cs348b: Image Synthesis Techniques

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CS348b: Image Synthesis

Goal: How to generate photorealistic images?

Applications

- **Movies**
- **Games**
- **Industrial design**
- **Architecture**
- **Commerce**
- **Cultural heritage**
- **Simulators (ML) and trainers**

***War for the Planet of the Apes* (2017)**

***The Abyss* (1989)**

Jurassic Park (1993)

***Toy Story* (1995)**

***Titanic* (1997)**

***Bunny* (1998)**

***Gravity* (2013)**

***Battle Angel* (2019)**

Architecture: Impulse Arts, “Wochendhaus”

Enrico Cerica

Ikea Catalog

Image courtesy of Porsche, Epic Games and NVIDIA

Product Design

Simulation / ML Training: Aurora

Physically-Based Rendering

Modeling and Simulating the World

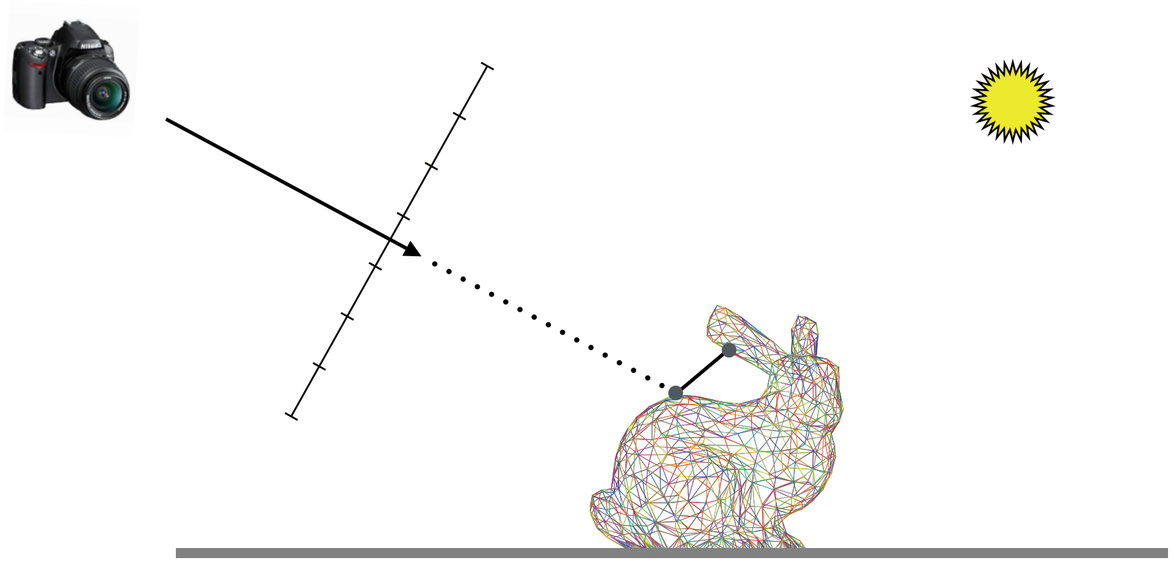
***Titanic* (1997)**

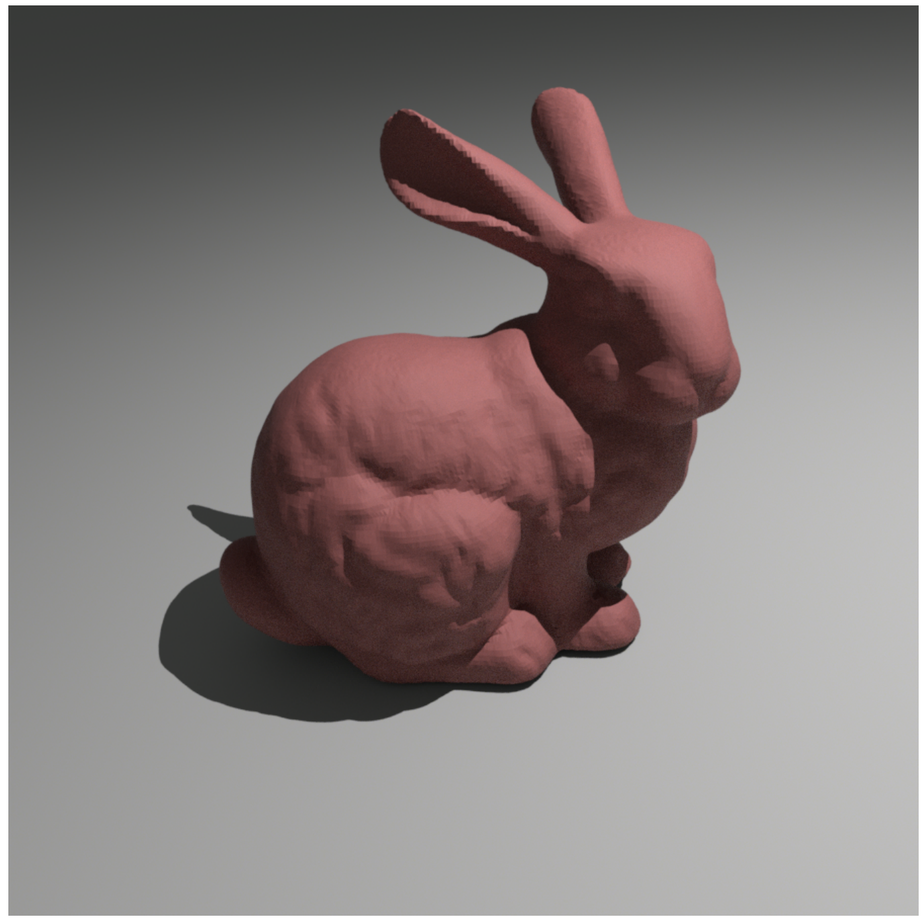
War for the Planet of the Apes (2017)

NVIDIA Marbles At Night (2021)

