



# The Beauty and Joy of Computing



## Lecture #4 HowItWorks : 3D Graphics

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### 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)

[www.technologyreview.com/news/518721/leap-motions-struggles-reveal-problems-with-3-d-interfaces/](http://www.technologyreview.com/news/518721/leap-motions-struggles-reveal-problems-with-3-d-interfaces/)

[www.leapmotion.com](http://www.leapmotion.com)

### 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



[http://en.wikipedia.org/wiki/3D\\_computer\\_graphics](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
  - I graduated from this group in 2000
- 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



"Avatar" (wikipedia)

### Video Games

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



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



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[events.game-artist.net/scene\\_from\\_a\\_movie/](http://events.game-artist.net/scene_from_a_movie/)

## ...although that line is often blurred



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events.game-artist.net/scene\_from\_a\_movie/winners.php

## Aside: Scenes from a Movie winner



"Blade Runner" by The Replicants



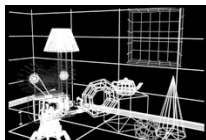
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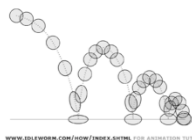


web.engr.oregonstate.edu/~mjb/intro2009/

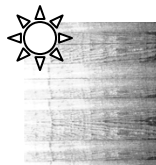
## 3D Graphics : How it's done (simplified)



"Shutterbug Rendering Progression" by Pixar



"Squash & Stretch" by idleworm.com



"Procedural Wood" by Pixar



"Shutterbug Rendering Progression" by Pixar



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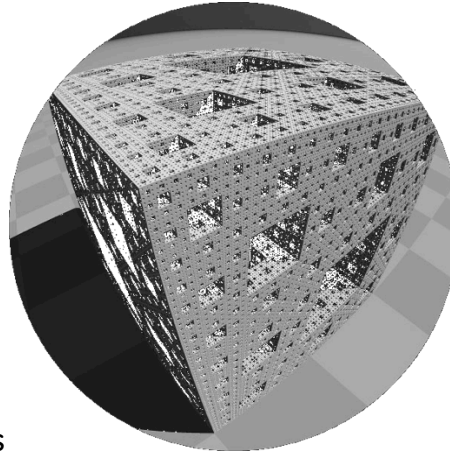


[www.youtube.com/watch?v=FOOynE1F4P4](http://www.youtube.com/watch?v=FOOynE1F4P4)  
[www.cyberware.com](http://www.cyberware.com)



## Modeling

- **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)



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[web.engr.oregonstate.edu/~mjb/intro2009/en.wikipedia.org/wiki/Motion\\_capture](http://web.engr.oregonstate.edu/~mjb/intro2009/en.wikipedia.org/wiki/Motion_capture)  
[www.youtube.com/watch?v=1wK1Ixr-UmM](http://www.youtube.com/watch?v=1wK1Ixr-UmM)

## Animation

- **Could come from**
  - Interactive keyframing
  - 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

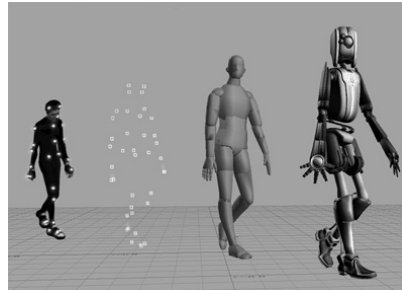


Image by Hipocrite (wikipedia)



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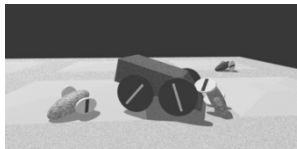
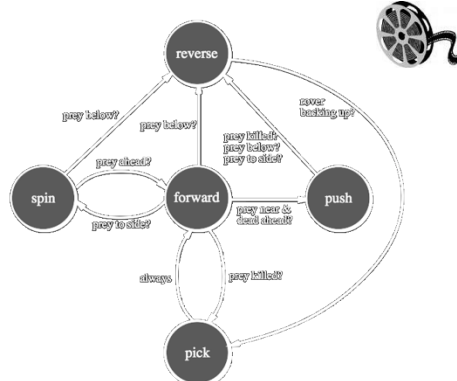
## Creature War ... Animation automatic!

