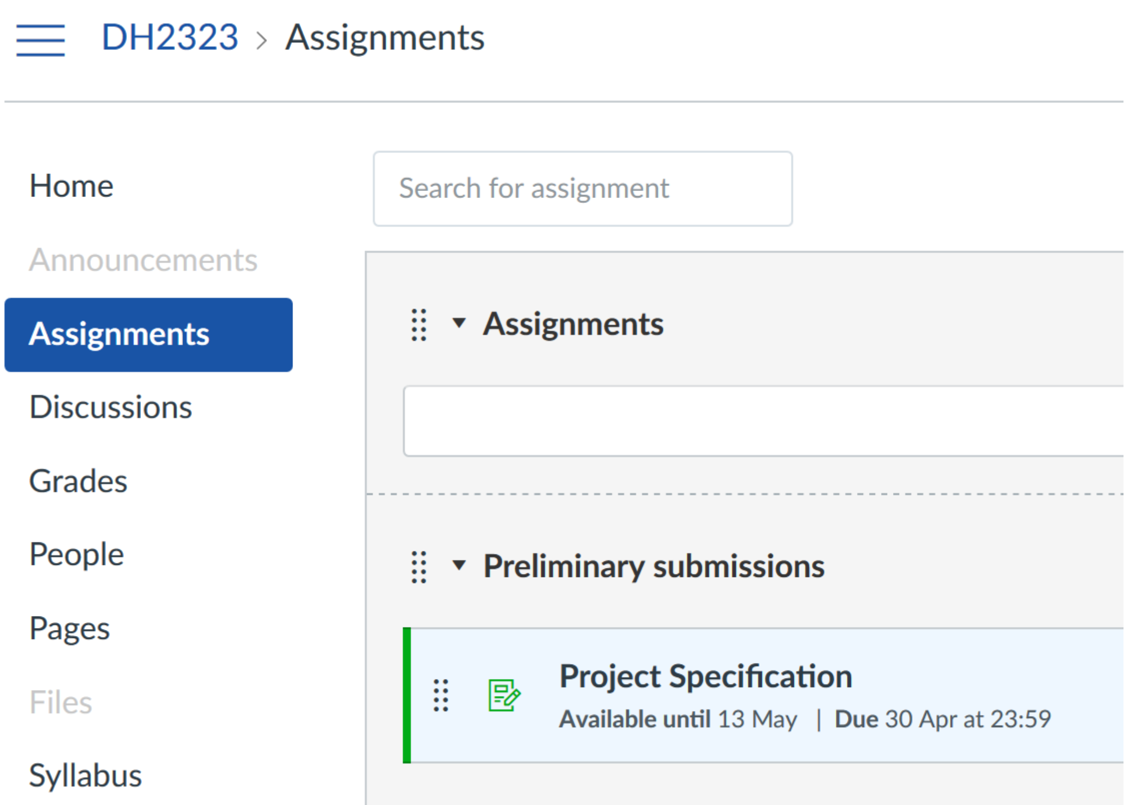
Project specifications



Canvas is now open for preliminary project specification submission!

Project specification

- Start to think about your project topics and form groups (if desired)
- Canvas already open
- Write up an initial specification
  - Initially a few sentences/paragraphs of details about the group and project idea
  - Include information about the grade you are aiming for
  - Submit to Canvas for feedback

Project specifications

1) Make sure to include your intended grade in the specification (e.g. A-B grade, basic pass, etc), since this has a large impact on the type of feedback that we may provide.

2) You are not graded on your preliminary project specification. It is an opportunity for you to receive feedback from the course team on your project idea. It is strongly recommended that you do it, especially if you are seeking higher grades in the course.

3) You can change your project specification any time you wish. It does not represent a promise by you to complete anything that you mention in it i.e. it is meant to be a helpful method for you to communicate and develop your project idea.

4) You should iteratively improve and add more detail to your specification and resubmit to get updated feedback. The more detail that you can provide about your assignment, the better the feedback that we can usually provide to you.

5) The format is up to you. We suggest that you start off with sending us a basic idea and then add detail from there.

ROYAL INSTITUTE OF TECHNOLOGY

DH2323 DGI18

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

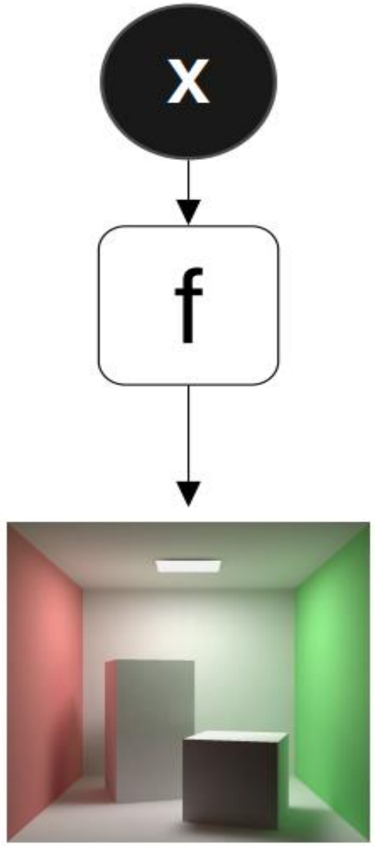
Image Synthesis

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

Recall:

An underlying process generates observations

Can control generation through parameters



Nice Results

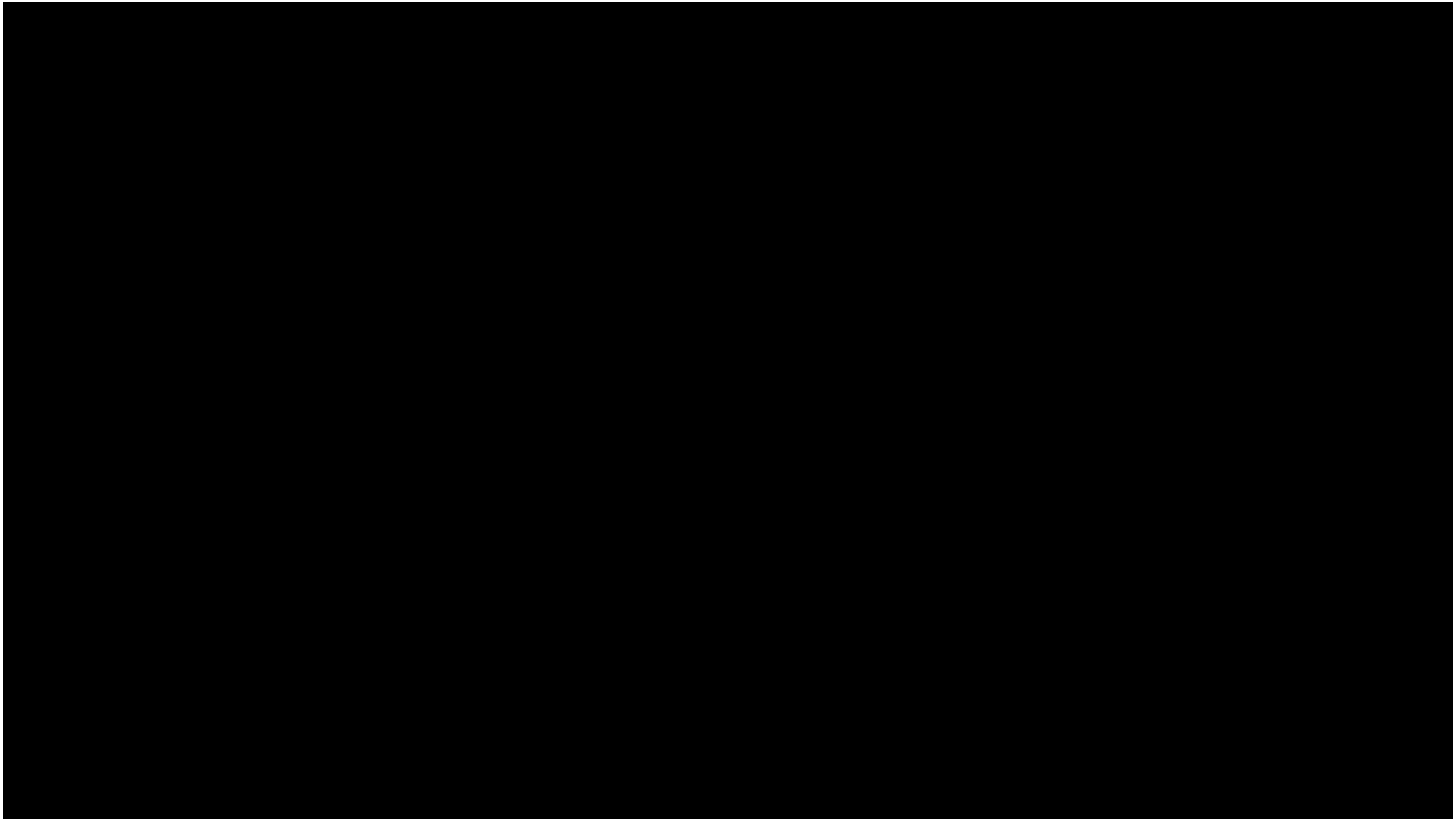
"Distant Shores" by Christoph Gerber

"Christmas Baubles" by Jaime Vives Piqueres

"Still with Bolts" by Jaime Vives Piqueres

ROYAL INSTITUTE
OF TECHNOLOGY

Importance of Lighting



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 …

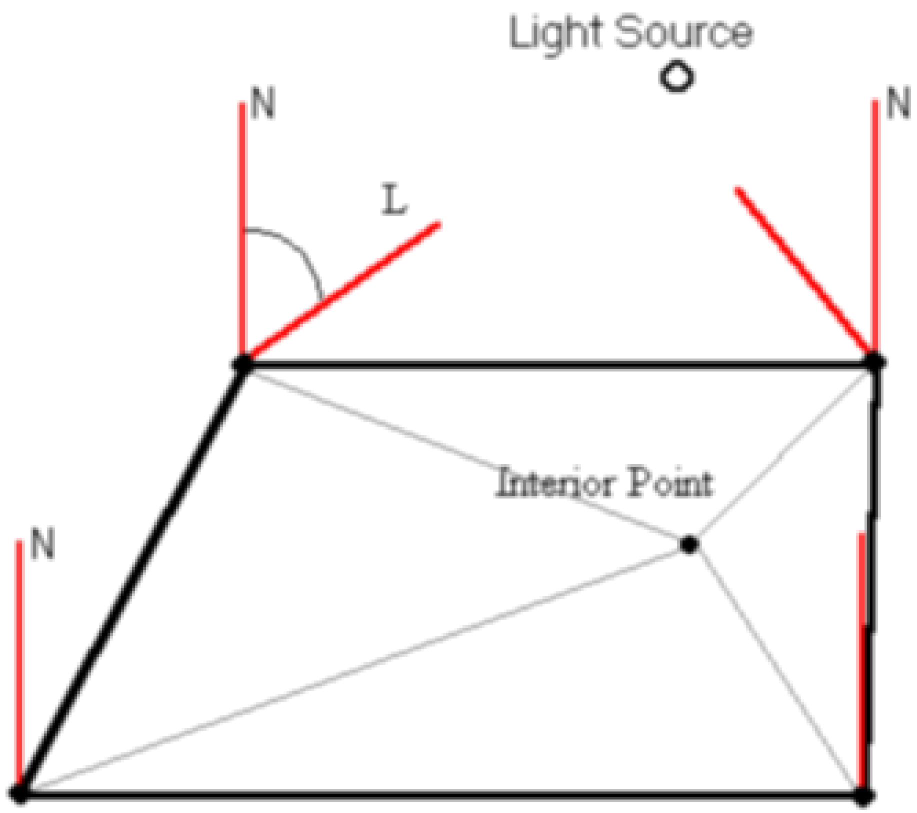
- Not as accurate or compelling as global models

ROYAL INSTITUTE OF TECHNOLOGY

How Can It Be Modelled?

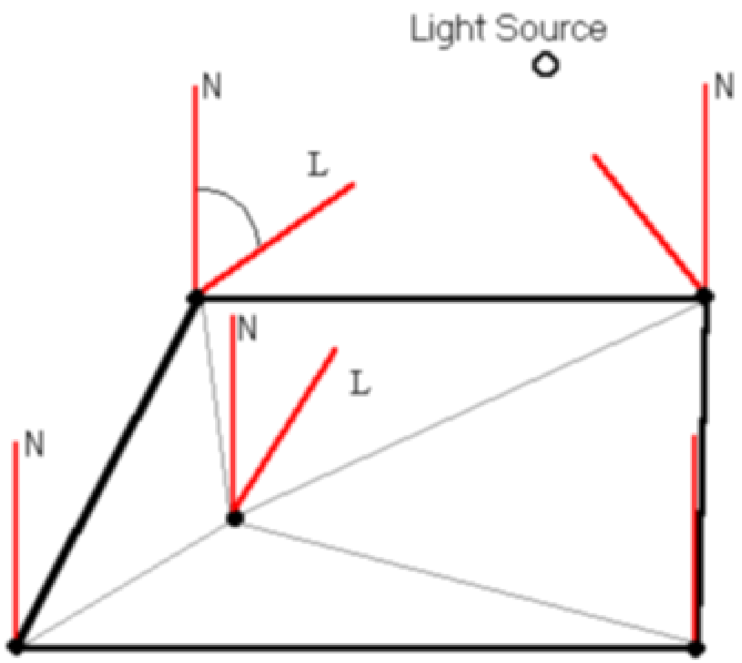
- Use a *lighting model* as inspiration
- But real light extremely complicated to simulate
  - Light bounces around the environment
  - Heavy processing required even for coarse approximations
  - Simplifications allow real-time performance
- Lighting models:
  - Lambertian – we will consider this first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

