# CS10
# The Beauty and Joy of Computing

## Lecture #2
## HowItWorks : 3D Graphics

## 2012-06-19

UC Berkeley
Computer Science
Summer Instructor
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## NEW FASTEST SUPERCOMPUTER IN THE WORLD!

An IBM machine at Lawrence Livermore National Labs just took the title

| Date | System | Manufacturer | Country | Speed* | |
|------|--------|--------------|---------|--------|--|
| June 2012 | Sequoia | IBM | U.S. | | 16.32 |
| June 2011 | K Computer | Fujitsu | Japan | | 8.16 |
| Nov. 2010 | Tianhe-1A | NUDT** | China | | 2.57 |
| Nov. 2009 | Jaguar | Cray | U.S. | | 1.75 |
| June 2008 | Roadrunner | IBM | U.S. | | 1.026 |

*Measured in petaflops, or quadrillion calculations per second
**National University of Defense Technology
Source: Top500.org semiannual rankings

The Wall Street Journal

http://on.wsj.com/LUA5Cp

# 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**



"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

- <1/30 second / frame



"Avatar" (wikipedia)



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

# Aside: Scene from a Movie winner



"Blade Runner" by The Replicants

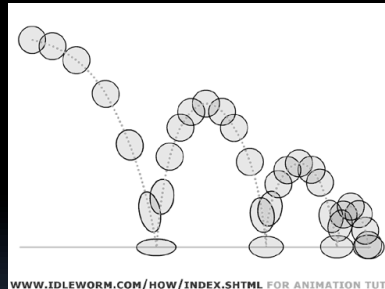# 3D Graphics : How it's done (simplified)

Modeling → Animation → Lighting & Shading → Rendering
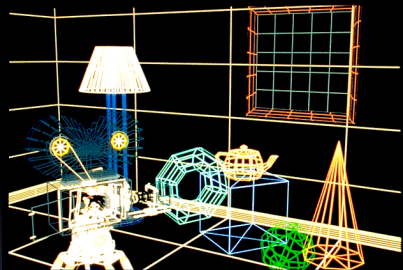