- **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"

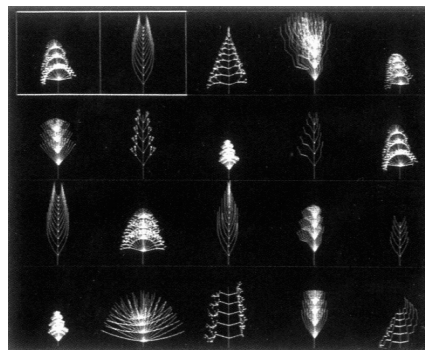


## Genetic Algorithms

- 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)

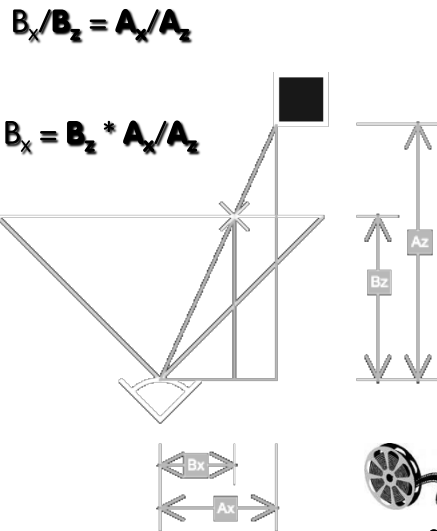


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# 3D Projection Basics (in Rendering)

- **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 usu higher



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## 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)

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## 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



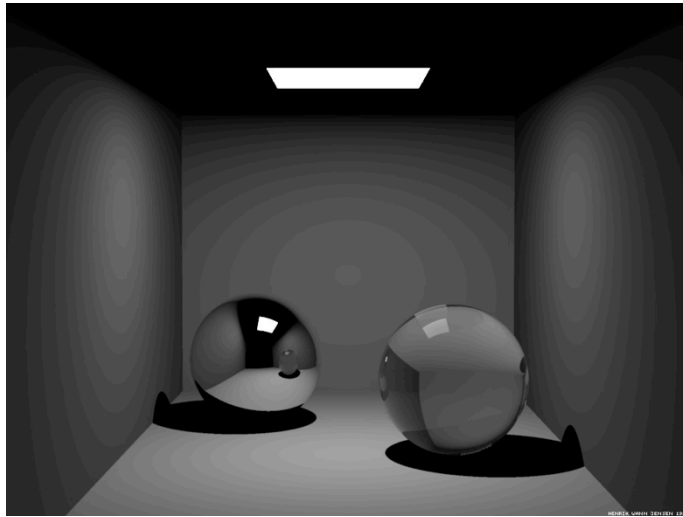
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Image courtesy Henrik Jensen @ UCSD

## Direct Illumination Image

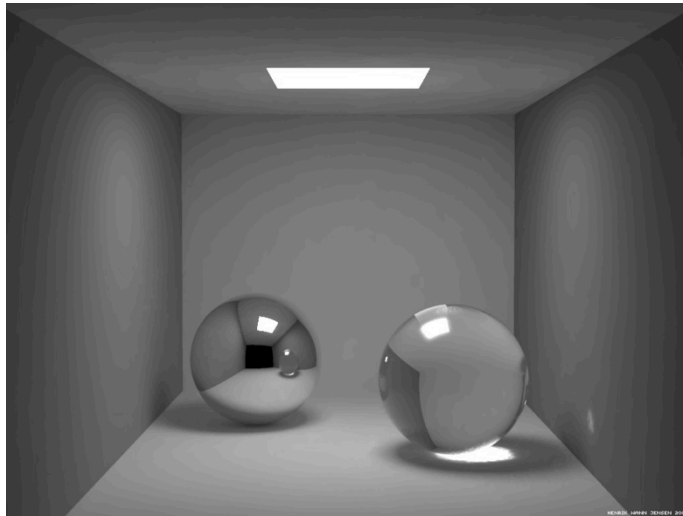


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Image courtesy Henrik Jensen @ UCSD

## Global Illumination Image



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# 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



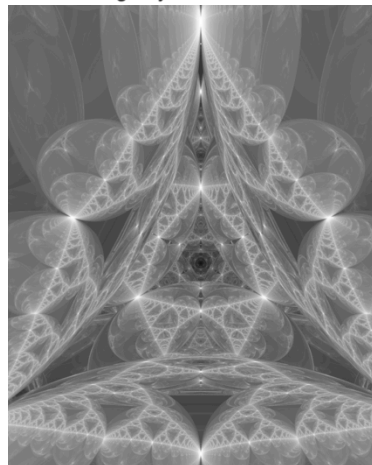
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# Summary

- **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)
- **It allows people to exercise right and left sides of brain**
  - Opportunities @ Cal!

Image by Kevin Beason



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