Now Playing:

Digital Love
Daft Punk
from *Discovery*
Released March 13, 2001

Graphics Grab Bag

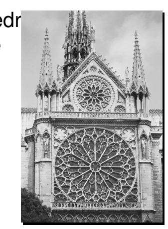
Rick Skarbez, Instructor
COMP 575
November 27, 2007

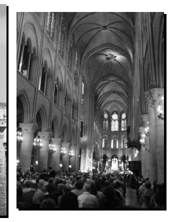
Announcements

- You need to arrange to talk to me before December 1 for your project update
- I am going to attempt to reserve a room/time on December 11 for project presentations
- The final deadline for project submissions will be the evening of December 12
- The final exam is Friday, December 14 at 4:00pm in this room (SN 011)

The Pursuit of Photorealism

- What if you wanted to render a real place?
  - Say, the Cathedral of Notre Dame in Paris





Example drawn from Debevec's SIGGRAPH 99 Course

The Pursuit of Photorealism

- You could:
  - Acquire accurate measurements of the building
  - Use these measurements to construct a geometric model
  - Apply the appropriate material properties to every surface
  - Use some advanced global illumination technique to simulate light bouncing around the cathedral

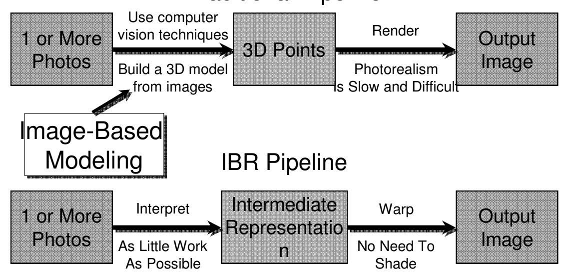
The Pursuit of Photorealism

- Alternatively, you could:
  - Take a picture of the cathedral from the desired viewpoint
    - This would be much easier
    - Also, it would <u>look better</u>
      - Pictures are by definition photorealistic

What is IBR?

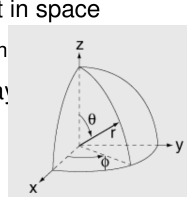
- It can mean any number of things
  - As a short definition, we can say that it is any technique that uses images (of some kind), either directly rendering with them or using them to create models

IBR vs. Traditional CG



The Math Behind Photographs

- Can think of a photograph as a "catalog" of the colors of the rays that pass through a single point in space
  - *i.e.* a pinhole, or a camera len
- We can parametrize any ray as [Φ, θ, x, y, z]
  - The ray through point (x,y,z) in direction (Φ, θ)



The Plenoptic Function

Adelson & Bergen,
"The Plenoptic Function and Elements of Early Vision"

- Describes the light received
  - At any position,
  - From any direction,
  - At any time

$$P(V_x, V_y, V_z, \theta, \phi, \lambda, t)$$

The Plenoptic Function

- Simplifications:
  - Ignore changes over time
  - Use 3-component color instead of wavelength
  - Left with a 5D function:
    - P(Φ, θ, x, y, z)
      - 3D position
      - 2D orientattion

Panoramas

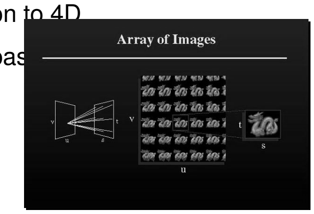
- A panorama stores a 2D plenoptic function
  - Always a single center of projection
  - Can be stitched (that is, put together from multiple smaller images) or taken by a single camera with complicated lensing

Panoramas as Virtual Environments

- Pros:
  - Easy to make
- Cons:
  - No sense of 3D
  - Fixed viewpoint
  - Hard to navigate

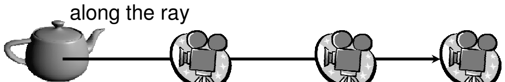
Function: Light Fields and Lumigraphs

- Can take advantage of empty space around the camera to reduce the plenoptic function to 4D
- Build up a databas of ray values
  - How and why?



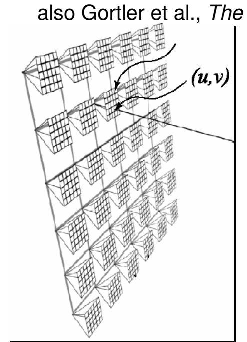
Why 4D from Empty Space?

