ROYAL INSTITUTE OF TECHNOLOGY

DH2323 DGI17

INTRODUCTION TO
COMPUTER GRAPHICS AND INTERACTION

GLOBAL ILLUMINATION

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Based on DGI12 notes by Carl Henrik Ek

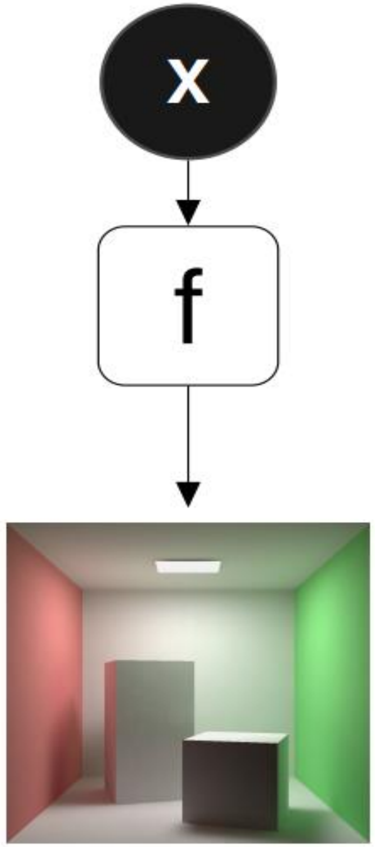
Image Synthesis

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

"Distant Shores" by Christoph Gerber

"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

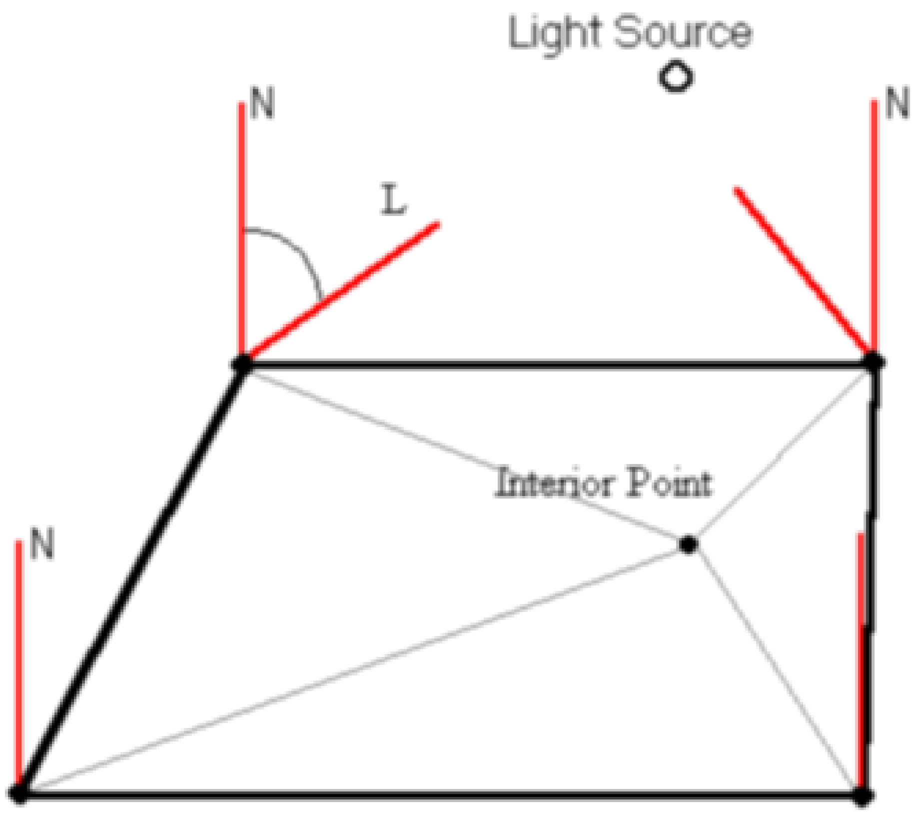
But …

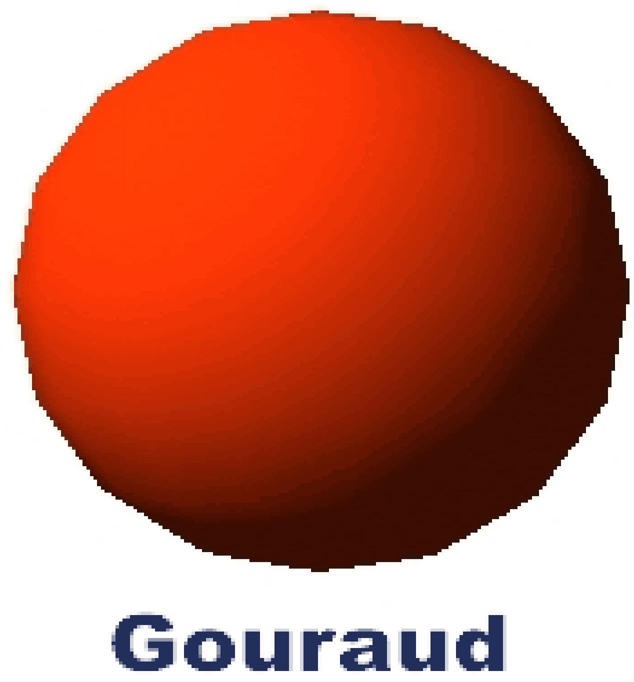
- Not as accurate or compelling as global models

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...

