ROYAL INSTITUTE OF TECHNOLOGY

DH2323 DGI16

INTRODUCTION TO COMPUTER GRAPHICS AND INTERACTION

GLOBAL ILLUMINATION

Christopher Peters

CST, KTH Royal Institute of Technology, Sweden

chpeters@kth.se

http://kth.academia.edu/ChristopherEdwardPeters

Based on DGI12 notes by Carl Henrik Ek

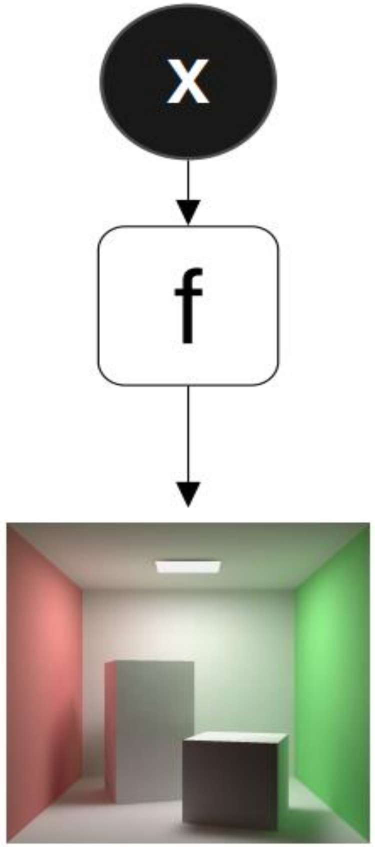
Image Synthesis

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

Recall:

An underlying process generates observations

Can control generation through parameters



Nice Results

"Distant Shores" by Christoph Gerber

"Christmas Baubles" by Jaime Vives Piqueres

"Still with Bolts" by Jaime Vives Piqueres

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

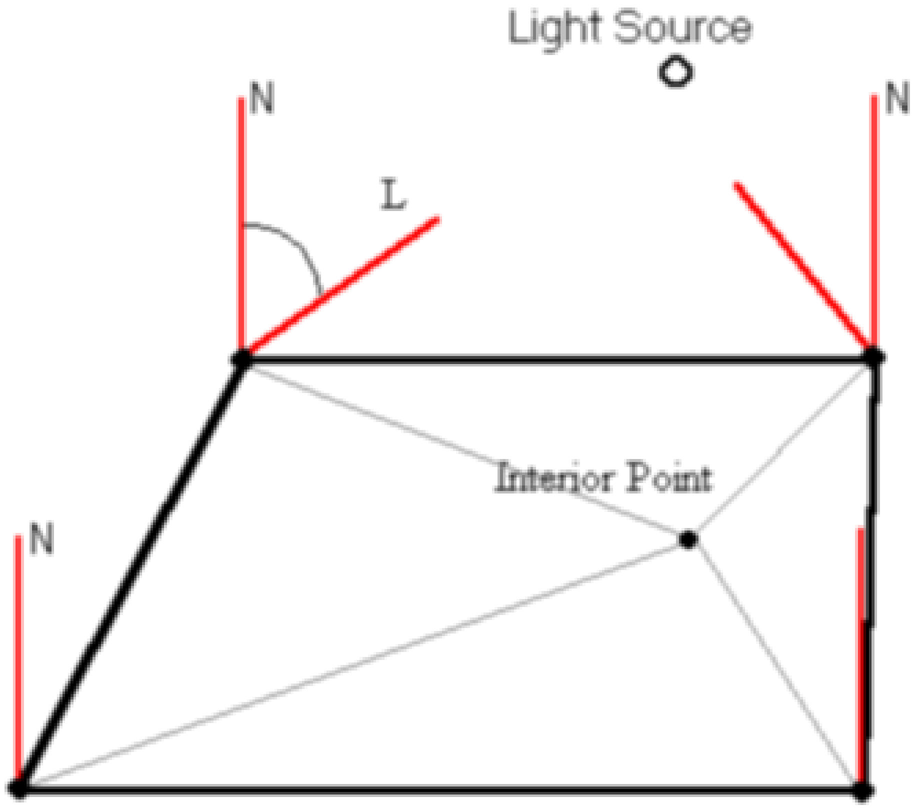
But …

- Not as accurate or compelling as global models

How Can It Be Modelled?