"Shutterbug Rendering Progression" by Pixar

"Squash & Stretch" by idleworm.com

"Procedural Wood" by Pixar

"Shutterbug Rendering Progression" by Pixar

# Modeling
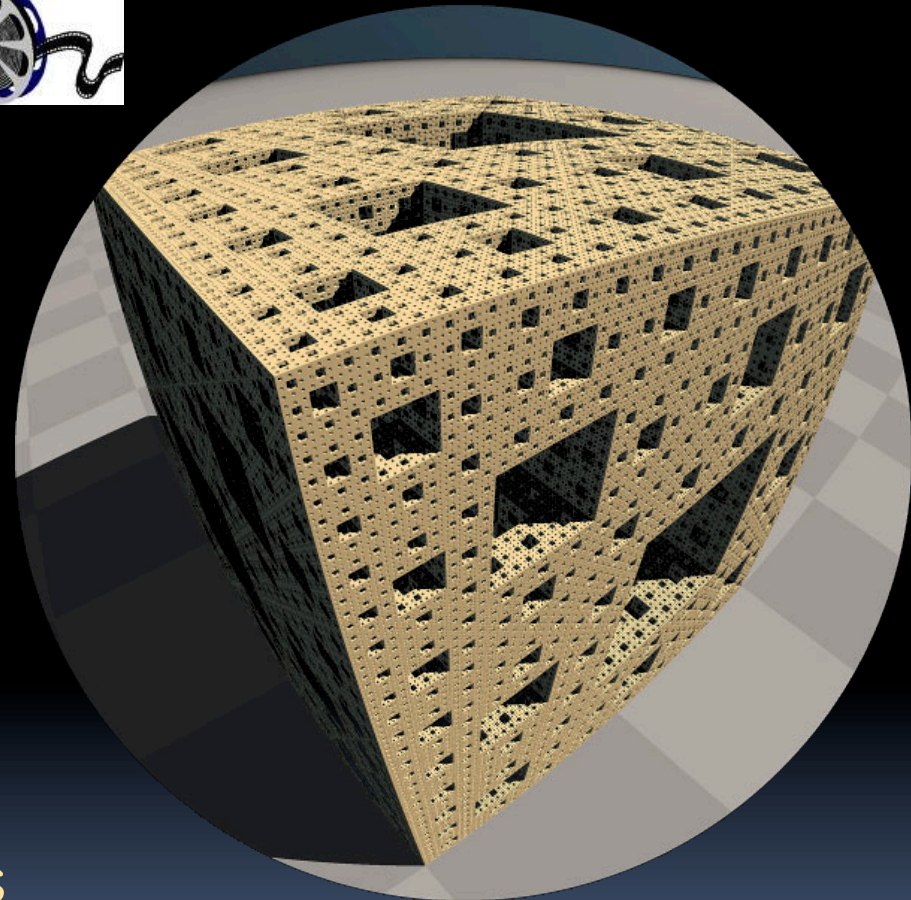
- **Could come from**

  - 
  - 
  - 
  - 

- **This also involves**

  - 
    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 keyframing
  - Procedural motion
  - Motion capture
    -
      animators out of a job
    - Used in Avatar, LotR, …
  - Physics
  - Evolution, Rule systems
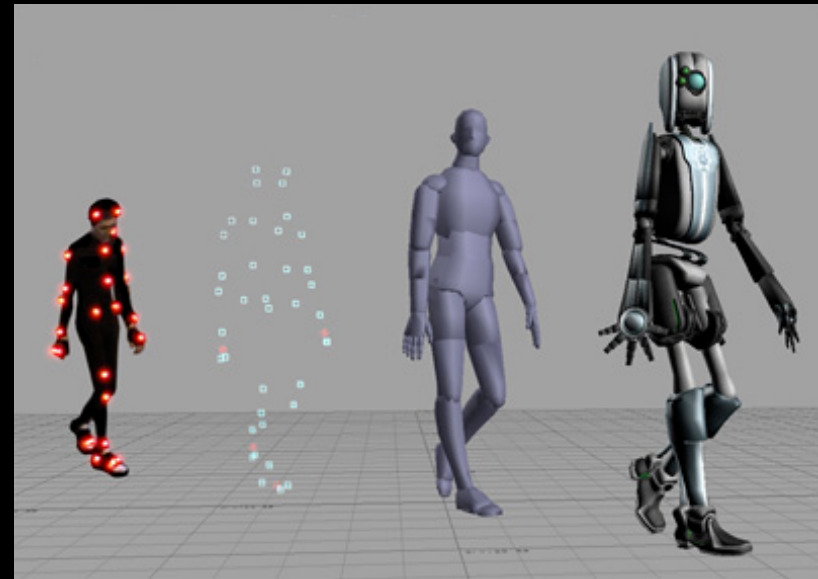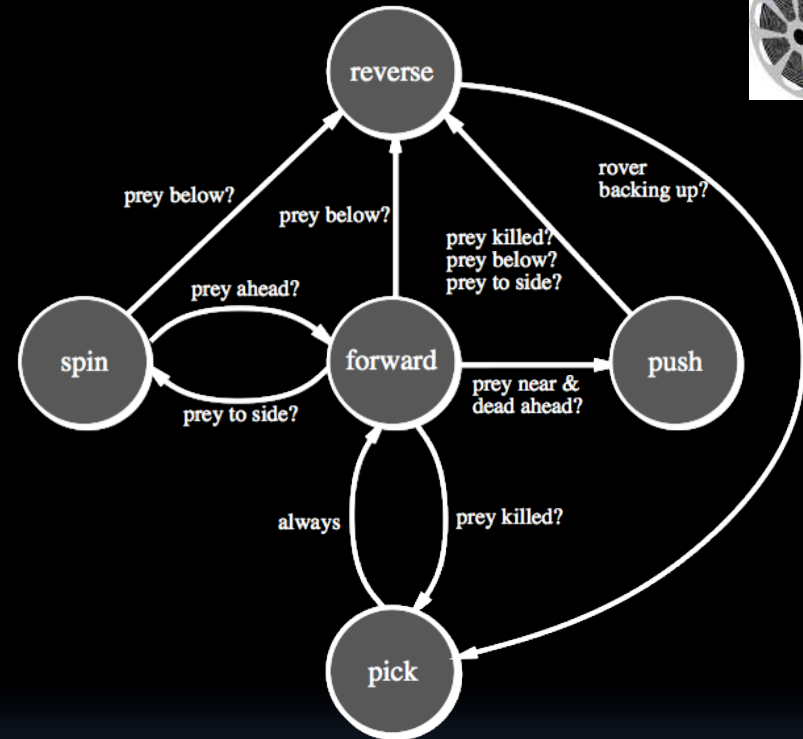- **Emotions conveyed!**
  - Humans are very good at reading bad motion