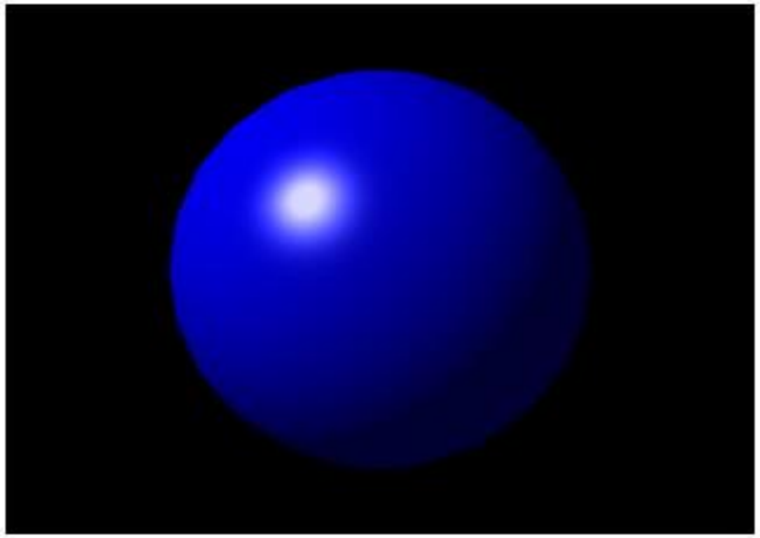
Gouraud Shading



Wikimedia Commons

Phong Shading





PHONG SHADING

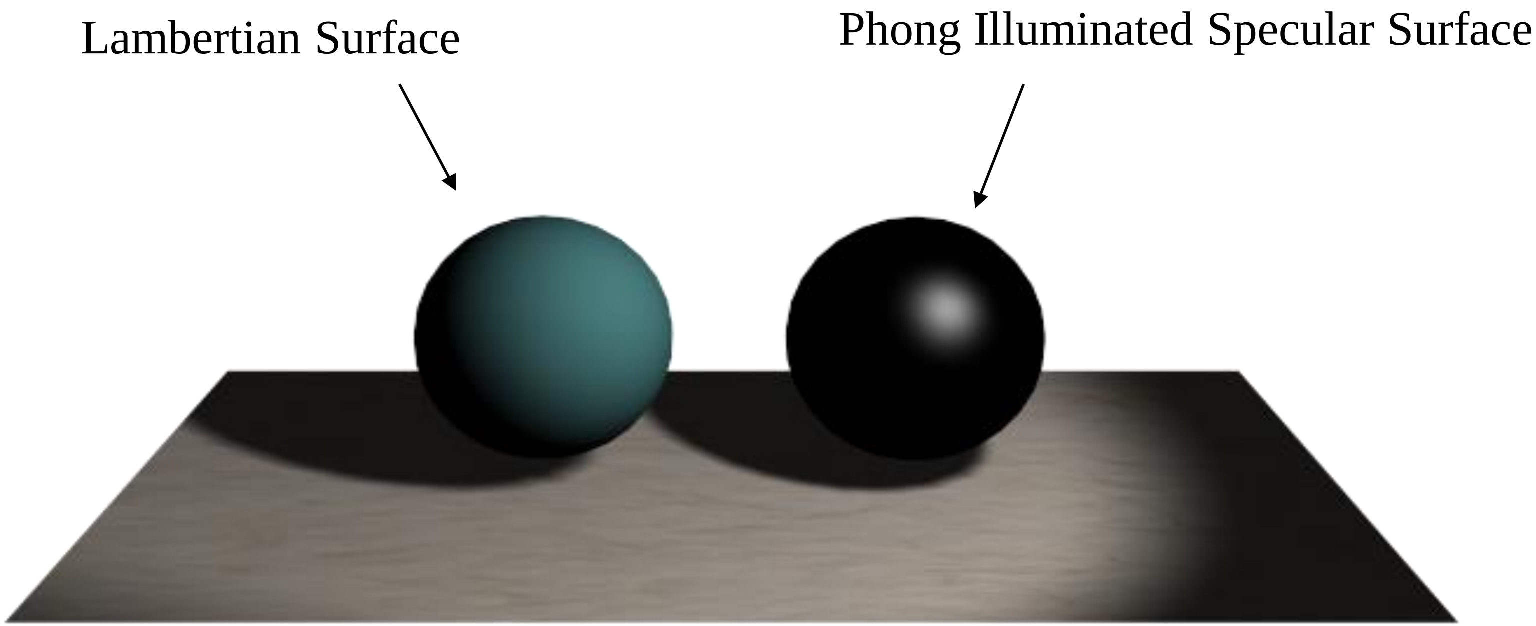
Wikimedia Commons

- 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

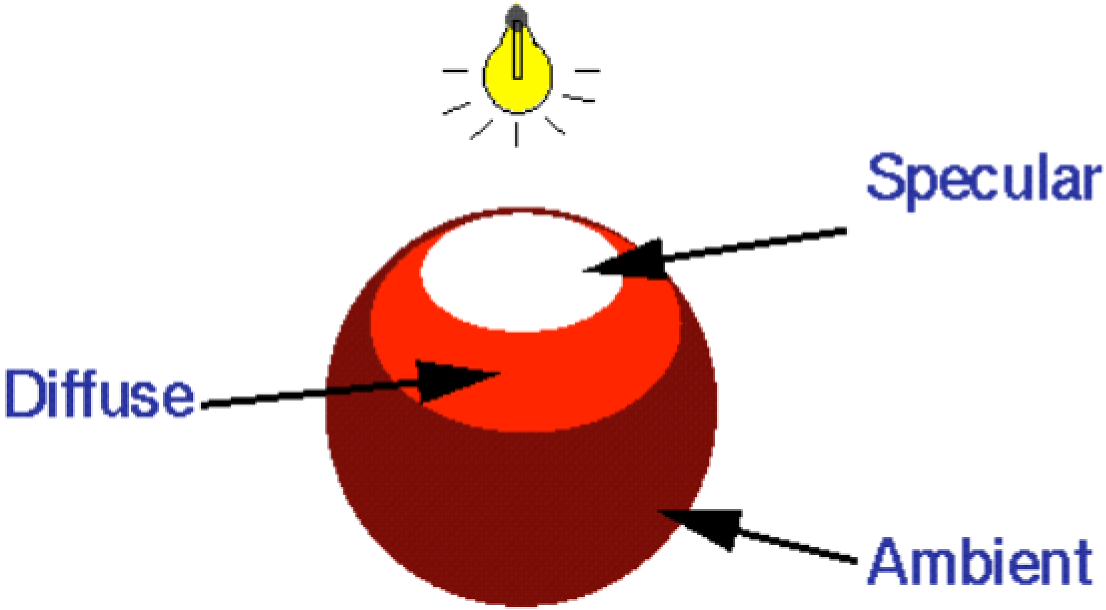
Lambertian Vs Phong



ROYAL INSTITUTE OF TECHNOLOGY

Overall

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



ROYAL INSTITUTE
OF TECHNOLOGY

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

ROYAL INSTITUTE OF TECHNOLOGY

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

ROYAL INSTITUTE OF TECHNOLOGY

Global Illumination

- Example techniques:
  - Ray tracing (in its advanced form)
  - 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

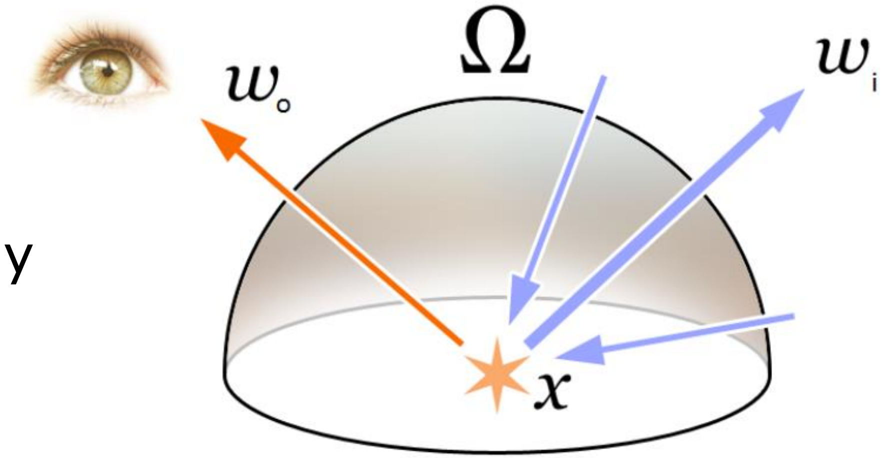
Given:

- Incoming light function
- BRDF

Basis:

- Law of conservation of energy

Hemisphere containing all w_i



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

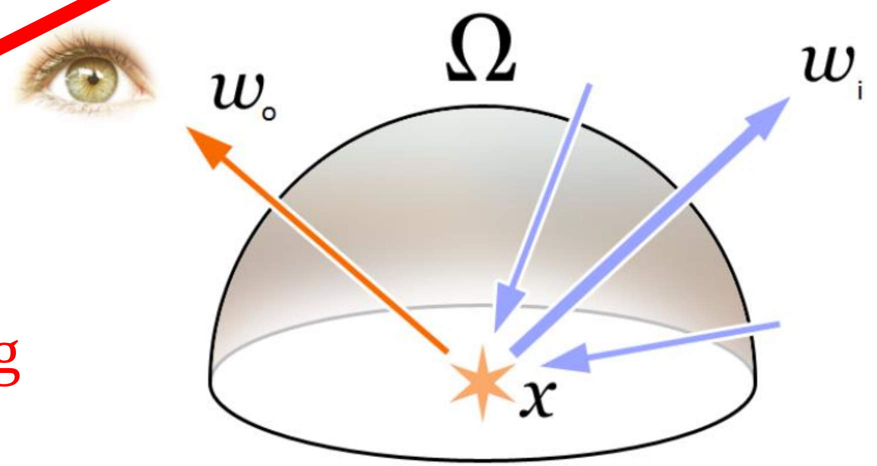
Describes:

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

Given:

- Incoming light function
- BRDF

Hemisphere containing all w_i



Integral over unit hemisphere containing all possible w_i

Simplifications

- Simplification #1: use *isotropic point* light sources
- Isotropic means that the light source **radiates energy equally** in all directions
  - Simplifies our light source energy equations that we'll look at
  - When we mention light, we are really talking about **energy**
- Simplification #2: simulate only specific surface types
  - Makes it easier to specify materials and calculate reflections
  - But visually limited

Radiant Intensity

- Light is defined by its *Radiant Intensity*, **I**
  - Radiant Intensity is measured in *Watts/sr*
  - *sr* is the solid angle (in steradians)
  - $I = \phi / 4\pi r^2$
  - ϕ is the energy *leaving* the surface per unit time
  - Known as *power* or *flux* and measured in *Watts*
  - But: it's a point light source, so it radiates light equally in all directions
  - So $r^2 = 1$ (unit sphere)

    => $\mathbf{I} = \phi / 4\pi$
- Now know energy leaving light source in any direction