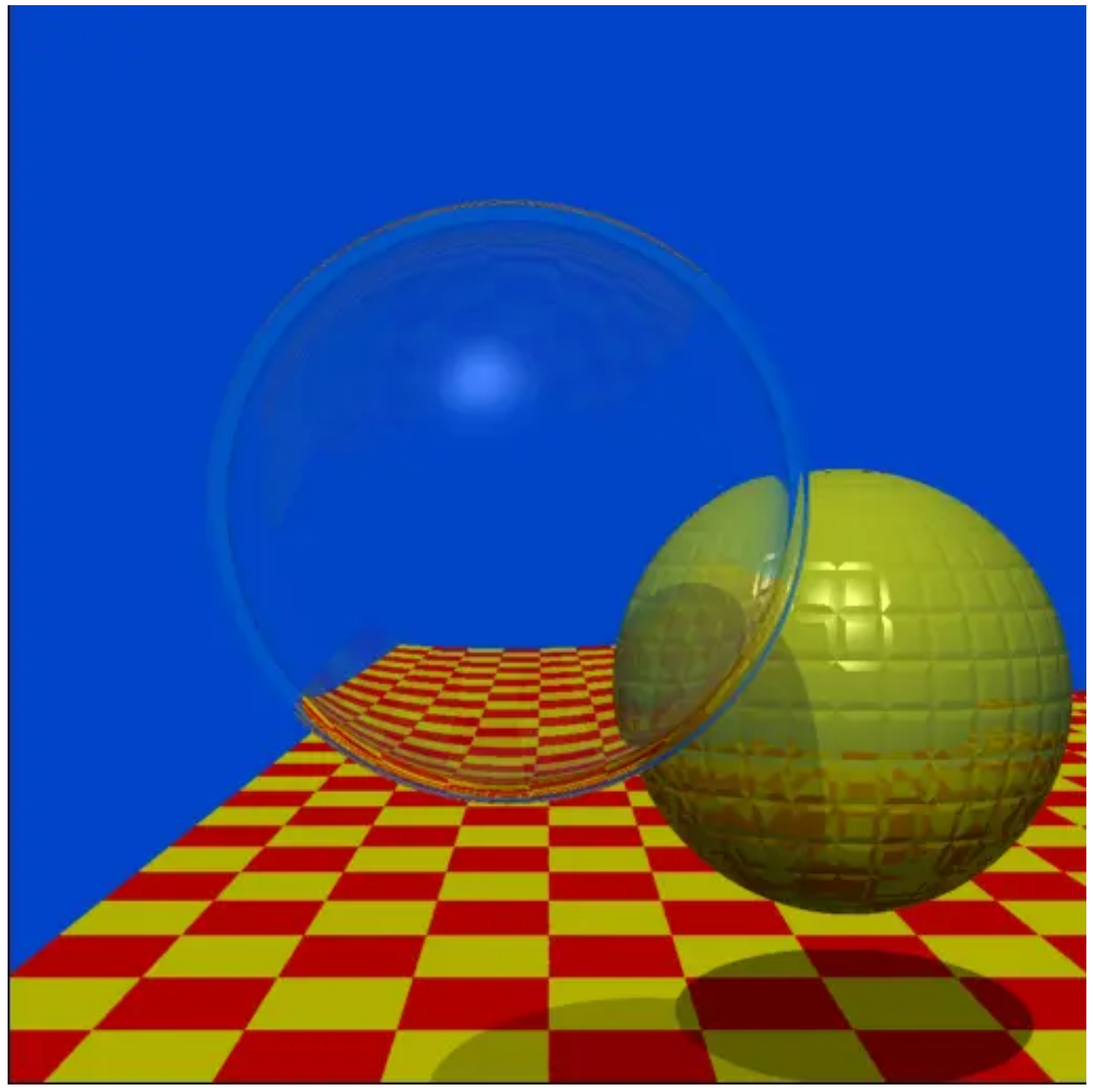
Ray Tracing and Path Tracing