Image by Hipocrite (wikipedia)

# Creature War… Automatic Animation!

- ## 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
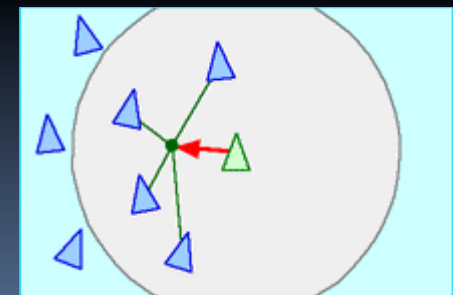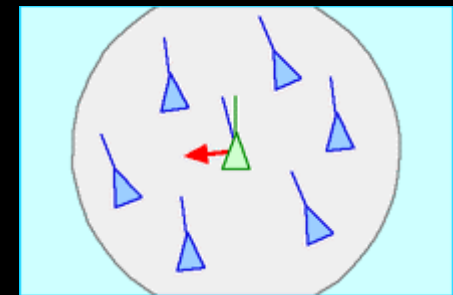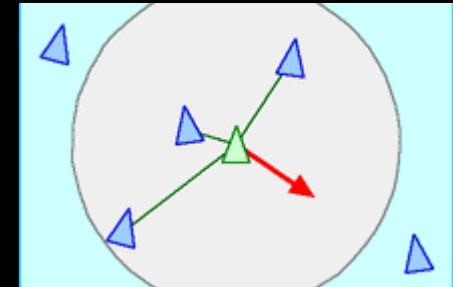  - Great example of rule-drive motion!

Creature "rules"

# Boids

- **Craig Reynolds, 1986**
- **Realistic motion of flocks**
- **No leader**
- **Three simple rules**
  - Separation
  - Alignment
  - Cohesion
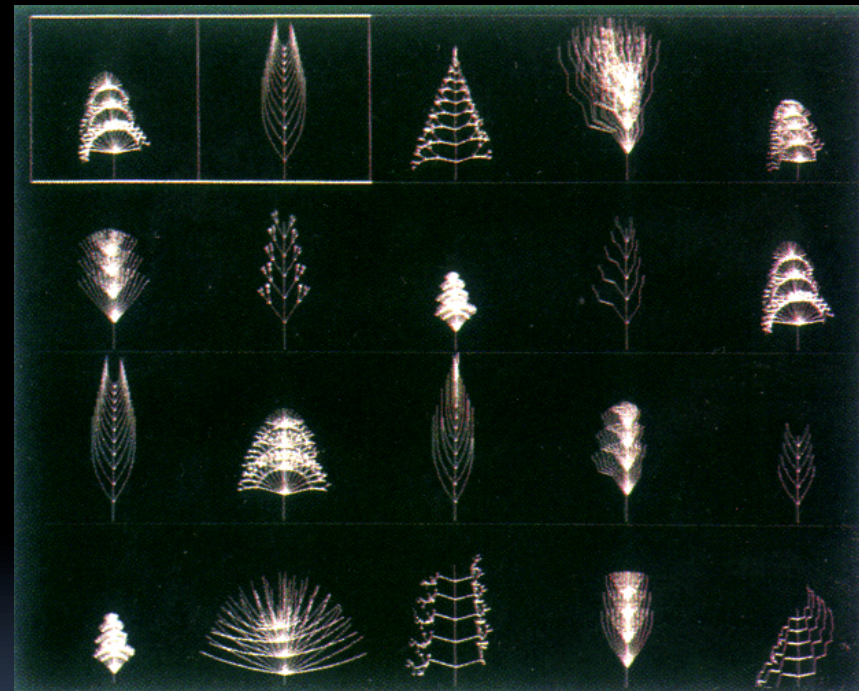- **Implemented for PingPongPlus as undergraduate research**