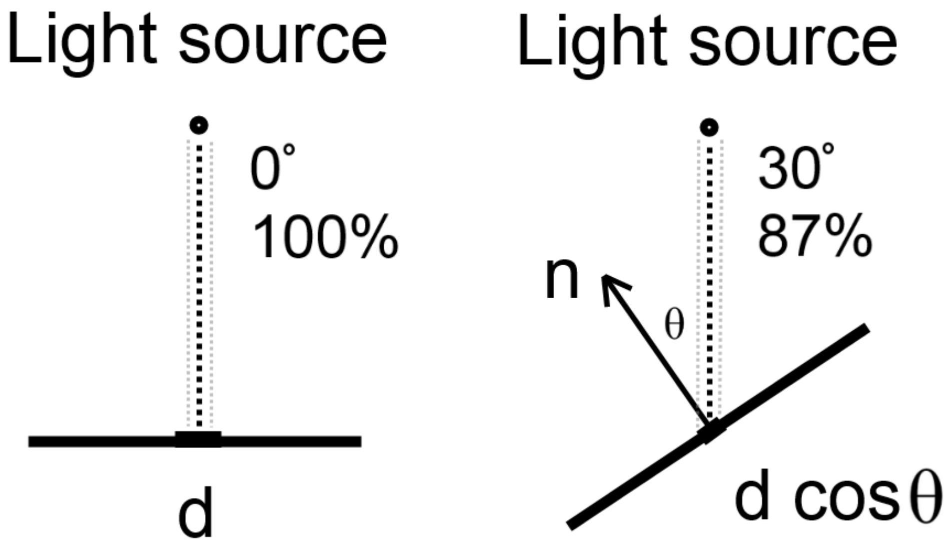
ROYAL INSTITUTE OF TECHNOLOGY

Inverse Square Law

- But we want to know the energy *arriving* at a surface
- This *irradiance,* E, may now be determined:
  - Irradiance is the flux per unit area at a point x, a distance r from the point light source
  - We know the source radiates **I** Watts in all directions
  - So the power is radiated through a sphere centred at the lightsource
  - At a distance r from the source, the surface area of this sphere is $4\pi r^2$ => the power per unit area at x is: $\mathbf{E = \phi / 4\pi r^2}$
  - This assumes the surface at x is perpendicular to the direction to the light source
  - To handle all angles, we must apply the **cosine rule**

The Cosine Law

- A surface orientated perpendicular to a light source will receive more energy than a surface orientated at an angle to the light source
  - More energy = brighter appearance
- The irradiance E is proportional to 1/area
- As the area increases, the irradiance decreases
  - As θ increases, the irradiance (thus surface brightness) decreases:



Lambertian Illumination Model

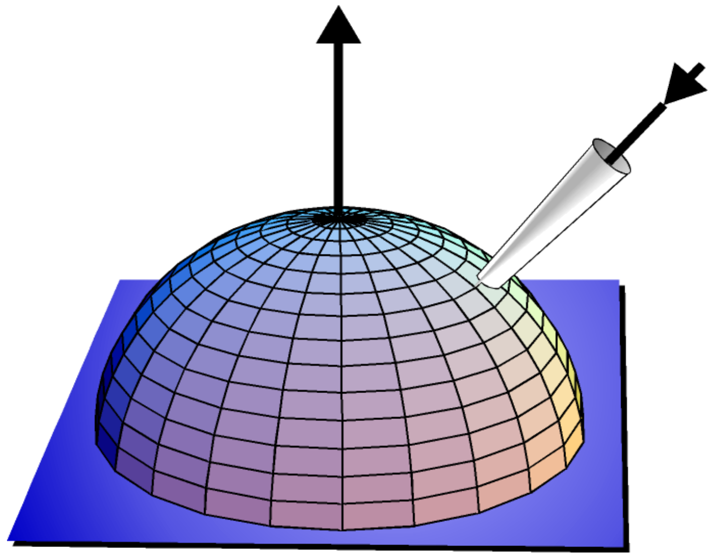
- Cosine rule is used to implement Lambertian surfaces
  - Also known as *diffuse* surfaces
- Diffuse surfaces reflect light equally in all directions
- The surface is characterised by a reflectance parameter ρ_d

$$\forall \ \rho_d(\mathbf{x}) = \phi_i / \phi_r$$

ϕ_i is the incident power

ϕ_r is the reflected power

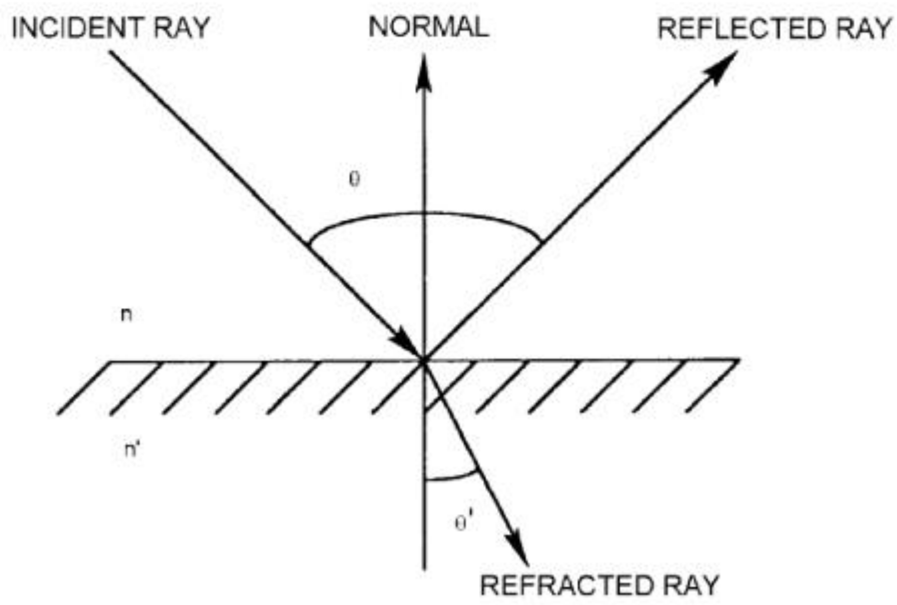
- So the *reflectance* is the ratio of the total incident power to the total reflected power



Surfaces

Must also consider rays hitting and bouncing off surfaces

1. Incoming ray hits surface
2. Divided into,
   - reflected component
   - refracted component

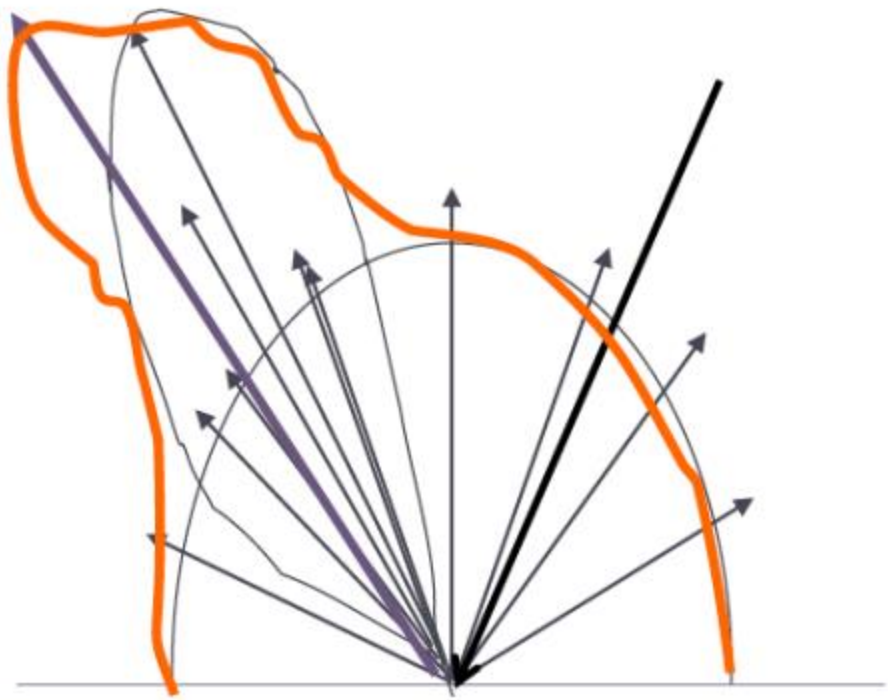


Surface types can reflect/refract rays in different ways

Accurate Reflection

Complex opaque surfaces scatter incoming light in many different directions

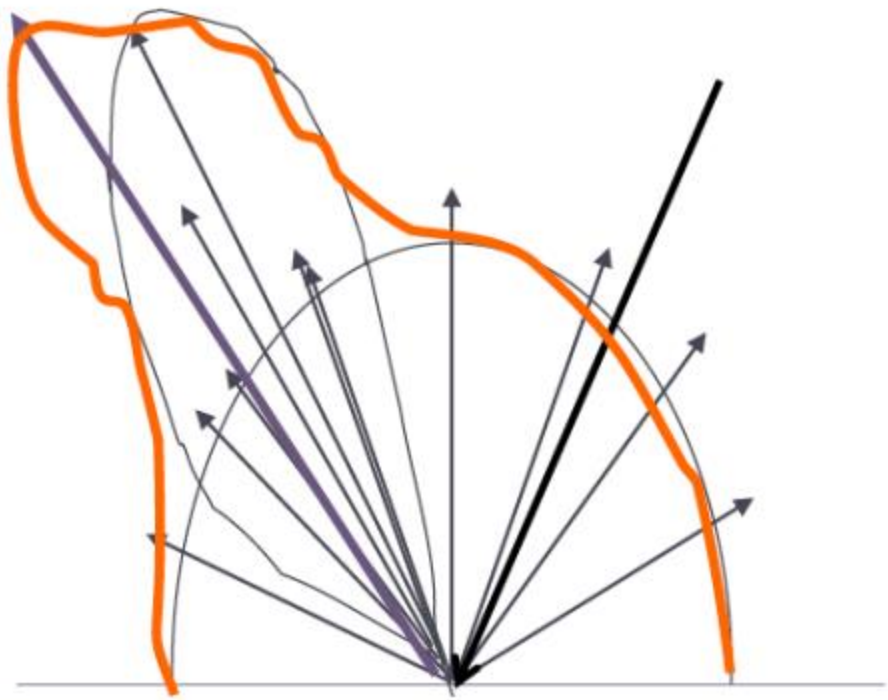
- BRDF - **B**idirectional **R**eflectance **D**istribution **F**unction