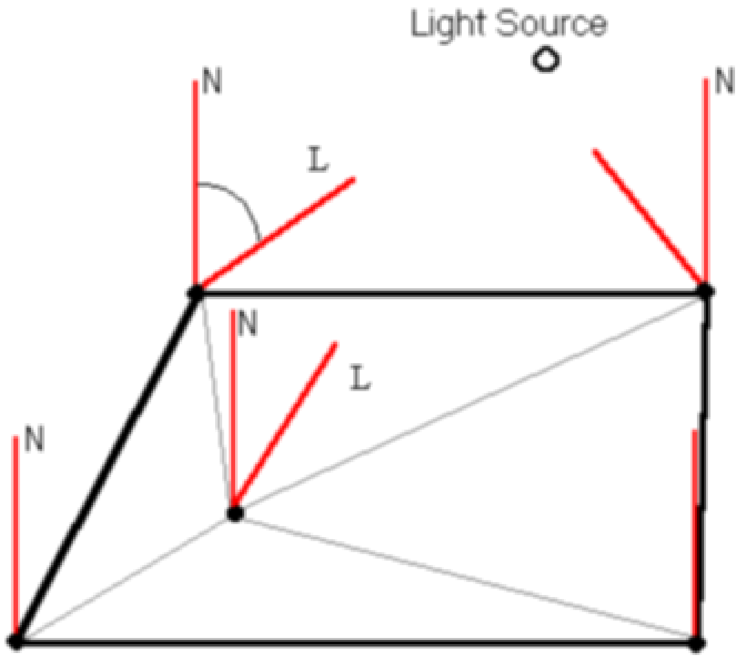
Gouraud Shading

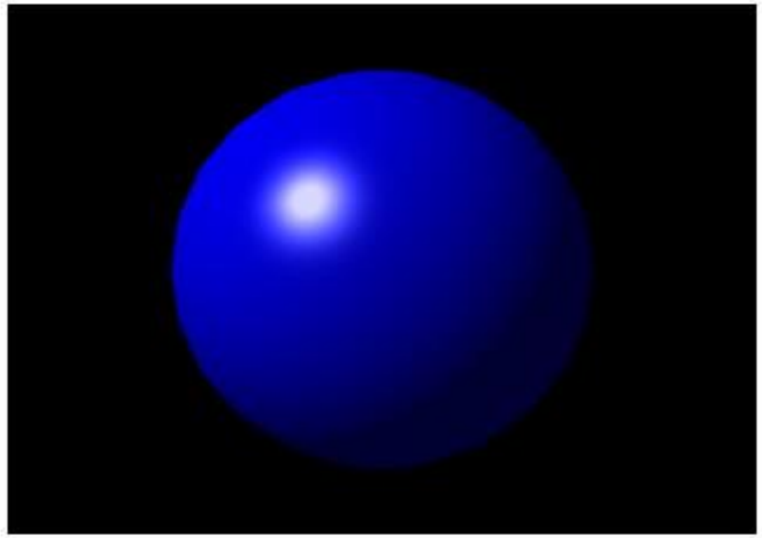




Wikimedia Commons

Phong Shading





PHONG SHADING

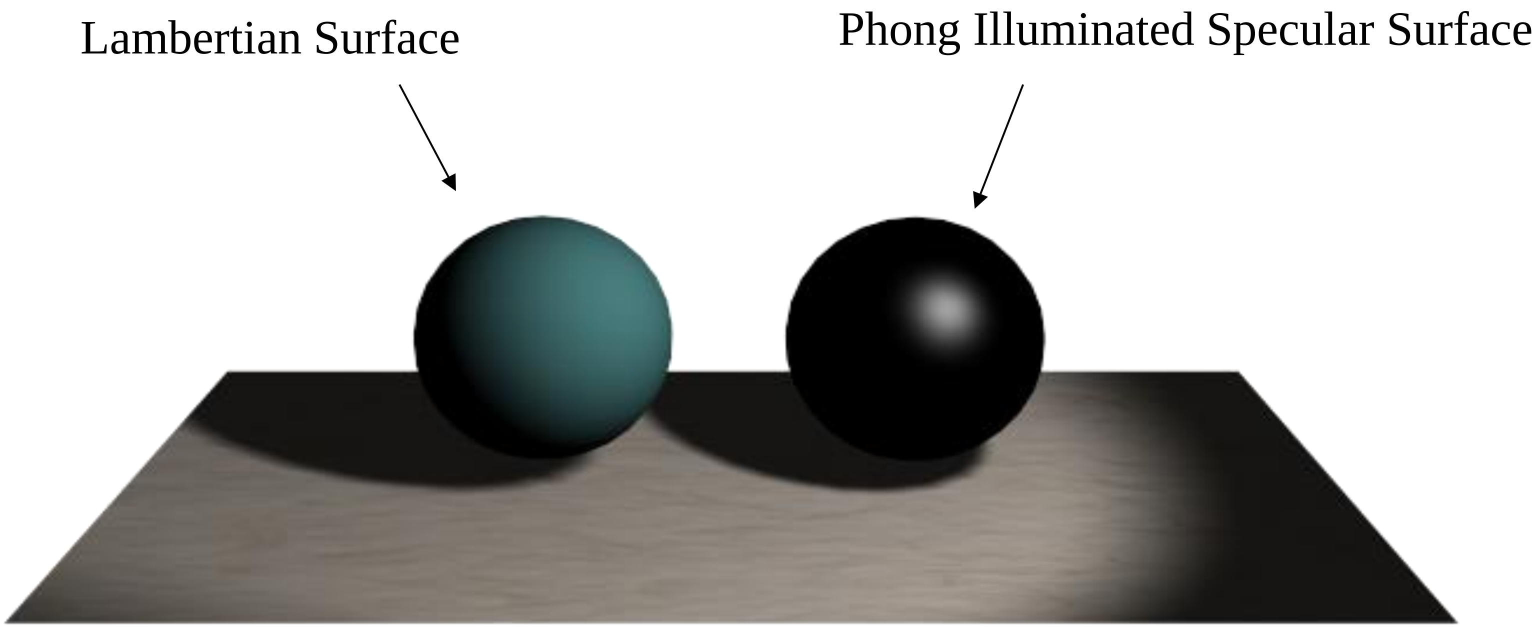
Wikimedia Commons

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