# Genetic Algorithms

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

Photo by Hank Morgan

evolved virtual creatures

# 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!"…**



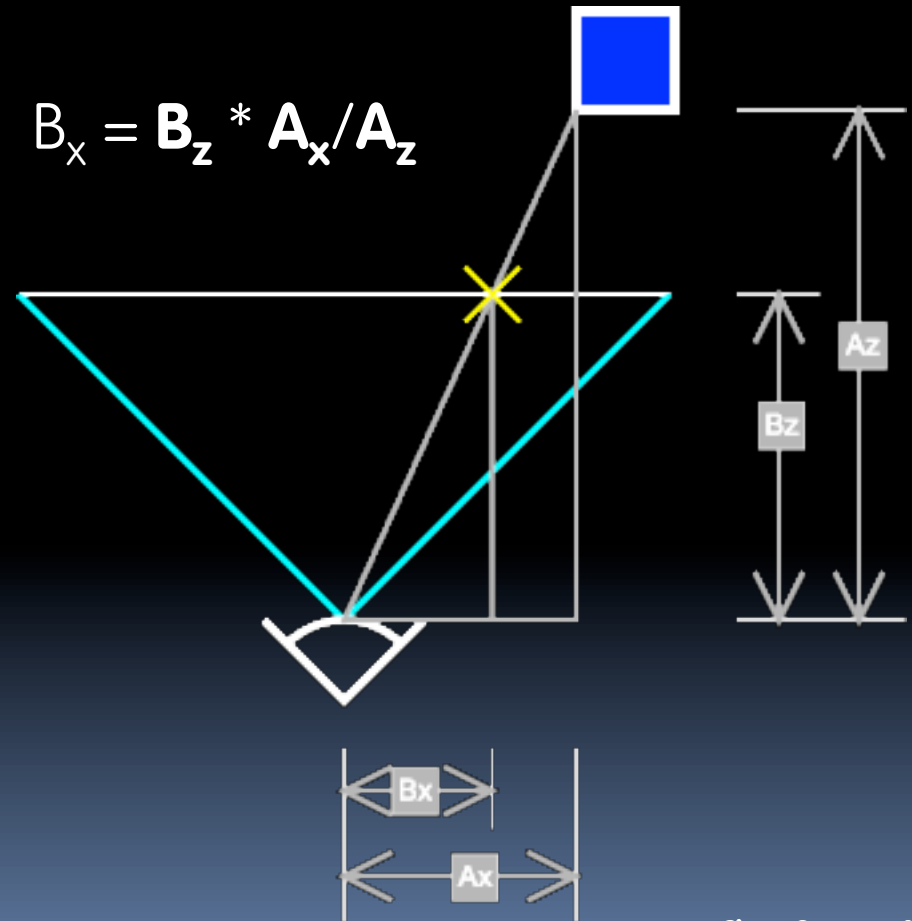"Harvest Time" by Gilles Tran (POV-RAY)

# 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

$$B_x/\mathbf{B_z} = A_x/\mathbf{A_z}$$

$$B_x = \mathbf{B_z} * A_x/A_z$$

Chun, Summer 2012

# Rendering : Global Illumination

- **What's our goal?**

  - simulate what real light does in real world
  - "Photo-realism"