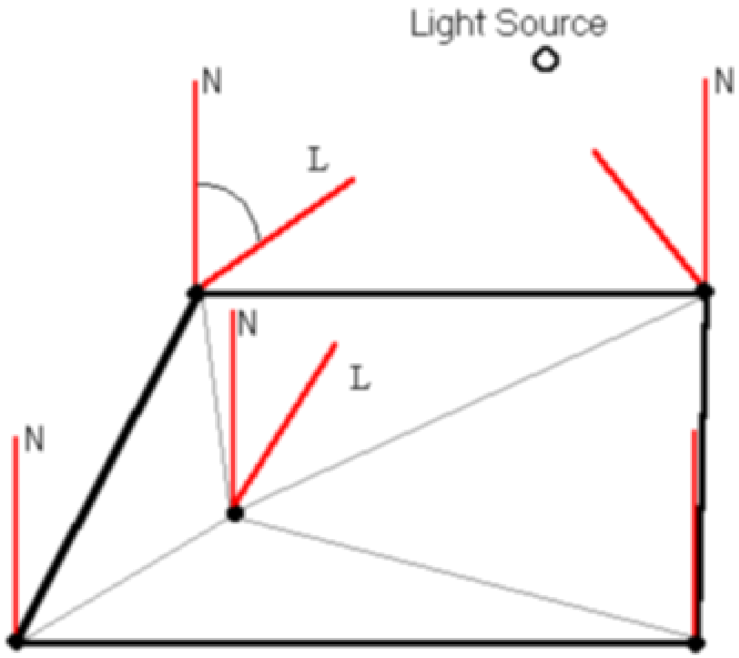
- Use a *lighting model* as inspiration
- But real light extremely complicated to simulate
  - Light bounces around the environment
  - Heavy processing required even for coarse approximations
  - Simplifications allow real-time performance
- Lighting models:
  - Lambertian – we will consider this first
  - Phong – not to be confused with *Phong shading*
  - Blinn-Phong and others...

