DH2323 DGI16

INTRODUCTION TO
COMPUTER GRAPHICS AND
INTERACTION

GLOBAL ILLUMINATION

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Based on DGI12 notes by Carl Henrik Ek
Image Synthesis

In computer graphics, create images based on a *model*

Recall:
- An underlying process generates observations
- Can control generation through parameters
Nice Results

"Christmas Baubles" by Jaime Vives Piqueres

"Still with Bolts" by Jaime Vives Piqueres

"Distant Shores" by Christoph Gerber

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DH2323 Global Illumination

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Some Classifications

- **Local Illumination**
  - Consider lighting effects only directly from the light sources and ignore effects of other objects in the scene (e.g. reflection off other objects)

- **Global Illumination**
  - Account for all modes of light transport
Why Go Local?

- Usually easy to control and express
  - Director's chair: important when you want a scene to look a certain way

- Fast
  - Easier to obtain real-time performance (or just tractable calculations)

- Do not require knowledge of the entire scene

But …

- Not as accurate or compelling as global models
How Can It Be Modelled?

- Use a *lighting model* as inspiration
- But real light extremely complicated to simulate
  - Light bounces around the environment
  - Heavy processing required even for coarse approximations
  - Simplifications allow real-time performance

- Lighting models:
  - Lambertian – we will consider this first
  - Phong – not to be confused with *Phong shading*
  - Blinn-Phong and others...
Gouraud Shading

Gouraud Shading

Gouraud

Wikimedia Commons
Phong Shading

- Phong shading can reproduce highlights in the center of a polygon that Gouraud Shading may miss
Phong Illumination Model

NOT the same as Phong Shading
Lambertian Vs Phong

Lambertian Surface

Phong Illuminated Specular Surface
Overall

- Ambient
- Diffuse
- Specular
- Per light source or scene
Some Classifications

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  - Consider lighting effects only directly from the light sources and ignore effects of other objects in the scene (e.g. reflection off other objects)

- **Global Illumination**
  - Account for all modes of light transport
Global Illumination

- Account not only for light coming directly from light sources
- Also reflected light bouncing around the scene
- Appear more photo-realistic
- But computationally more expensive than local illumination approaches
  - Slower
- Speed-up techniques are always important
Global Illumination

- Example techniques:
  - Ray tracing (sound familiar?)
  - Radiosity
  - Path tracing
  - Metropolis light transport
  - Ambient occlusion
  - Photon mapping
  - Image based lighting
The Rendering Equation

\[ L_0(x, \omega_o, \lambda, t) = L_e(x, \omega_o, \lambda, t) + \int_{\Omega} f_r(x, \omega_i, \omega_o, \lambda, t) L_i(x, \omega_i, \lambda, t) (\omega_i \cdot n) \, d\omega_i \]

Describes:
Total amount of light emitted from a point x along a specific viewing direction

Given:
-Incoming light function
-BRDF

Basis:
-Law of conservation of energy

BRDF
Account for angle w.r.t. light

Hemisphere containing all \( w_i \)

Incoming radiance
BRDF

Schwartz et al., Measurement Devices Focusing on the Developments at the University of Bonn, 2014
The Rendering Equation

\[ L_o(x, \omega_o, \lambda, t) = L_e(x, \omega_o, \lambda, t) + \int_{\Omega} \rho(x, \omega_i, \omega_o, \lambda, t) L_i(x, \omega_i, \lambda, t) (\omega_i \cdot n) \, d\omega_i \]

Describes:
Total amount of light emitted from a point \( x \) along a specific viewing direction

Given:
- Incoming light function
- BRDF

Account for angle w.r.t. light

Hemisphere containing all \( \omega_i \)

Integral over unit hemisphere containing all possible \( \omega_i \)
Raytracing

- Few bounces (relatively)
- Light rays striking surface from
  - Light source
  - Specular/refractive direction
- Easy to implement
- Ignore diffuse objects inter-object relationships
Radiosity

- Conservation of light energy
- Integrate radiance leaving the surface in all directions
- Thermal engineering; FEM for solving rendering eq.
  - Illumination as heat transfer
- View independent
Radiosity

- Surfaces divided up into *patches*
- Do operations between patches
  - Form factors (how well patches are oriented w.r.t. each other, occlusions, distance)
  - Calculate brightness of each patch
Radiosity

- Diffuse bouncing of light
Radiosity

- Recursive/iterative technique
Radiosity

- View independent
- Can calculate solution for an entire scene off-line
- View scene from any view point in real-time

Video: https://www.youtube.com/watch?v=8i2M255Zw9I
Global Illumination

Ray tracing:
– Good for specular
– Bad for diffuse

Radiosity:
– Good for diffuse
– Bad for specular

Hybrid techniques
Photon Mapping

- Superset/hybrid of ray tracing and radiosity
- View dependent
- Handles diffuse and specular well
- Rays from light source and camera traced separately until termination criteria met
- Connected to produce luminance value
- Realistically simulate interaction of light with different objects
Photon Mapping

- **Pass 1: Construct photon map**
  - Light packets sent into scene from light sources
  - When photon intersects object, details stored in a photon map
  - Photon may be reflected (BRDF), absorbed or refracted depending on surface

- **Pass 2: Rendering**
  - Estimate radiance of every pixel of image based on photon map
  - Ray trace scene
Caustics

- Curved regions of bright reflected or refracted light
Sub-surface scattering

- Light bouncing around inside material before exiting

https://vimeo.com/36048029

Realistic Human Face Rendering for “The Matrix Reloaded”, Siggraph 2003
Links

http://www.cc.gatech.edu/~phlosoft/photon/
Great ray tracing and photon mapping applet

http://graphics.ucsd.edu/~henrik/papers/photon_map/
*The* photon mapping paper (Henrik Jensen)
Miscellany

• Bilda opening soon
  – Please only submit archive of all **final** labs + documentation

• You should be working on Lab 2
  – Any problems? Let me know!
  – Another lab help session will be organised soon

– User perception studies
Next lecture

- Rasterised Rendering I
- Wednesday 27\textsuperscript{th} April
- 13:00 – 15:00 B2