Phong Illumination Model

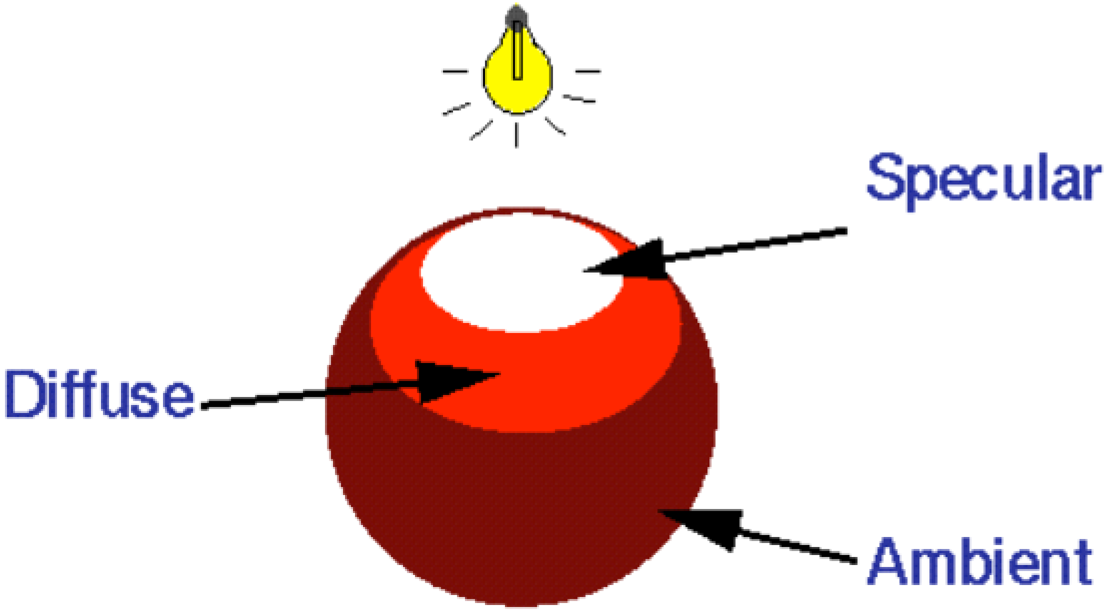
NOT the same as Phong Shading

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

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

Incoming radiance

Describes:

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

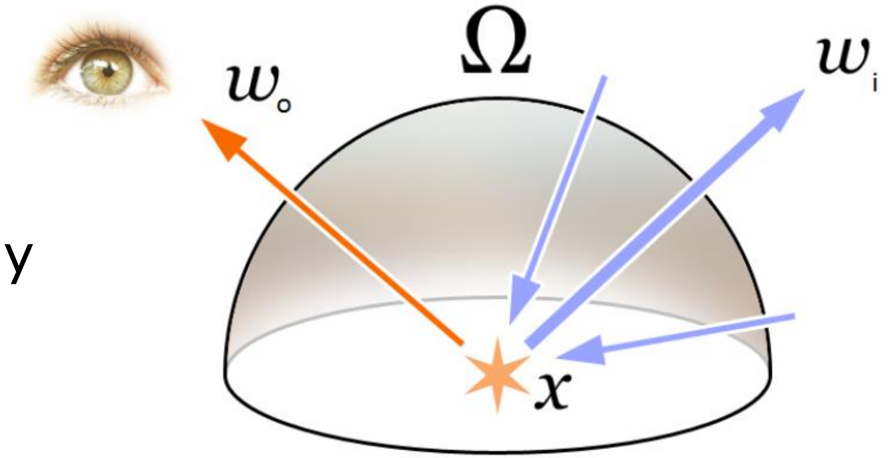
Given:

- Incoming light function
- BRDF

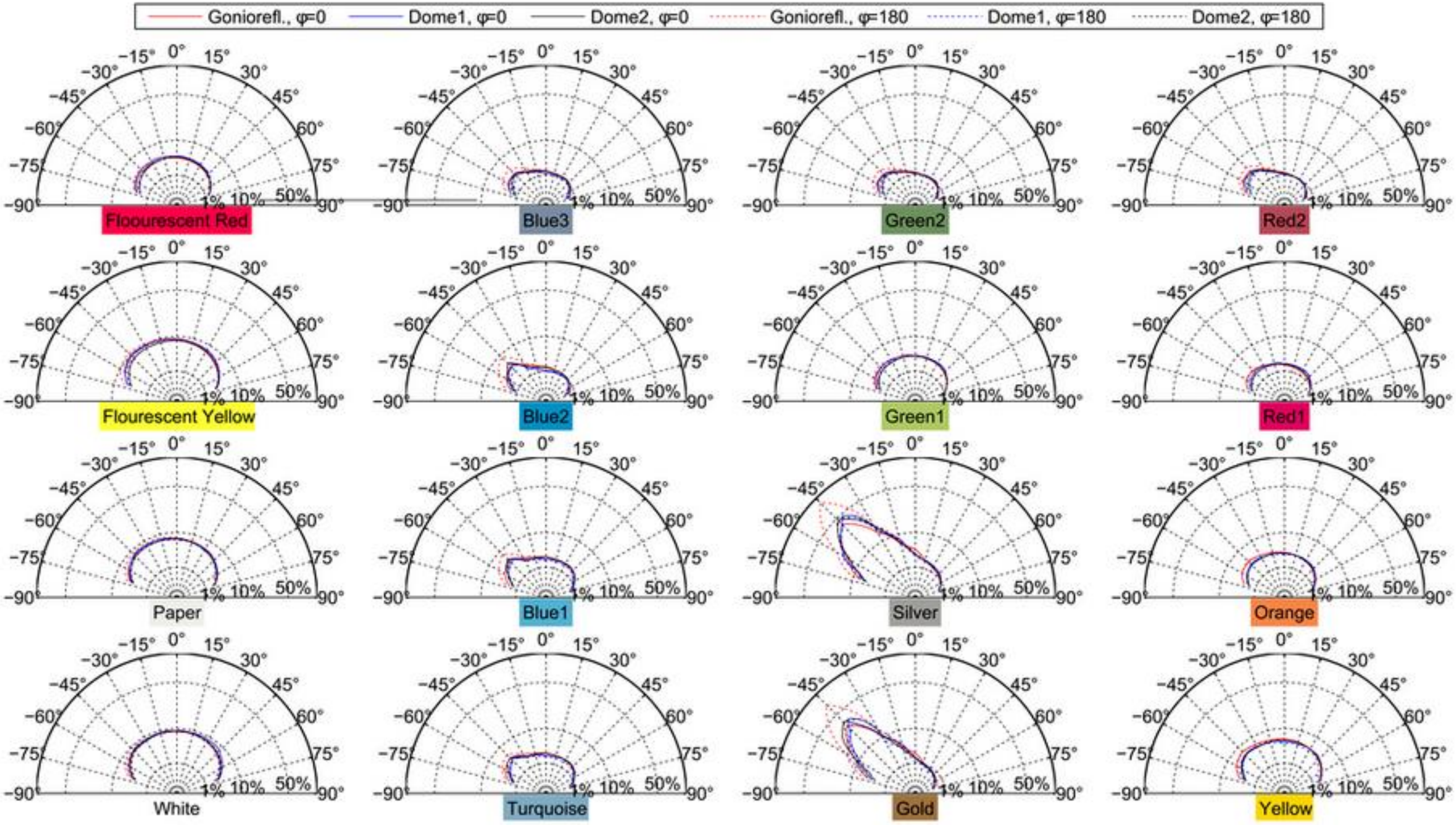
Basis:

- 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

Emitted radiance

BRDF

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Incoming radiance

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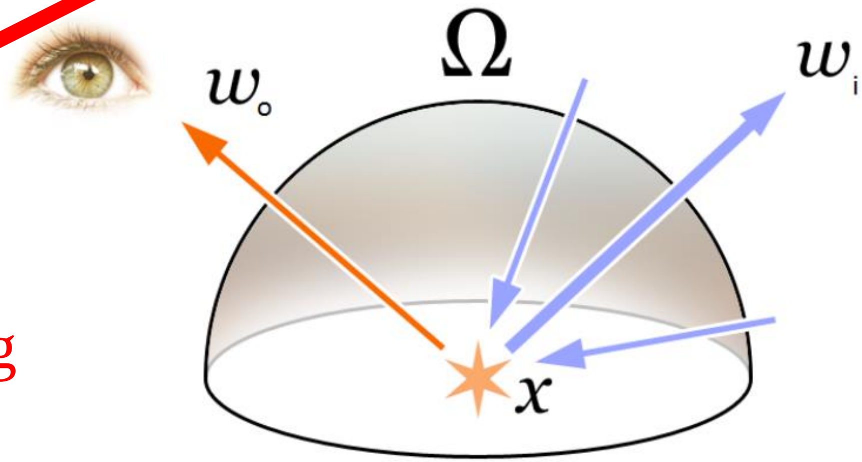
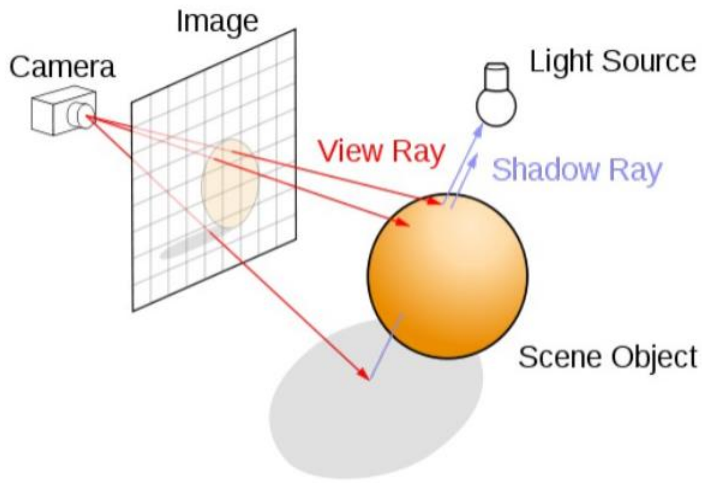
Hemisphere containing all w_i

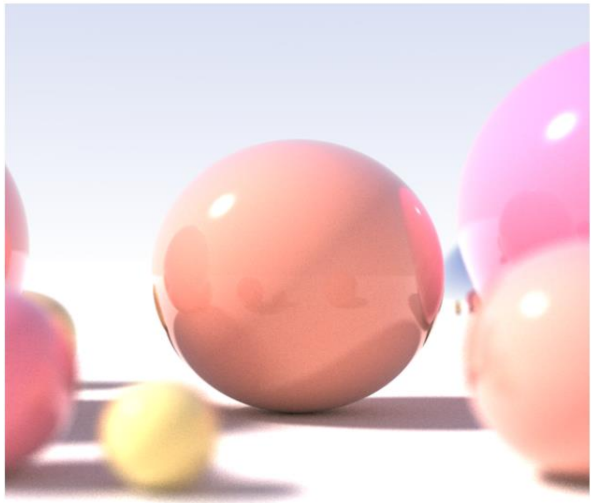


Integral over unit hemisphere containing all possible w_i

Raytracing

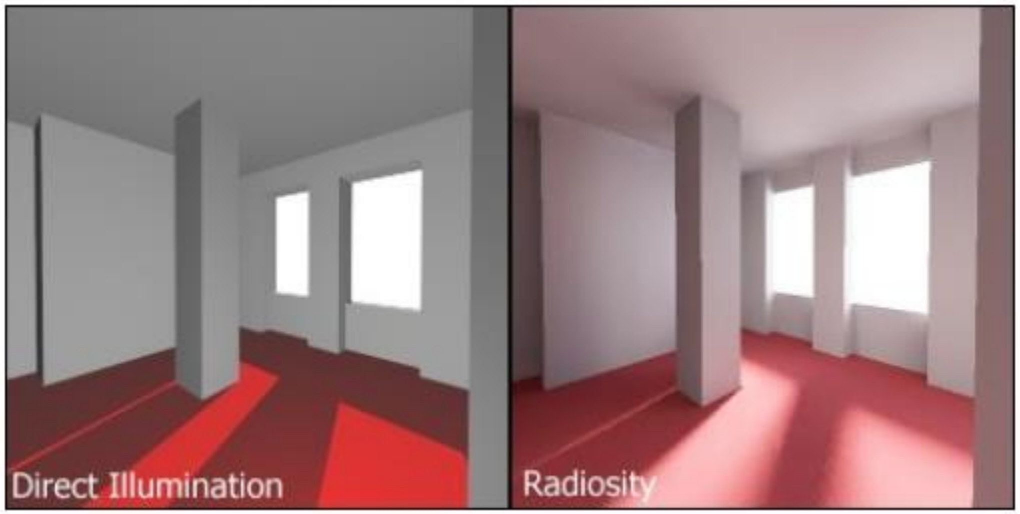
- Few bounces (relatively)
- Light rays striking surface from
  - Light source
  - Specular/refractive direction
- Easy to implement
- Ignore diffuse objects inter-object relationships