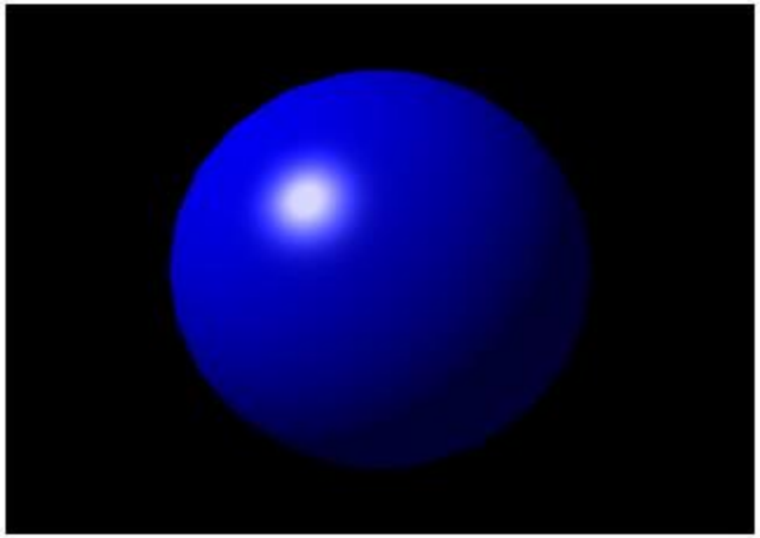
Gouraud Shading



Wikimedia Commons

Phong Shading





PHONG SHADING

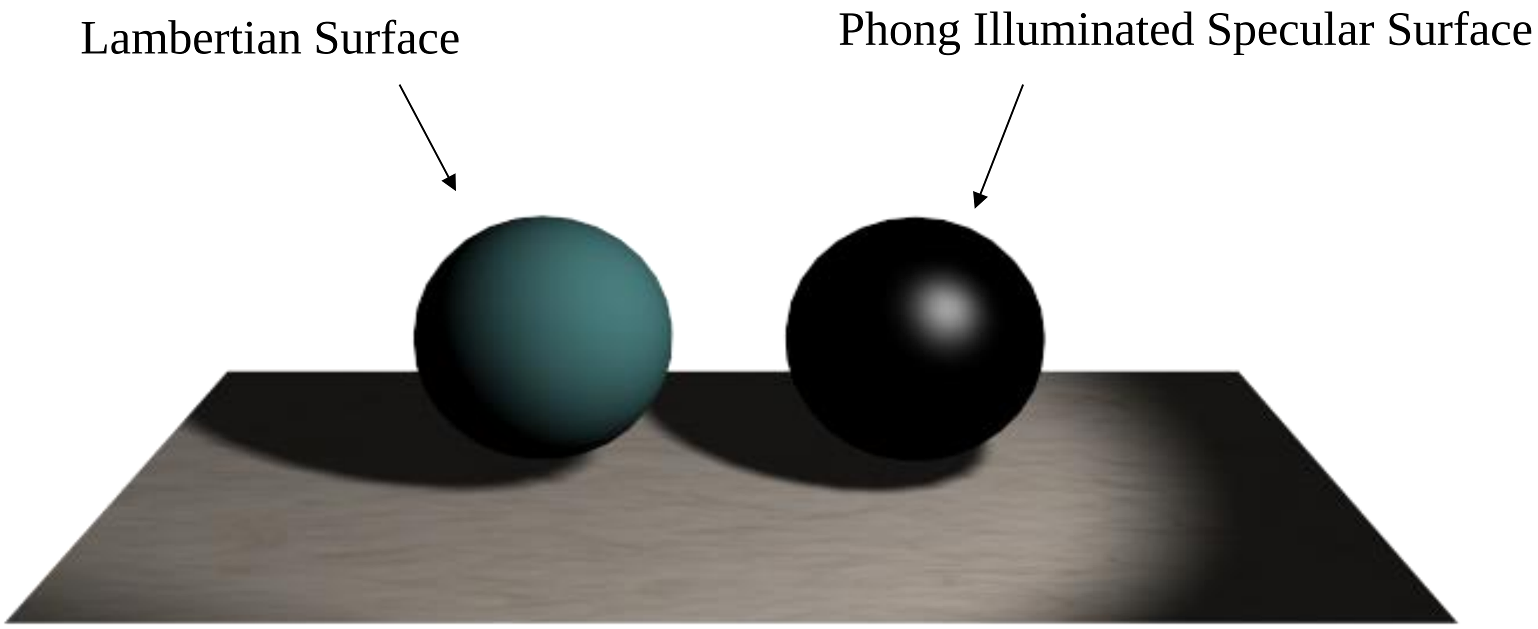
Wikimedia Commons

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

Phong Illumination Model

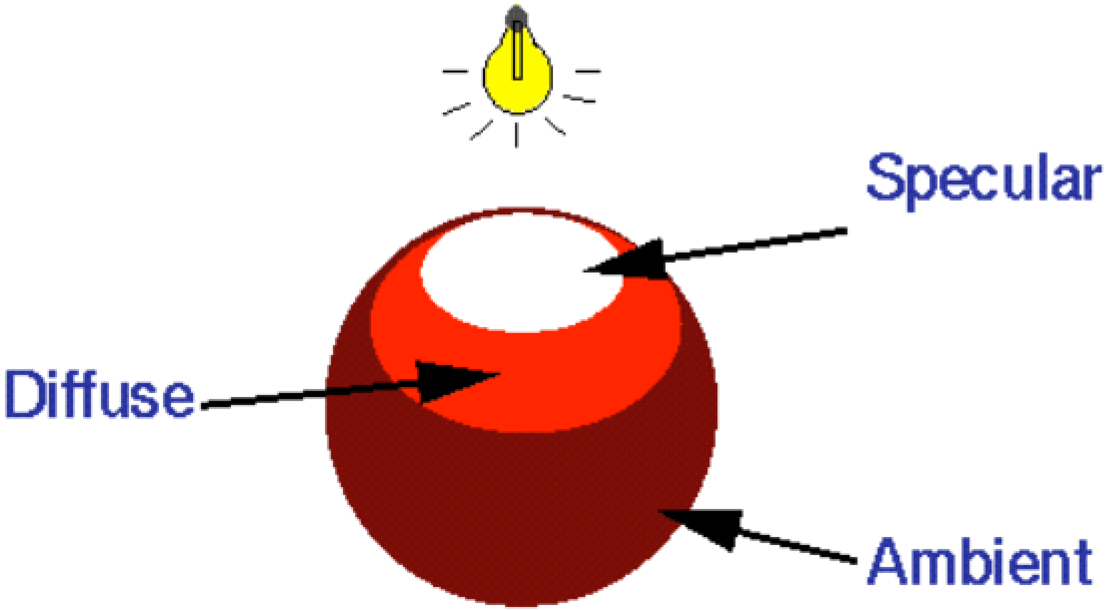
NOT the same as Phong Shading

Lambertian Vs Phong



Overall

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



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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