- If we assume that the camera is in empty space (*i.e.* all objects in the scene are distant)
  - We no longer have to worry about occlusions
  - A ray has the same color at every point along the ray



Light Fields

Levoy & Hanrahan, *Light Field Rendering* (SIGGRAPH 96)
also Gortler et al., *The Lumigraph* (SIGGRAPH 96)



- "Box of photons"
- Captured either by a moving camera or an array of cameras
- 6x6 5x5 images shown
- 16x16 512x512 in the original paper
  - 256 MB / image

Lumigraph Mapping

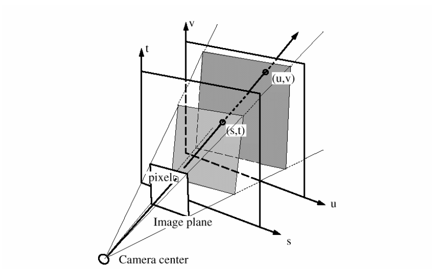
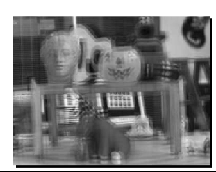


Figure 3: Relationship between Lumigraph and a pixel in an arbitrary image

Light Field Characteristics

- Pros:
  - Very attractive
  - Can be used to capture vide
- Cons:
  - Huge memory footprint
  - Difficult sampling issues
  - Only one plane in focus
  - Difficult to capture



No Geometry

- Note that neither of these techniques make any assumptions at all about geometry
  - Just show images
- Another technique in this vein is Concentric Mosaics, from Shum & He (SIGGRAPH 99)

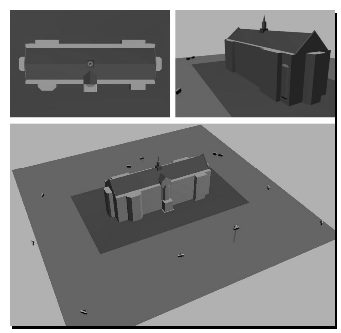
Facade

Debevec, SIGGRAPH 96

- Use a small number of images to generate a “blocks” model
  - Establish edge correspondences
  - Reconstruct by minimizing error
  - Do view-dependent texture mapping

Images with Edges Marked

Model



Novel View

IBR Review

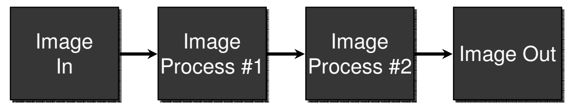
- Attempts to use real photographs to generate high-quality images without manual modeling
- Can include:
  - Automatically building geometry from images
  - Rendering a dynamic scene with no geometry
  - Something in between
- Any questions?

Today

- Grab bag
  - Filtering and image processing
  - Computer graphics in video games
  - Particle effects

Image Processing

- In short, "Image Processing" is just any process that operates on a single image, producing a modified new image
  - Think about a program like Photoshop
  - Sharpen, blur, sepia tone, red-eye removal, etc.



Filtering

- *Filtering* is any mathematical process that acts on some frequency components of a signal, and not others

Images with high frequency content

Filtering and Image Processing

- Many image processing tasks are filters applied to the image signal
  - Blurring preserves low frequencies and dampens high ones
  - Sharpening does the opposite
- NOTE: Because of Photoshop terminology, virtually any image processing function can be called a "filter", even when it is not a filter in the mathematical sense

Example: 1D Moving Average

Example: 3 Point Moving Average

$y[x]$: *Input Signal*
$z[x]$: *Output Signal*

$$z[x] = \frac{y[x-1] + y[x] + y[x+1]}{3}$$

$$z[x] = \alpha y[x-1] + \beta y[x] + \gamma y[x+1]$$

$$\alpha = \beta = \gamma = \frac{1}{3}$$

Example: 3 Point Moving Average

y[x] =	6	9	12	3	15	3	6

multiplied by

coefficients =	1/3	1/3	1/3

equals

subtotals =	3	4	1

and sums to

z[x] =	-	-	8	-	-	-	-

Example: 3 Point Moving Average

y[x] =	6	9	12	3	15	3	6

multiplied by

coefficients =	1/3	1/3	1/3

equals

subtotals =	4	1	5

and sums to

z[x] =	-	-	8	10	-	-	-

Example: 3 Point Moving Average

y[x] =	6	9	12	3	15	3	6

multiplied by

coefficients =	1/3	1/3	1/3

equals

subtotals =	1	5	1

and sums to

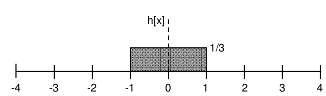
z[x] =	-	-	8	10	7	-	-

Example: 3 Point Moving Average

Kernel = (a.k.a. the Impulse Response Function)