- **Limitations**

  - There are <u>way</u> 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

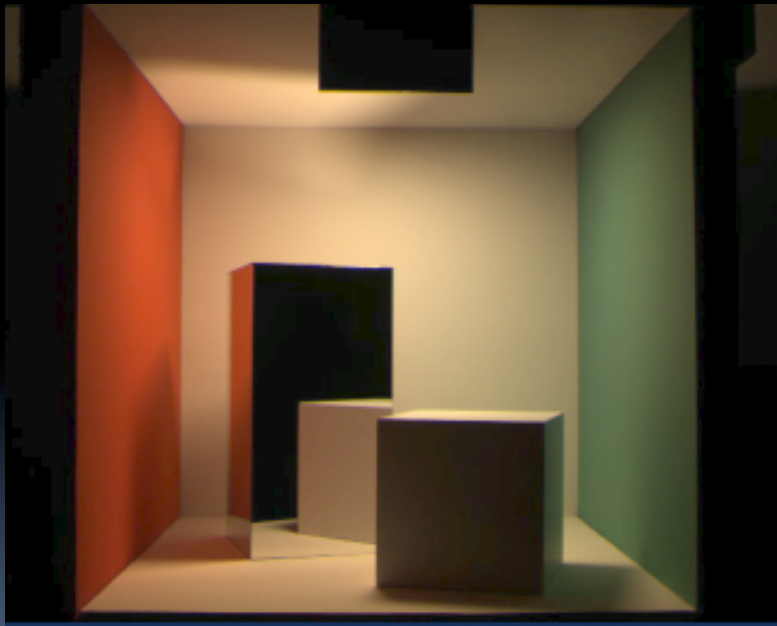- **Direct vs Global Illumination**
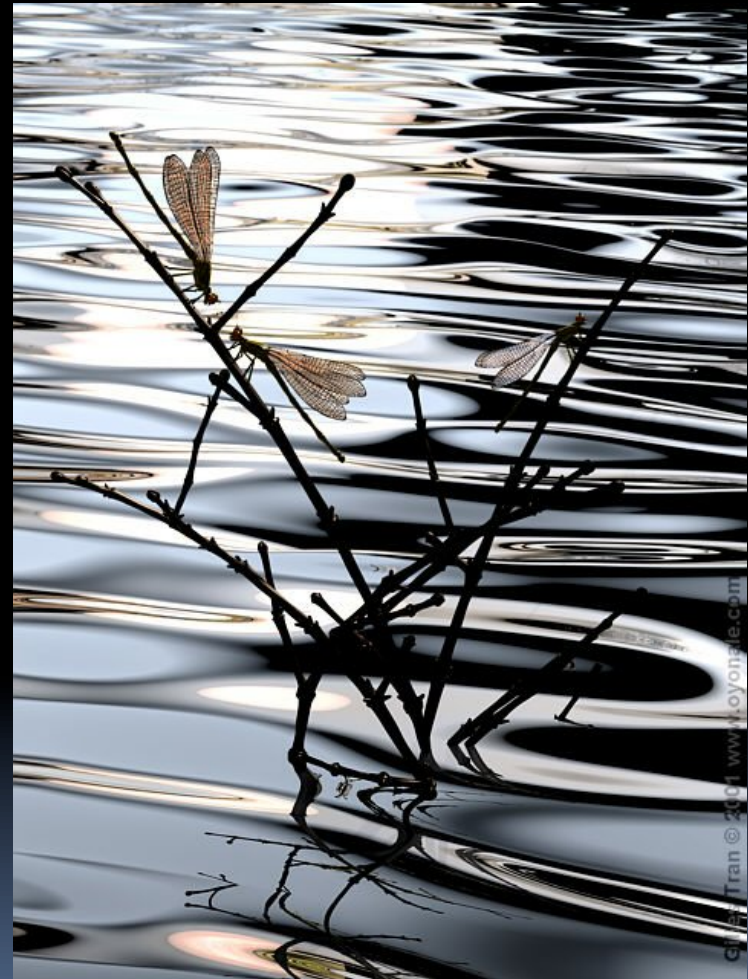
"The Lovers" by Gilles Tran. (POV-Ray)