Accurate Reflection

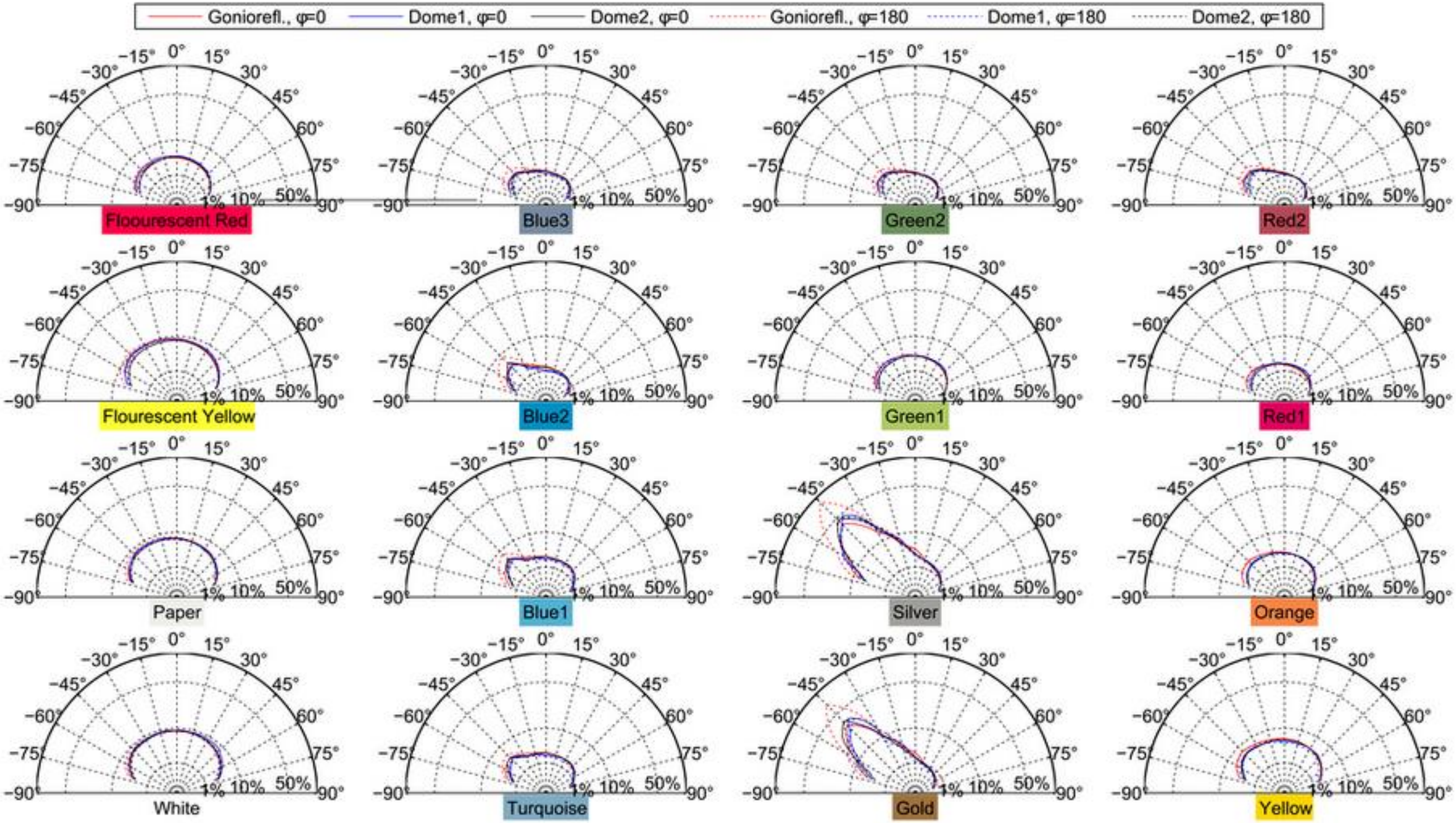
Complex opaque surfaces scatter incoming light in many different directions

- BRDF - **B**idirectional **R**eflectance **D**istribution **F**unction



Where does this information come from?

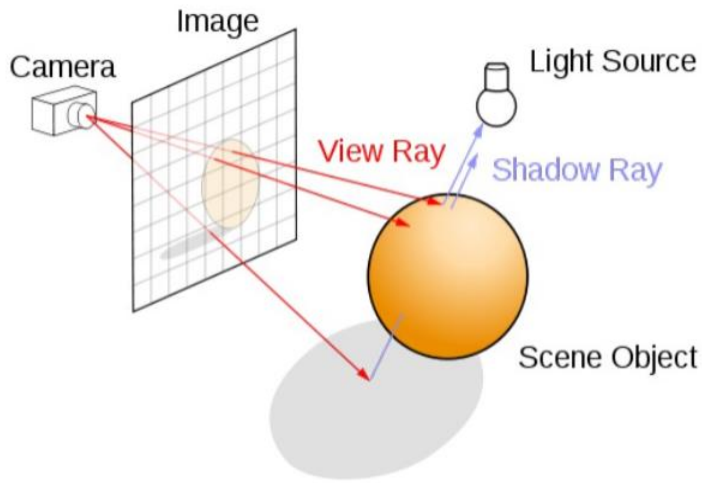
BRDF Revisited

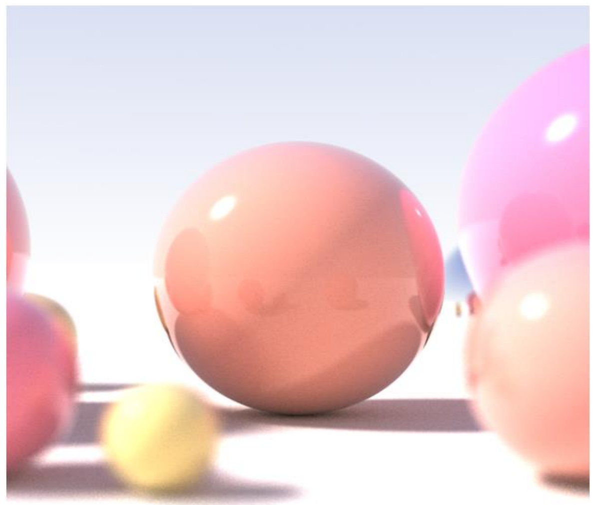


Schwartz et al., Measurement Devices Focusing on the Developments at the University of Bonn, 2014

Raytracing

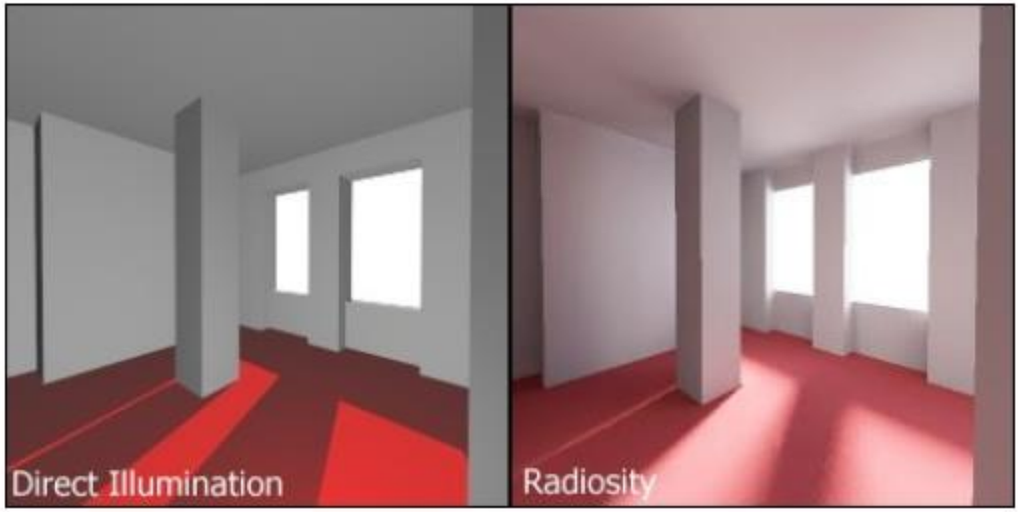
- Few bounces (relatively)
- Light rays striking surface from
  - Light source
  - Specular/refractive direction
- Easy to implement
- Ignore diffuse objects inter-object relationships