1/3	1/3	1/3

h[x] =	...	0	0	1/3	1/3	1/3	0	0	...
		h[−3]	h[−2]	h[−1]	h[0]	h[1]	h[2]	h[3]	



"Box Filter"

Filtering and Convolution

- Many filters are implemented as the convolution of two functions
- *Convolution* is, basically, an integral that measures the overlap of two functions as one is shifted over another
  - http://mathworld.wolfram.com/Convolution.html
- In practice, it means that the new value of a pixel depends not only on that pixel, but also its neighbors

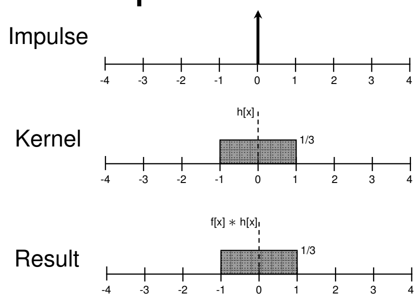
Convolution

- The convolution operation is typically denoted as '*'

$$(y * h)[x] = \sum_{n=-\infty}^{\infty} f[n]h[x-n]$$

- h is called either the *kernel* or the *impulse response function*

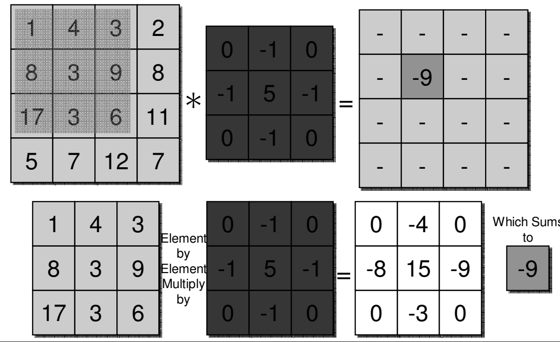
Why "Impulse Response Function"?



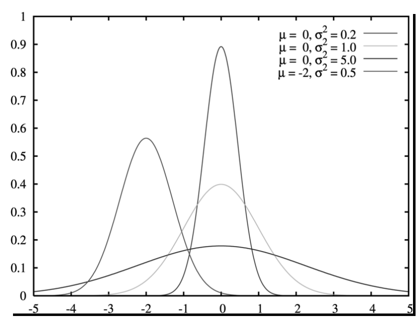
The kernel models how the system responds to an impulse input

... and any signal is really just a set of impulses of differing magnitudes at different times

Applying a 2D Filter



The Gaussian

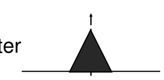


The Gaussian

$$Gaussian(x,\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\left(\frac{(x-\mu)^2}{2\sigma^2}\right)}$$

- x is the sample location, μ is the center of the Gaussian, and σ is its standard deviation (width)
- This is the "gold standard" of blur kernels
  - Box filter, "tent" filter, etc. are much simpler, but introduce artifacts

"Tent" filter



Gaussian Blur Example

7x7 Kernel
σ=1.0

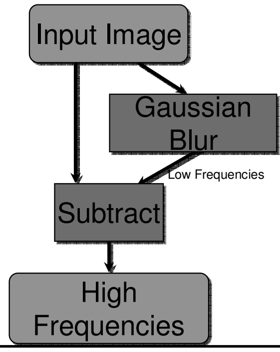
9x9 Kernel
σ=3.0

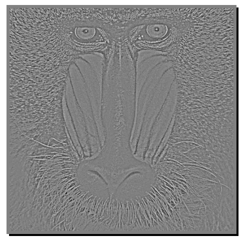
21x21 Kernel
σ=15.0

Low-Pass Filtering

- Blurring is an example of a *low-pass filter*
  - Low frequency features are preserved (passed on), while high frequency detail is reduced
- So if blurring gives us low frequency detail, how can we get high frequency detail?

