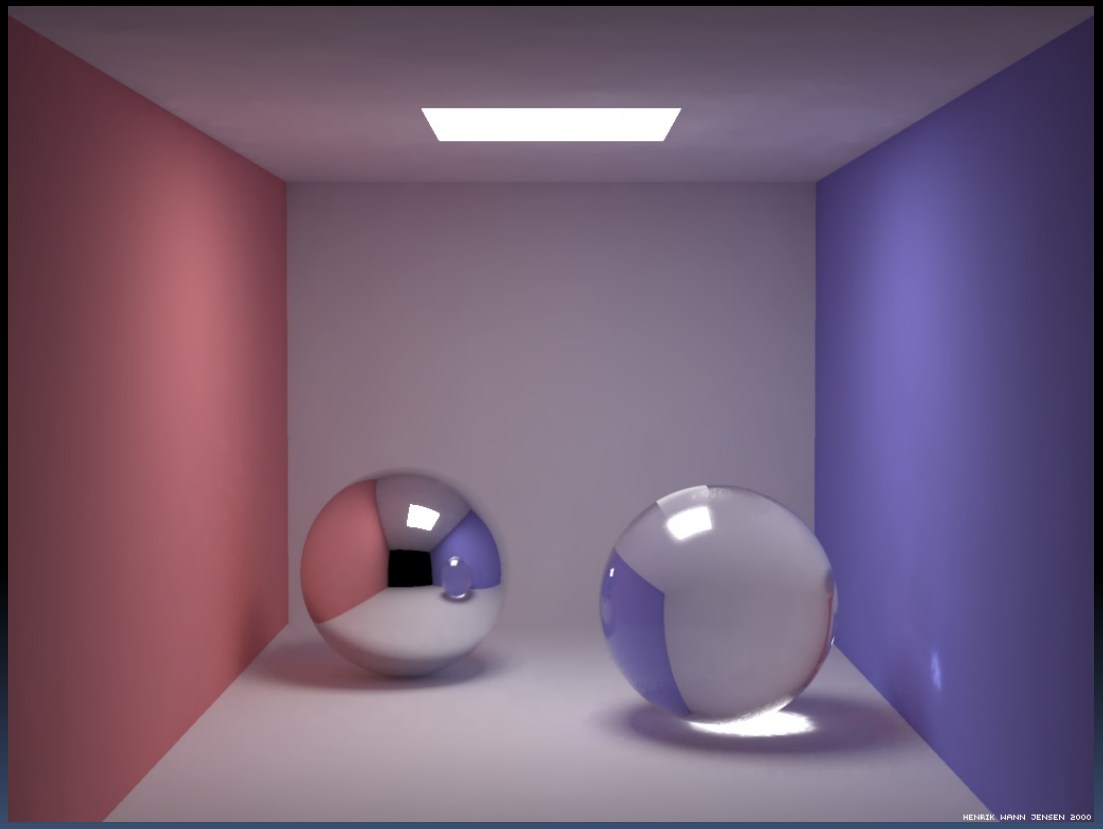
Global Illumination Image

Image courtesy Henrik Jensen @ UCSD



ucbugg.com

How to learn more? … UCBUGG!

- **UCB Undergrad Graphics Group**
  - No prereqs!!!
  - Student-led DeCal
  - Students make animated short film
    - Example : The Play3D
    - In 2002, made 3D recreation of famous Cal football play
- **CS184 : Intro to Computer Graphics**
- **CS194: Computational Photography**

kevinbeason.com/smallpt/

Summary

- **Beauty and Joy of Computing? You bet!**
- **The field of 3D Graphics has transformed film, television & video games**
- **How does it work?**
  - Modeling
  - Animation
  - Lighting & Shading & Camera
  - Rendering (film, games different)
- **Allows people to exercise both sides of brain**
  - Opportunities @ Cal!

Image by Kevin Beason