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

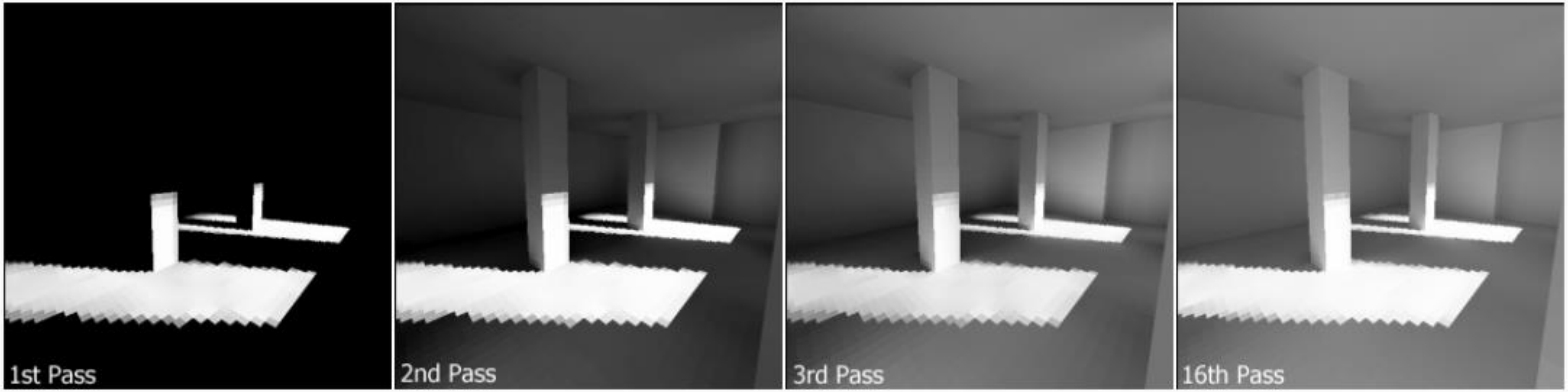
- Surfaces divided up into *patches*
- Do operations between patches
  - Form factors (how well patches are oriented w.r.t. each other, occlusions, distance)
  - Calculate brightness of each patch

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 at run-time

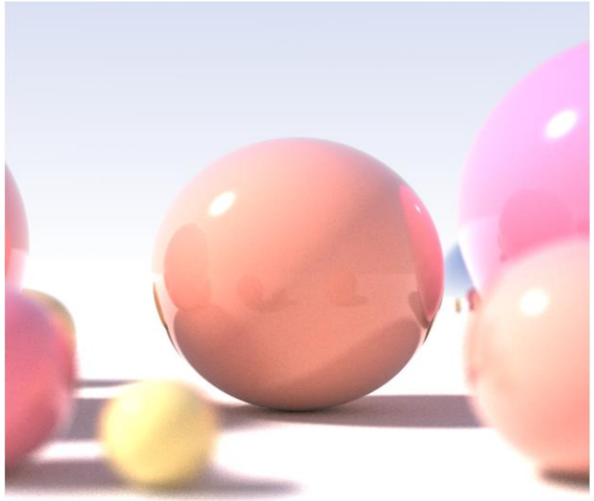
Video: https://www.youtube.com/watch?v=8i2M255Zw9I