Emitted radiance BRDF Account for angle w.r.t. light

$$L_o(\mathbf{x}, \omega_o, \lambda, t) = L_e(\mathbf{x}, \omega_o, \lambda, t) + \int_\Omega f_r(\mathbf{x}, \omega_i, \omega_o, \lambda, t)\, L_i(\mathbf{x}, \omega_i, \lambda, t)\, (\omega_i \cdot \mathbf{n})\, d\,\omega_i$$

Incoming radiance

Describes:

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

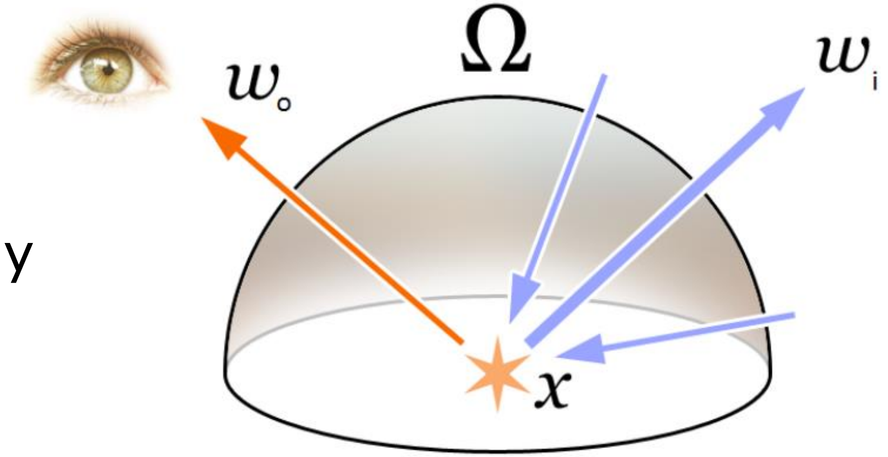
Given:

- Incoming light function
- BRDF

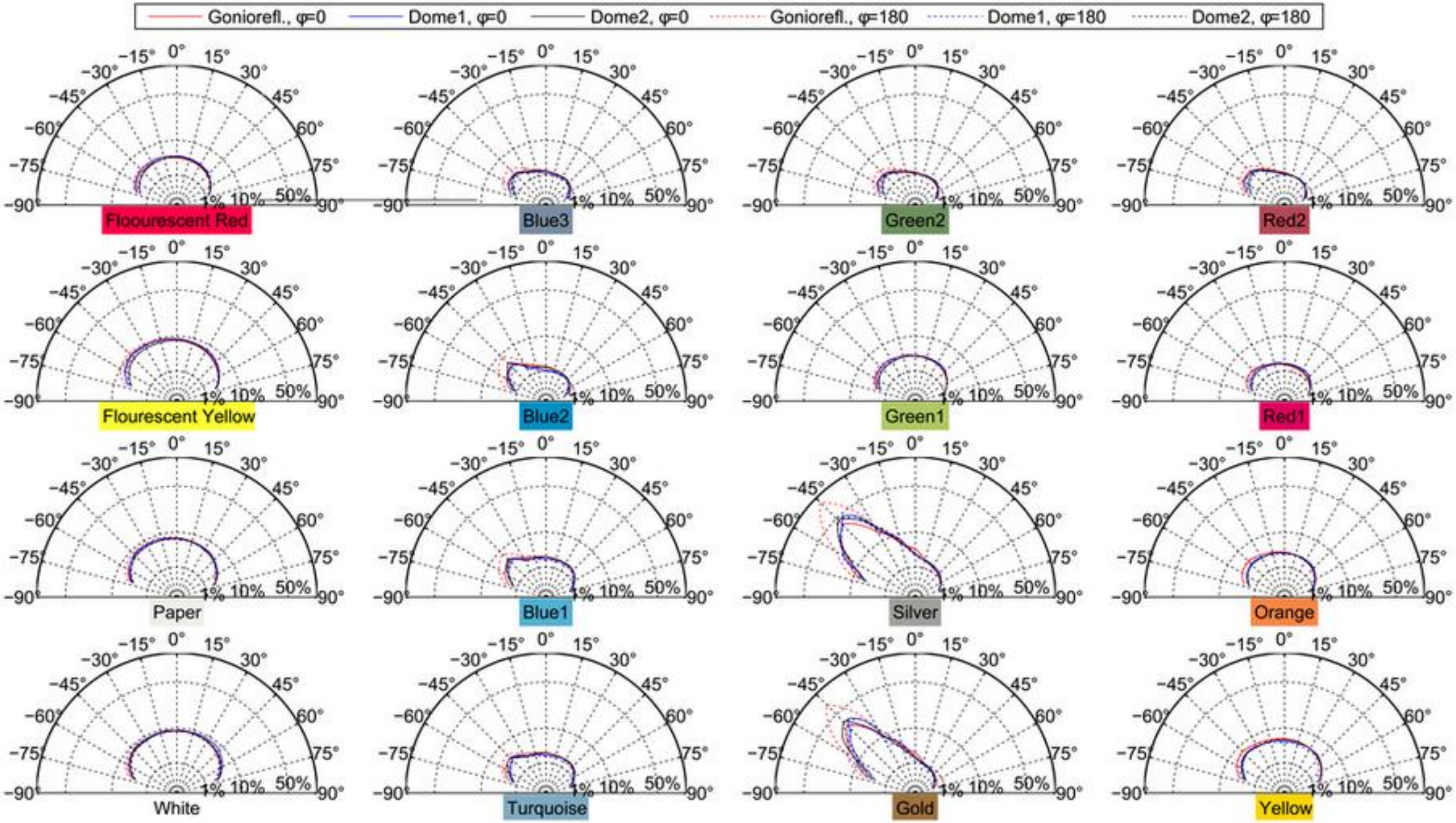
Basis:

- Law of conservation of energy

Hemisphere containing all w_i



BRDF



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

The Rendering Equation

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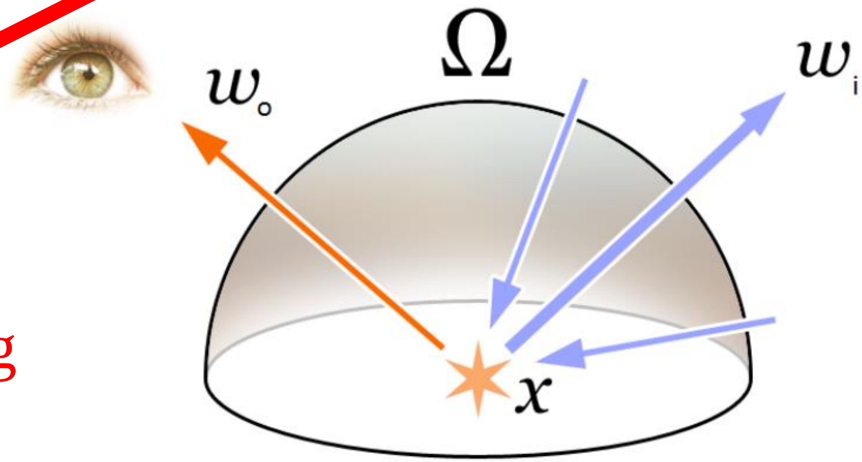
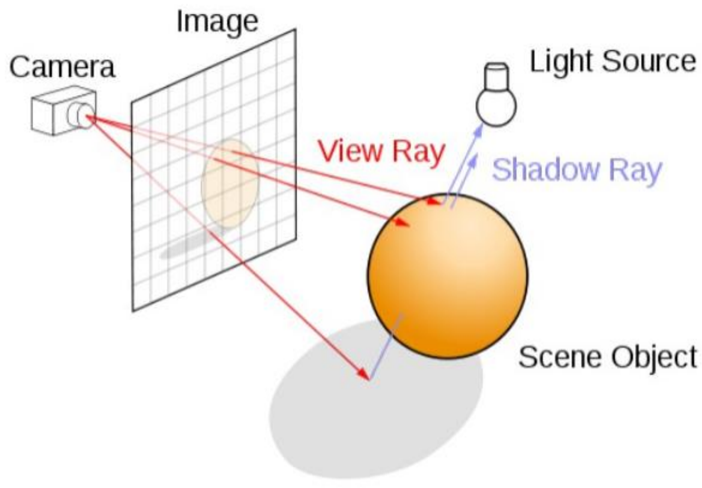
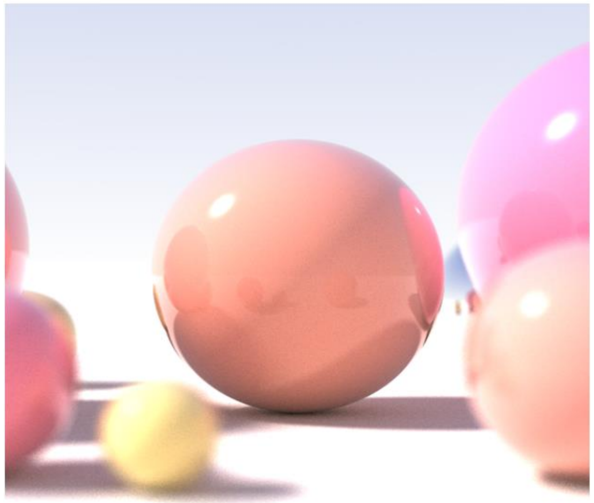