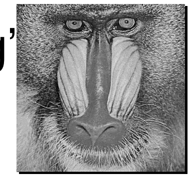
High-Pass Filtering

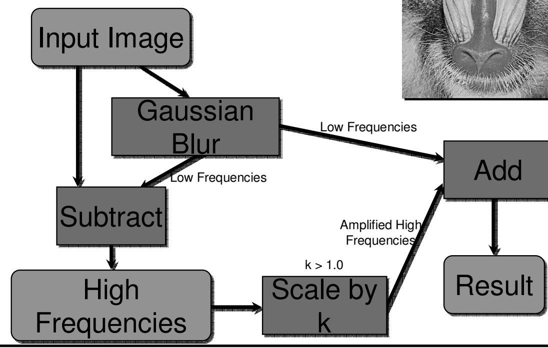




Offset by 128

"Unsharp Masking"





Filtering Review

- Filtering is an umbrella term for many different image processing techniques
- In many cases, applying a filter to an image involves applying a convolution with another function, commonly a Gaussian
- Some examples of image filters include sharpening and blur filters

Computer Graphics and Video Games

- At this point, you already have all the basic knowledge you need for video game programming
  - At least as far as basic graphics are concerned
- We used OpenGL, many games these days will use DirectX
  - If you can do one, you can do the other

What You Don't Know: Shaders

- Current, graphically advanced games will make extensive use of shaders
  - These will generally be incorporated with OpenGL or DirectX code
  - GLSL is the high-level, OpenGL-based shader
  - HLSL is the high-level, DirectX-based shader
  - Cg is a lower-level shader, usable with both APIs

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  - Cg is a lower-level shader, usable with both APIs

Shader Tutorials: Cg

- Kilgard, “Cg in 2 Pages”
  - http://xxx.lanl.gov/ftp/cs/papers/0302/0302013.pdf
- NeHe Cg Tutorial
  - http://nehe.gamedev.net/data/lessons/lesson.asp?lesson=47

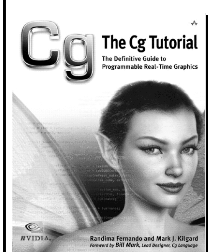
Shader Tutorials: GLSL

- GLSL Reference Sheet
  - http://www.mew.cx/glsl_quickref.pdf
- Lighthouse3D GLSL Tutorial
  - http://www.lighthouse3d.com/opengl/glsl/
- NeHe GLSL Tutorial
  - http://nehe.gamedev.net/data/articles/article.asp?article=21

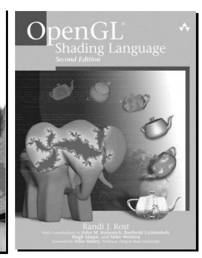
Shader Tutorials: HLSL

- Riemer’s HLSL Intro & Tutorial
  - http://www.riemers.net/eng/Tutorials/DirectX/Csharp/series3.php
- Pieter Germishuys HLSL Tutorial
  - http://www.pieterg.com/Tutorials/hlsl1.php

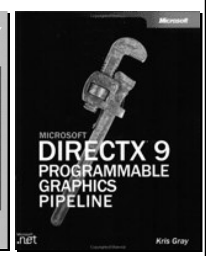
Shader Books



Cg



GLSL



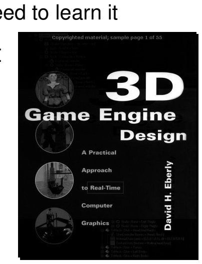
HLSL

What You Don’t Know: Graphics Middleware

- Many games are not developed directly in OpenGL/DirectX (at least not entirely)
- They often use middleware engines such as Emergent’s *Gamebryo* or Criterion’s *Renderware* (now owned by EA; no longer sold), or the open source *Ogre3D*
  - http://www.emergent.net/index.php/homepage/products-and-services/gamebryo
  - http://www.ogre3d.org/

Middleware

- Nothing I can really teach you about this
  - If you need use this in your work, then you have the preparation you need to learn it
- If you want to know how it gets made, then I recommend Eberly’s *3D Game Engine Design*



What You Don't Know: Physics

- Modern games generally seek accurate (or at least semi-accurate) physics behavior
- Almost nobody builds this from scratch
  - There are middleware solutions; Ageia's *PhysX* and *Havok* are the most common
    - PhysX: http://www.ageia.com/physx/
    - Havok: http://www.havok.com/

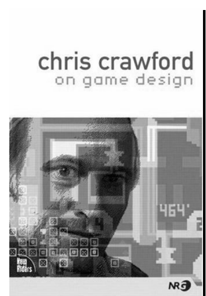
Physics Tutorial

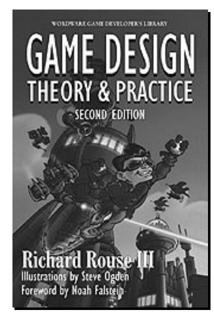
- If you want to learn more about physics simulation, a good place to start would be Chris Hecker's tutorial on rigid body dynamics
  - http://chrishecker.com/Rigid_Body_Dynamics