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

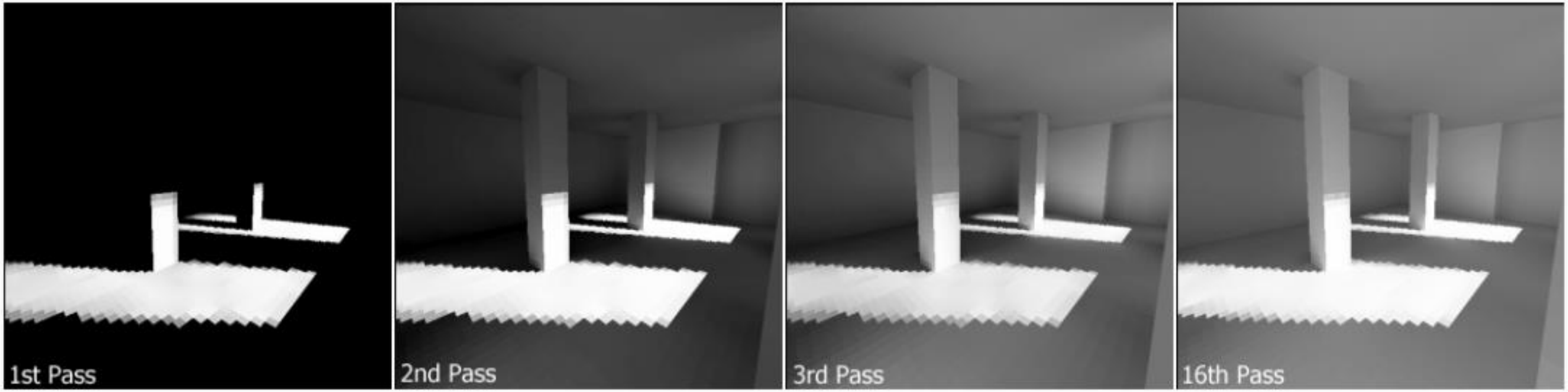
- Surfaces divided up into *patches*
- Do operations between patches
  - Form factors (how well patches are oriented w.r.t. each other, occlusions, distance)
  - Calculate brightness of each patch

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

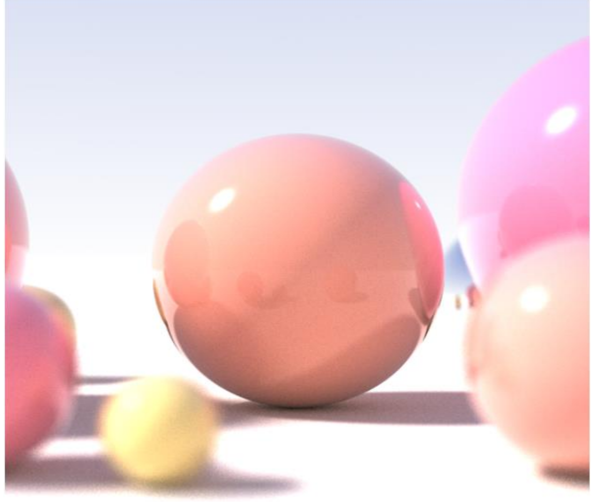
Video: https://www.youtube.com/watch?v=8i2M255Zw9I