# Cornell Box

*"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."*
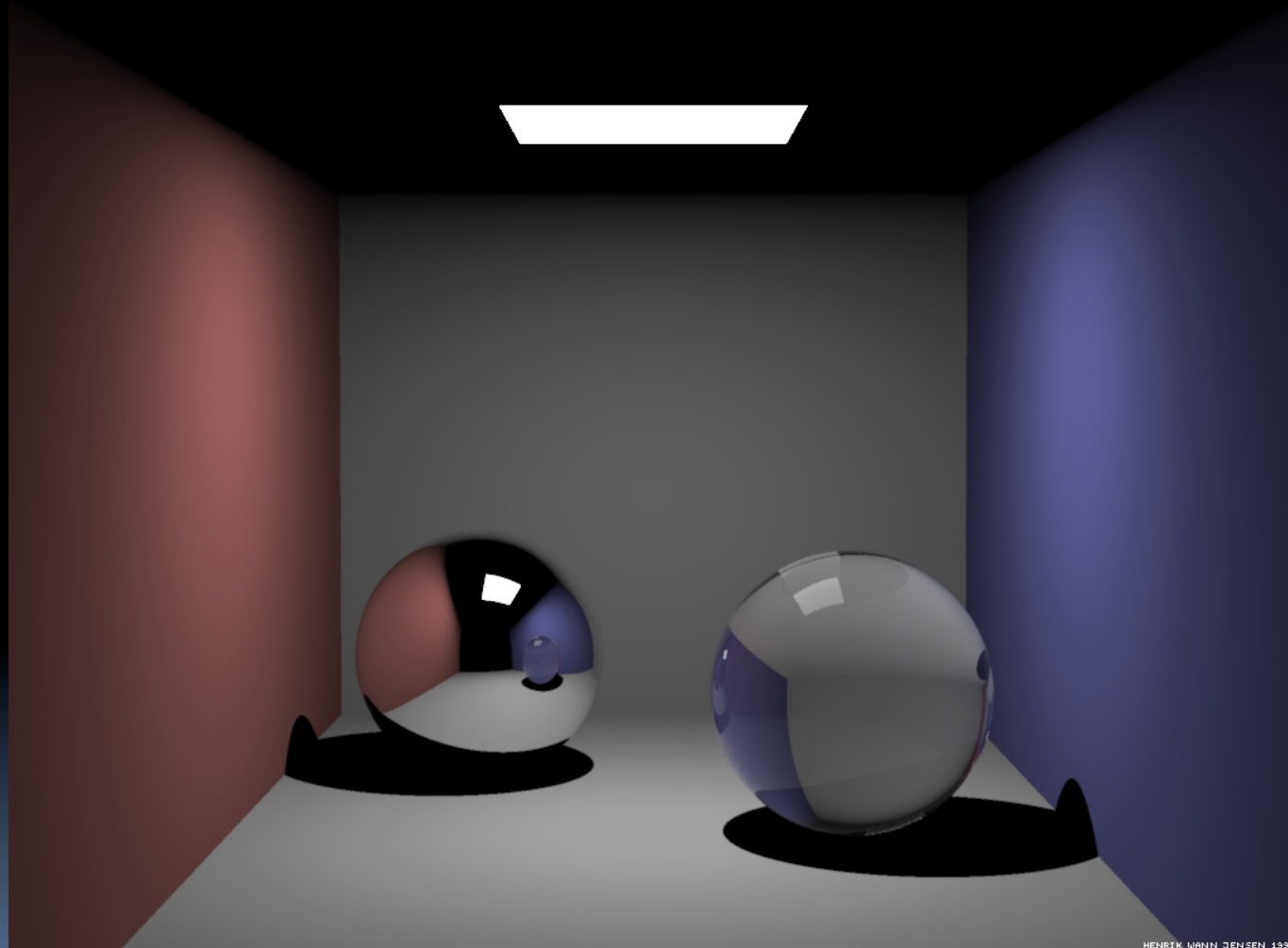
Photograph