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

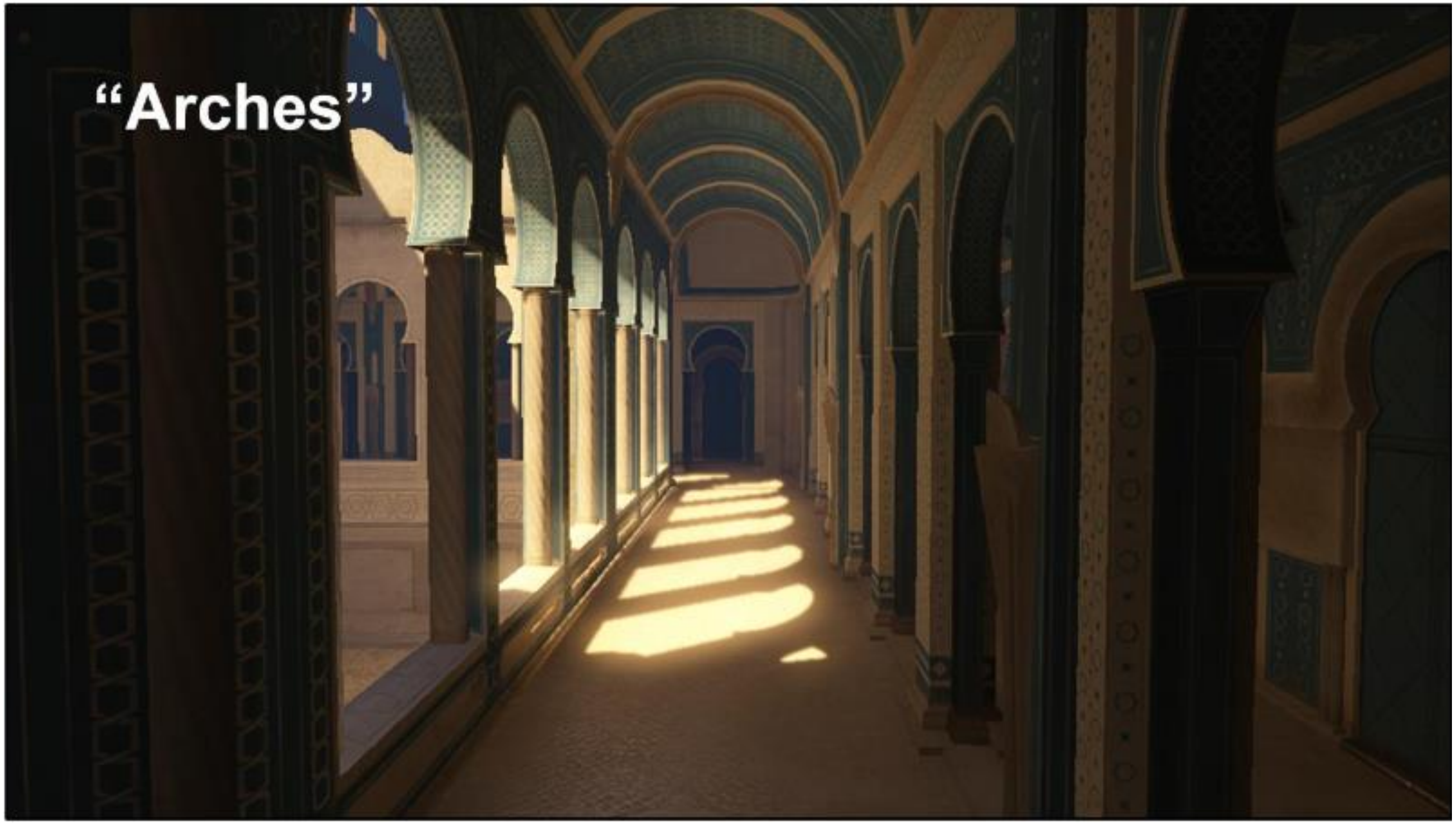
Photon Mapping

- 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

In real-time?