Global Illumination

Ray tracing:
- Good for specular
- Bad for diffuse

Radiosity:
- Good for diffuse
- Bad for specular

Hybrid techniques



ROYAL INSTITUTE OF TECHNOLOGY

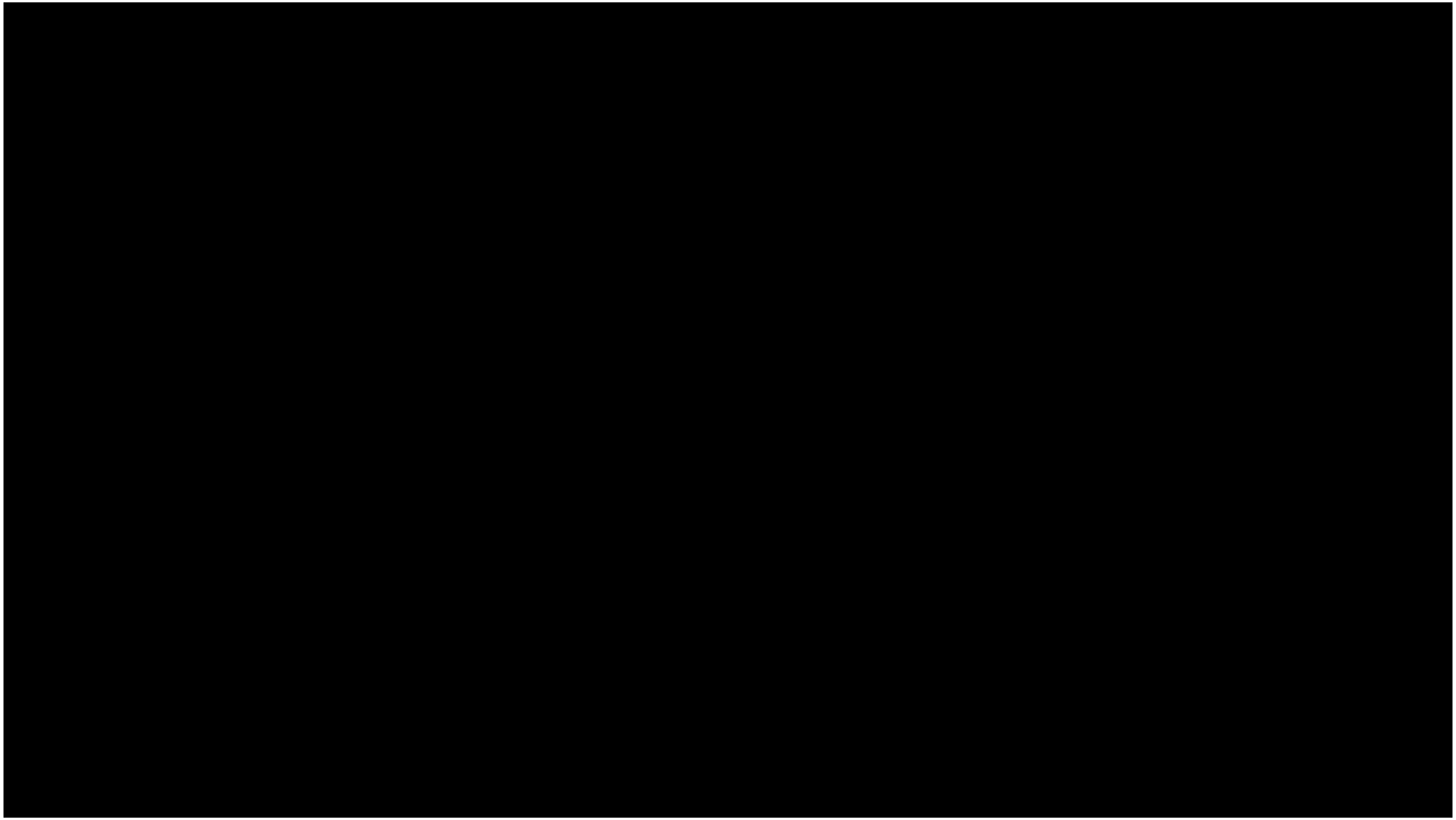
Photon Mapping

- 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

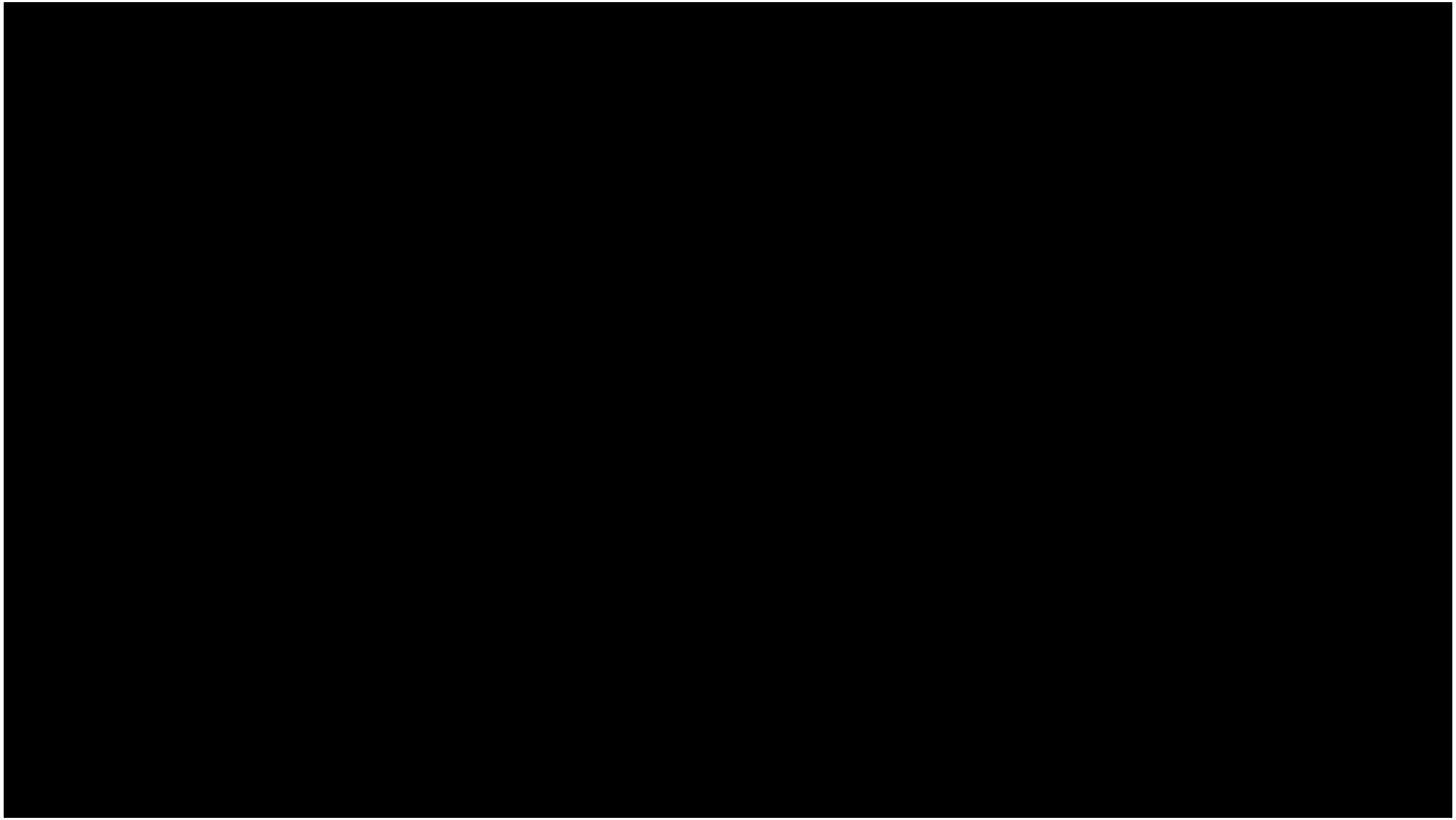
In real-time?



Enlighten

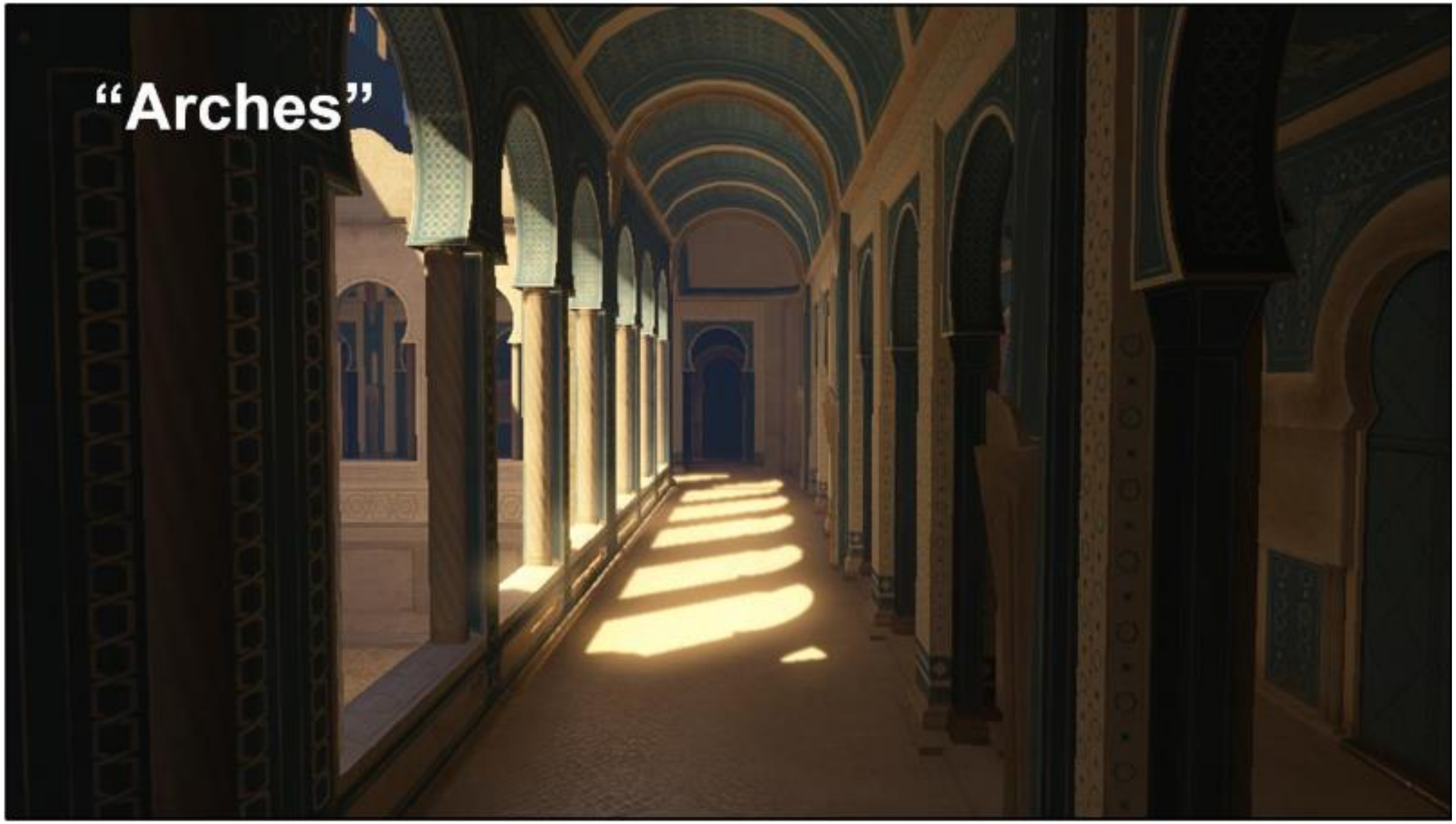
ROYAL INSTITUTE OF TECHNOLOGY

In real-time?