Rendering

# Direct Illumination Image

HENRIK WANN JENSEN 1999

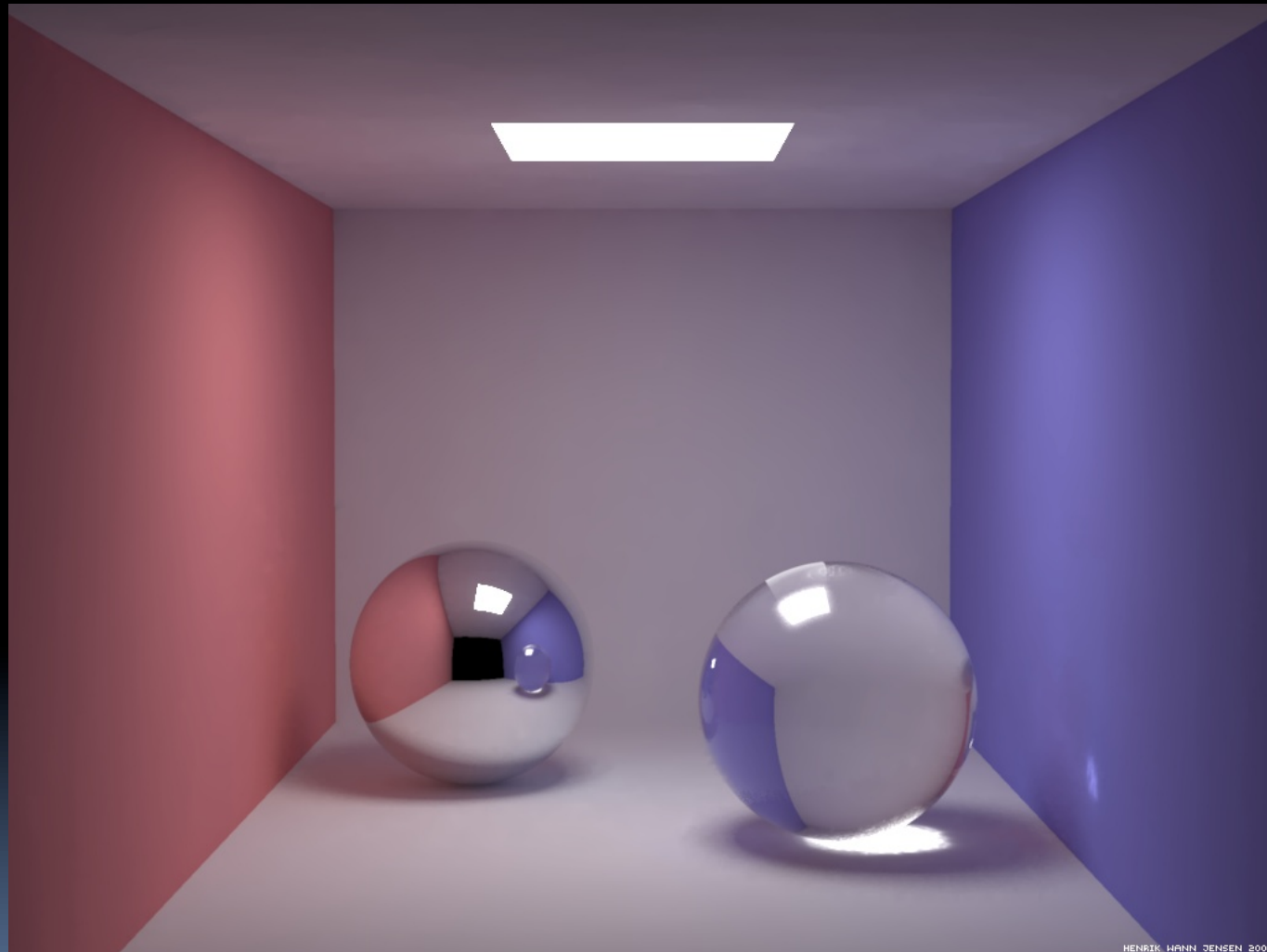# Global Illumination Image



HENRIK WANN JENSEN 2000

# 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 a 3D recreation of a famous Cal football play

- **CS184 : Intro to Computer Graphics**

# Summary

- **Beauty and Joy of Computing!**
- **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 their right and left brains**
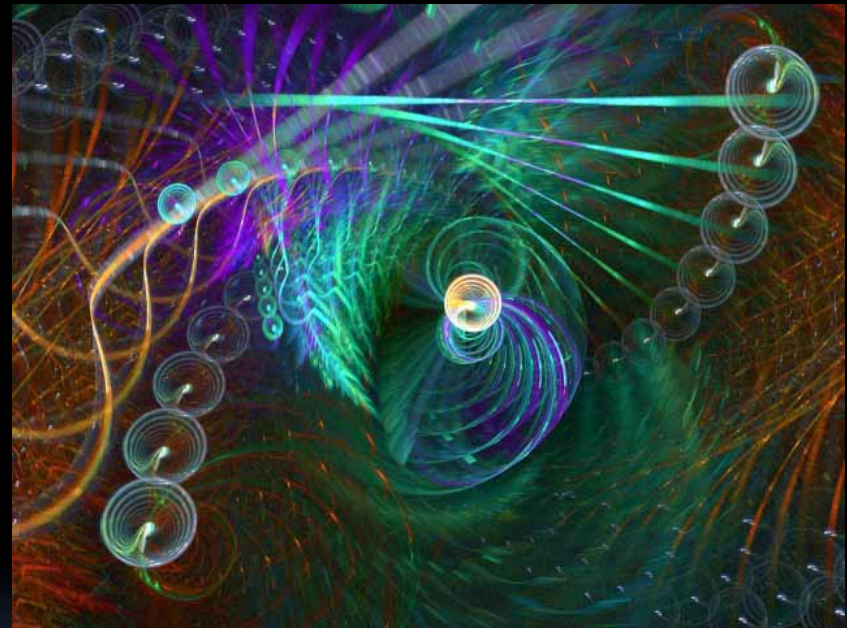  - Opportunities @ Cal!



**Image by Scott Draves**