Integral over unit hemisphere containing all possible w_i

Raytracing

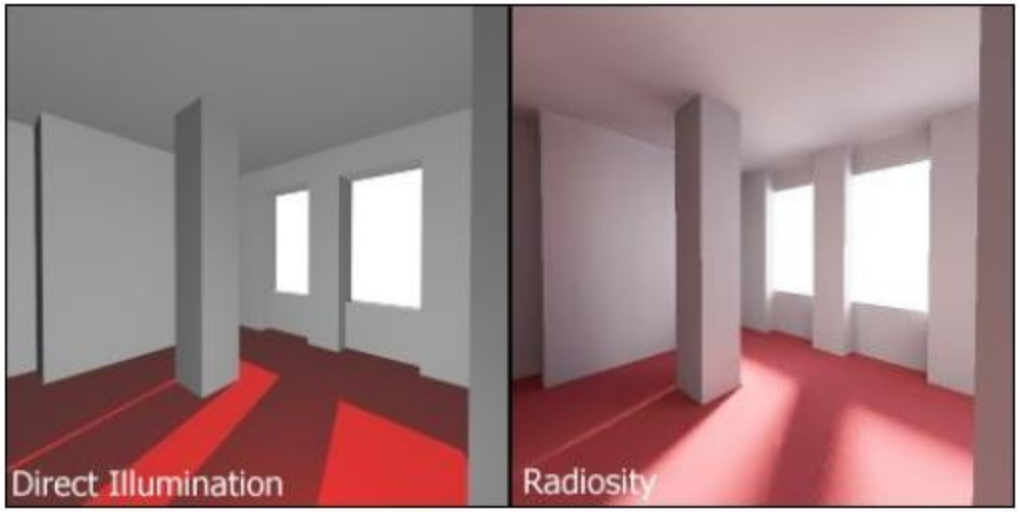
- Few bounces (relatively)
- Light rays striking surface from
  - Light source
  - Specular/refractive direction
- Easy to implement
- Ignore diffuse objects inter-object relationships





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

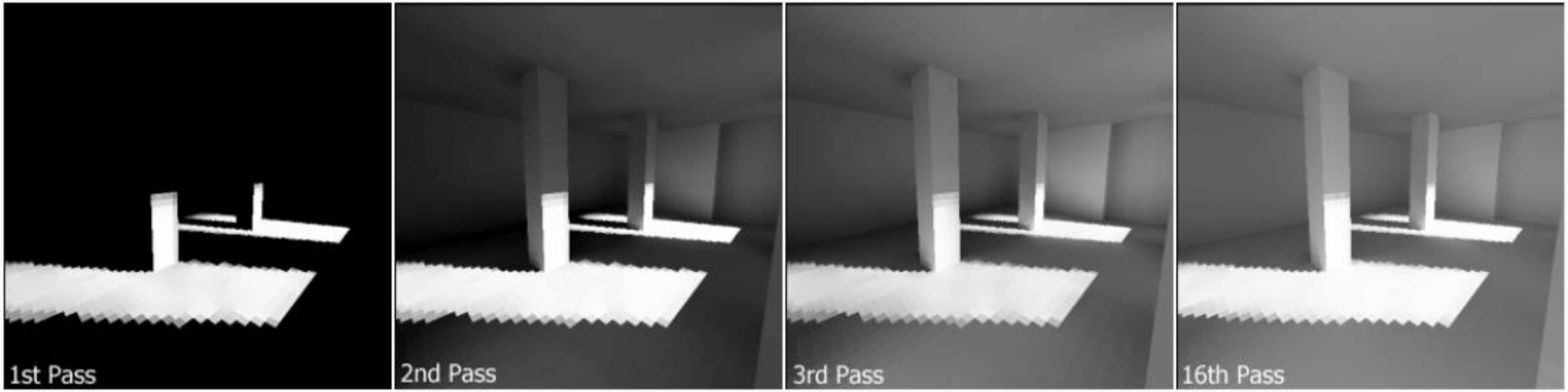
- Surfaces divided up into *patches*
- Do operations between patches
  - Form factors (how well patches are oriented w.r.t. each other, occlusions, distance)
  - Calculate brightness of each patch