Enlighten

Example: Enlighten



Example: Enlighten

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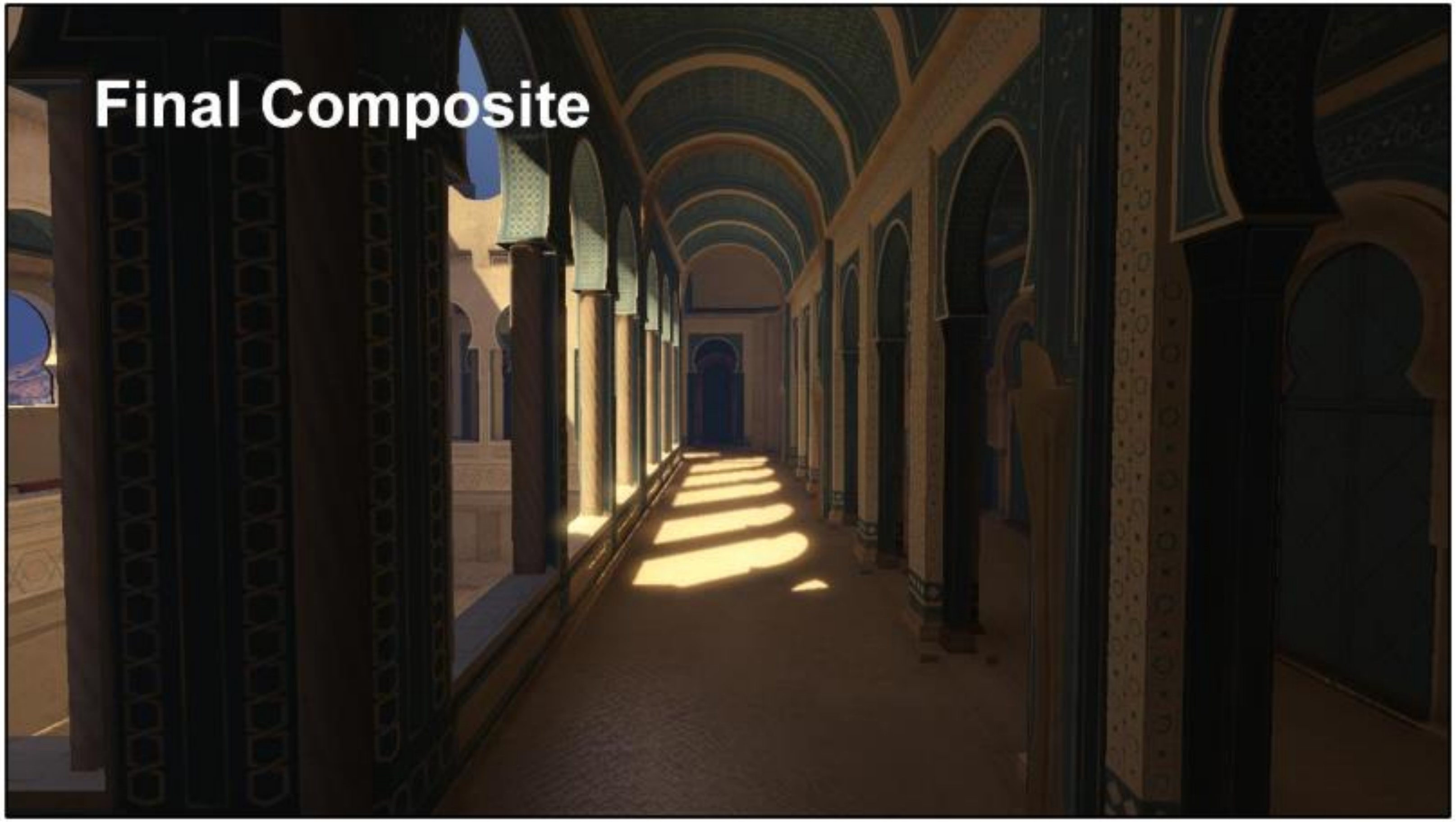
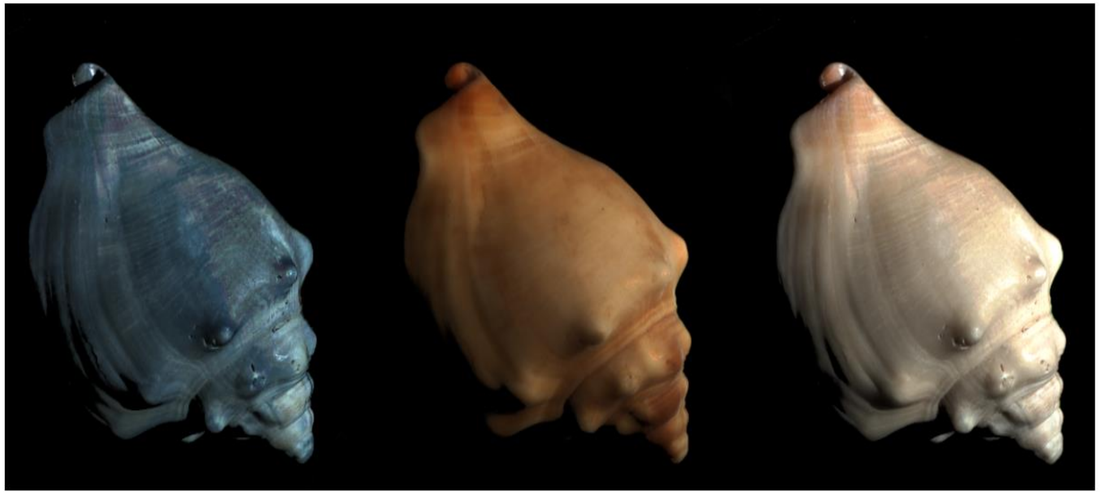


Caustics

- 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

Photon Mapping Links

http://www.cc.gatech.edu/~phlosoft/photon/

Great ray tracing and photon mapping

Applet + source code

Project specification

- Start to think about your project topics and form groups (if desired)
- Bilda opening soon
- Write up an initial specification
  - One or two paragraphs of details about the group and project idea
  - Include information about the grade you are aiming for
  - Submit to Bilda for feedback

Lab Help Sessions

- Visualisation (VIC) Studio:

  Thurs 27th, 10-12

  Thurs 4th, 13-15

  Thurs 11th, 15-17

- Will be added to your schedule soon

- More help sessions will be organised

Next lecture

- Rasterised Rendering I + *more*
- Monday 24th April
- 08:00 – 12:00 V2