Enlighten

Example: Enlighten



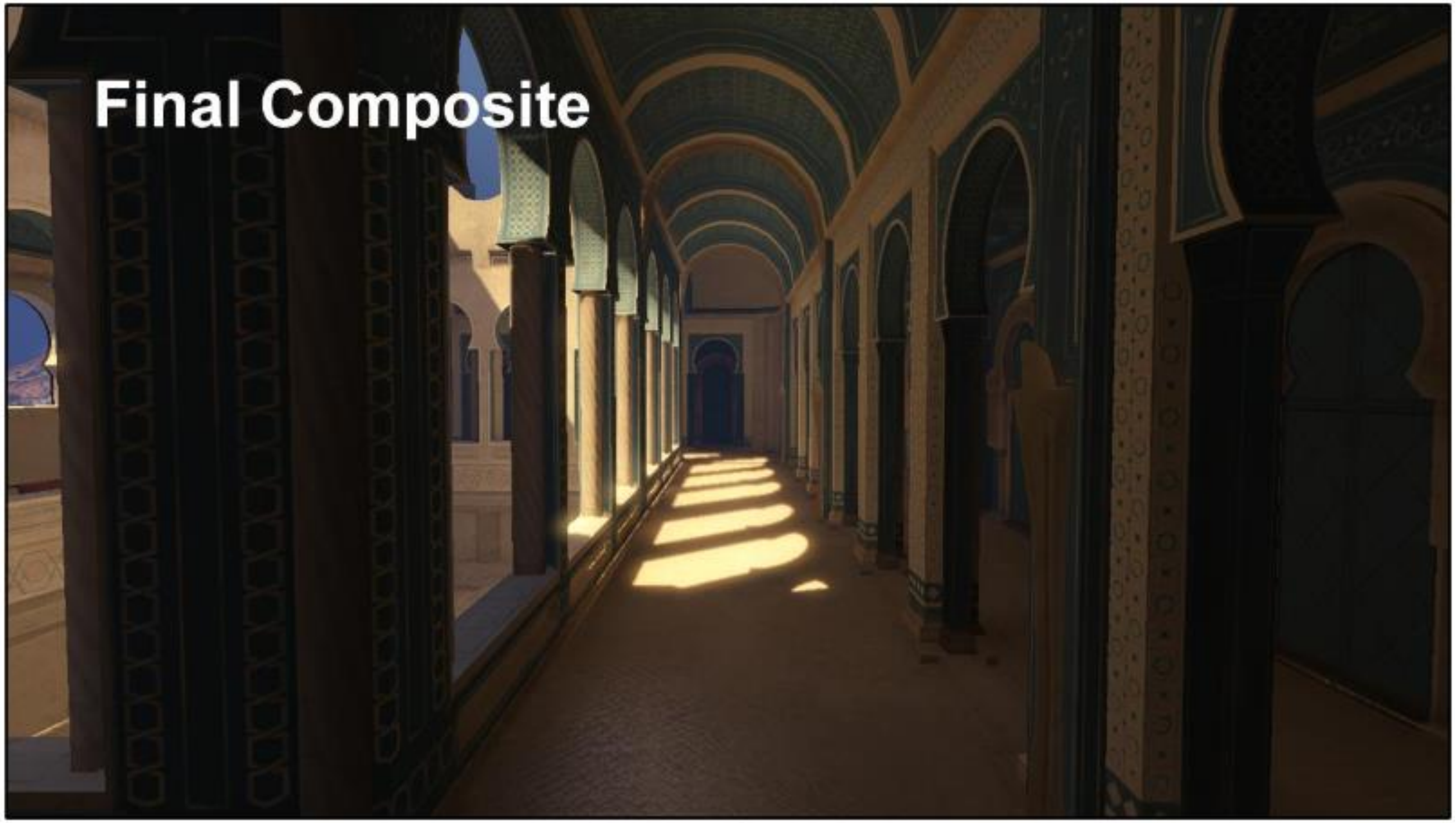
Example: Enlighten

Example: Enlighten

Example: Enlighten

Example: Enlighten

Example: Enlighten

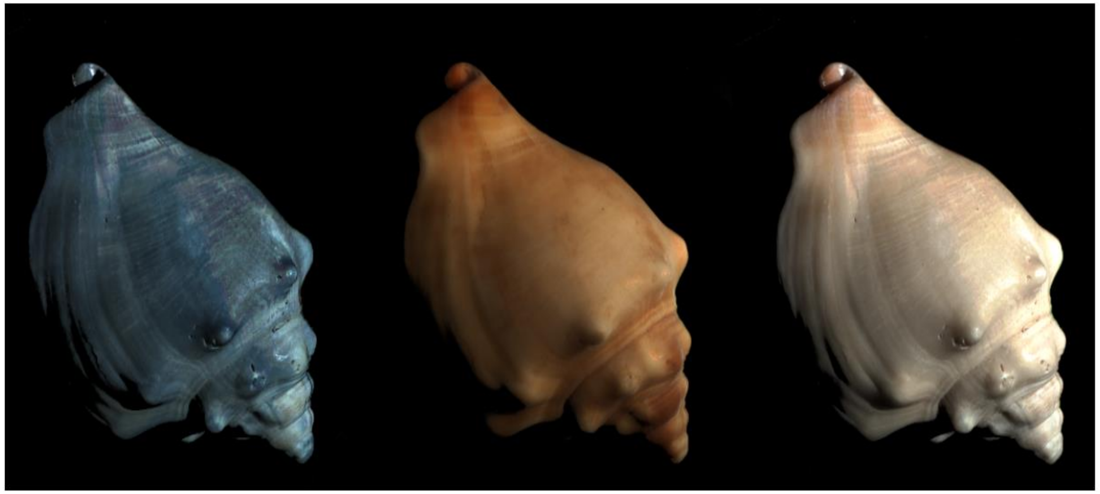


Caustics

- Curved regions of bright reflected or refracted light

Sub-surface scattering

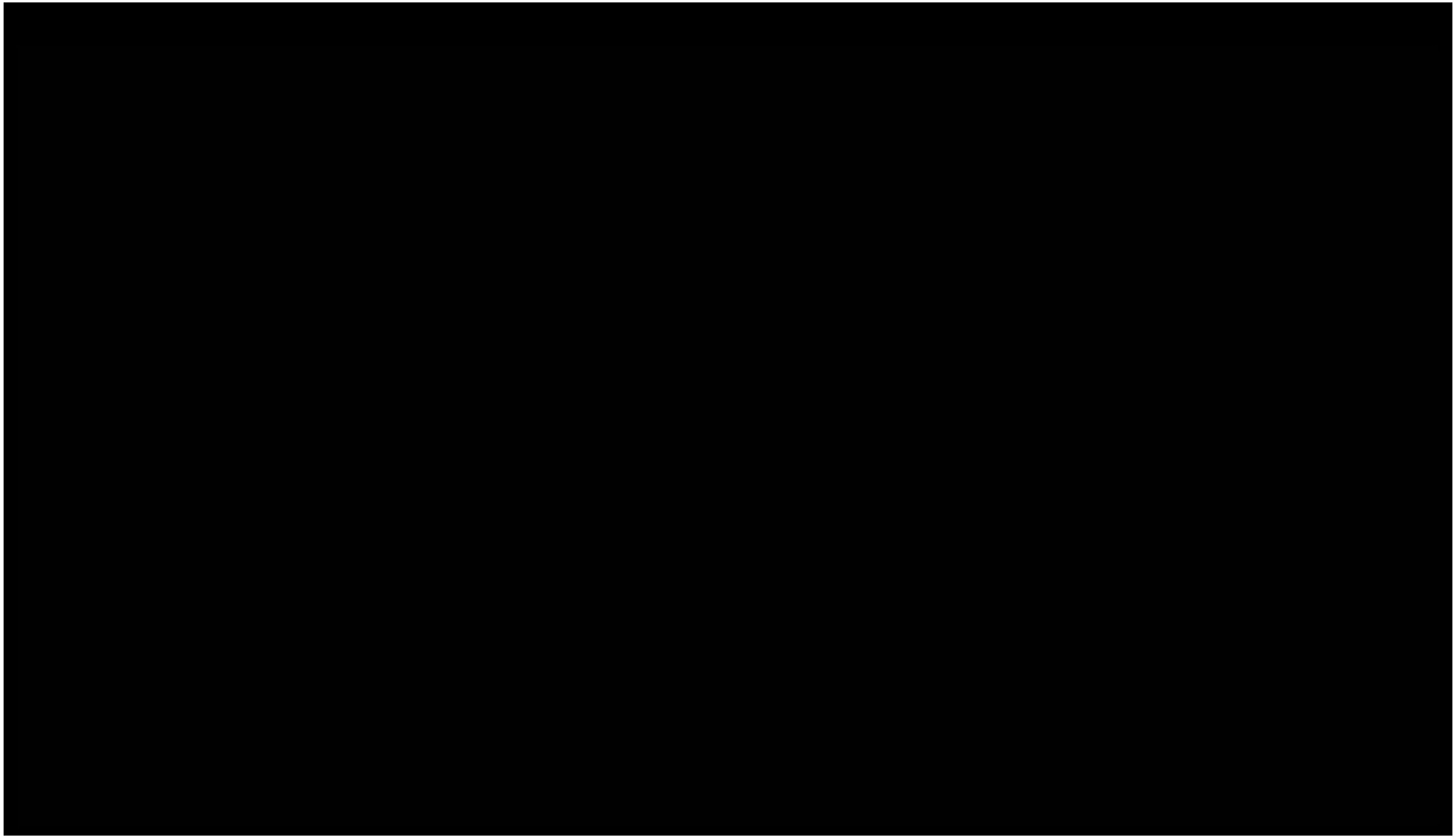
- Light bouncing around inside material before exiting



https://vimeo.com/36048029

Realistic Human Face Rendering for "The Matrix Reloaded", Siggraph 2003

Sub-surface scattering



Photon Mapping Links

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

Great ray tracing and photon mapping

Applet + source code

ROYAL INSTITUTE OF TECHNOLOGY

Next Meetings

Lecture: Introduction to Projects

- Monday 23rd April
- 08:00 – 10:00 D2

Lab session

- Monday 23rd April
- 10:00-12:00
- VIC Studio