Radiosity

- Diffuse bouncing of light

Radiosity

- Recursive/iterative technique



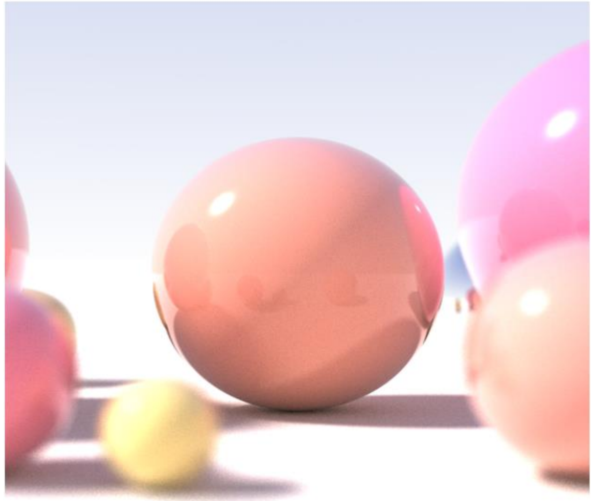
Radiosity

- 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

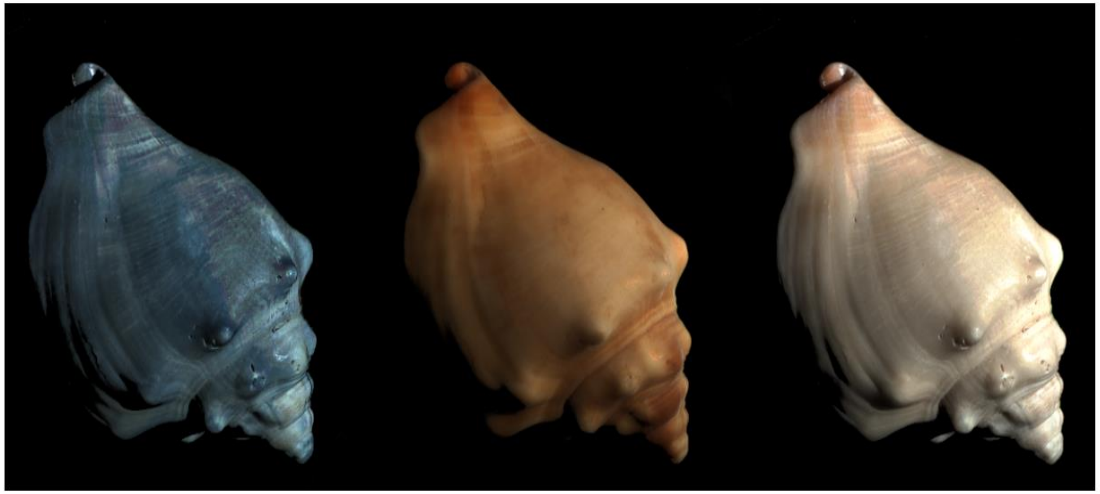
- Pass 1: Construct photon map
  - Light packets sent into scene from light sources
  - When photon intersects object, details stored in a photon map
  - Photon may be reflected (BRDF), absorbed or refracted depending on surface
- Pass 2: Rendering
  - Estimate radiance of every pixel of image based 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)

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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 27th April
- 13:00 – 15:00 B2