What You Don't Know: Game Design

- Even if you know everything about how to make a *pretty* game, that doesn't mean anything about how to make a *good* game
  - Of course, this goes far, far beyond the scope of this course
- I can tell you some books you could read if this is something you're interested in, though

Game Design Books





What You Don't Know: Modeling

- Well, I don't know it either
- Modeling is art
- That said, you will likely use tools like 3D Studio Max, Maya, or Blender for modeling

Game and Simulation Houses in the Triangle

- Epic
- Gamebryo
- Red Storm
- EA
- Many more:
  - Triangle IGDA: http://www.igda.org/nctriangle/

Game Development Discussion

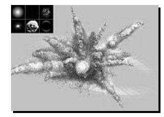
- Any questions?

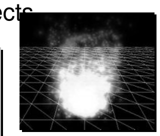
Particle Systems

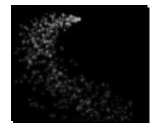
Bill Reeves, SIGGRAPH 83

Particle Systems – A Technique for Modeling a Class of Fuzzy Objects

- *Particle systems* are a set of techniques for modeling “fuzzy” effects
  - Fire
  - Clouds
  - Smoke
  - Water
  - Falling leaves
  - “Magic”
  - etc.







Particle Systems

- The term “particle system” was first used by Reeves to describe the method he used for the “Genesis effect” sequence in *Star Trek II* (1982)

Particle Systems

- Particle systems are different from normal object representations in several ways:
  1. An object is not represented by surface primitives, but by a “cloud” of particles
  2. The system is not static; new particles are created and old ones are destroyed
  3. The result is generally non-deterministic; stochastic processes are used to modify appearance

The Emitter

- The source of a particle system is called the *emitter*
- The emitter consists of
  - A location in 3D space, from which new particles spawn
  - All the initial particle behavior parameters
    - Velocity, spawning rate, lifetime, color, etc.

Particle Properties

- In Reeves’ original design, the particles had the following properties
  - Position
  - Velocity
  - Color
  - Lifetime
  - Age
  - Shape
  - Size
  - Transparency

Basic Method

- At each time step (say, each frame):
  1. Generate new particles
  2. Assign attributes to the new particles
  3. Destroy any particles past their lifetimes
  4. Transform and move all particles depending on their attributes; change particle attributes
  5. Render the particles

Randomness

- Generally, don't want all particles to have the same start point / velocity / etc.
- Add a random factor
  - Instead of emitting from a single point, emit from a random point in a sphere around the eimitter
  - Instead of emitting with a constant velocity, emit with some average velocity +/- a random amount
  - etc.

Rendering Particles

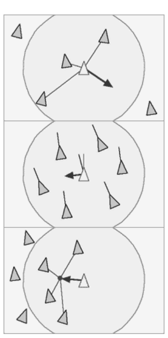
- There are several options:
  - Generate them early (*i.e.* before geometry processing), and just render as polygons
  - Generate them late, and just treat them like "lights"
    - Not lights in the sense that they illuminate other objects
    - But in the sense that you can simply add their contributions to the color of the pixel

Really Cool Extension: Flocking

Craig Reynolds, SIGGRAPH 87
Flocks, Herds, and Schools: A Distributed Behavioral Model

- In 1987, Craig Reynolds developed a way to extend particle systems to "boids" (bird-objects or bird-oids)
  - These are basically particles, but with attached geometry, and some basic "intelligence"

Flocking



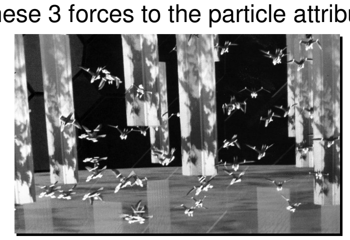
Separation:
Steer to avoid crowing local flockmates

Alignment:
Steer to the average heading of local flockmates

Cohesion:
Steer to the average position of local flockmates

Flocking

- That's pretty much all there is to it; add these 3 forces to the particle attributes



http://odyssey3d.stores.yahoo.net/comanclascli2.html

Next Time

- Course / final exam review