Ray Traced Visibility and Shadows



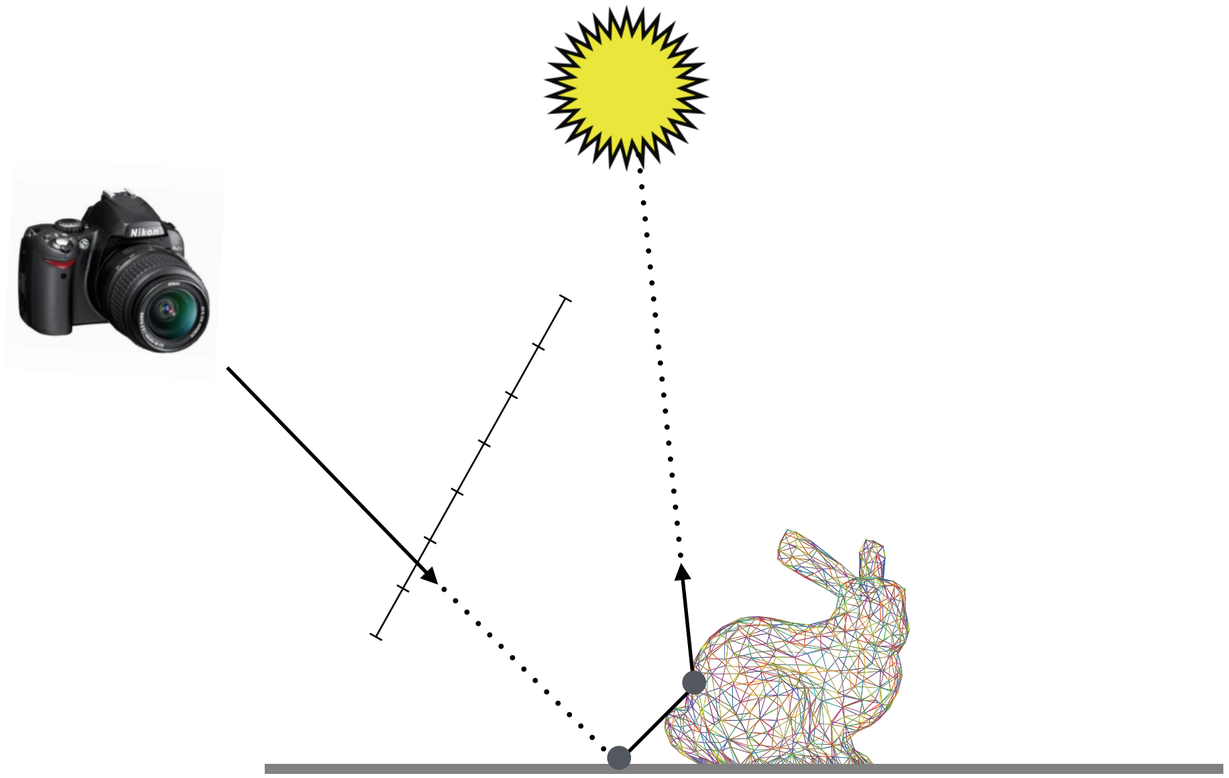


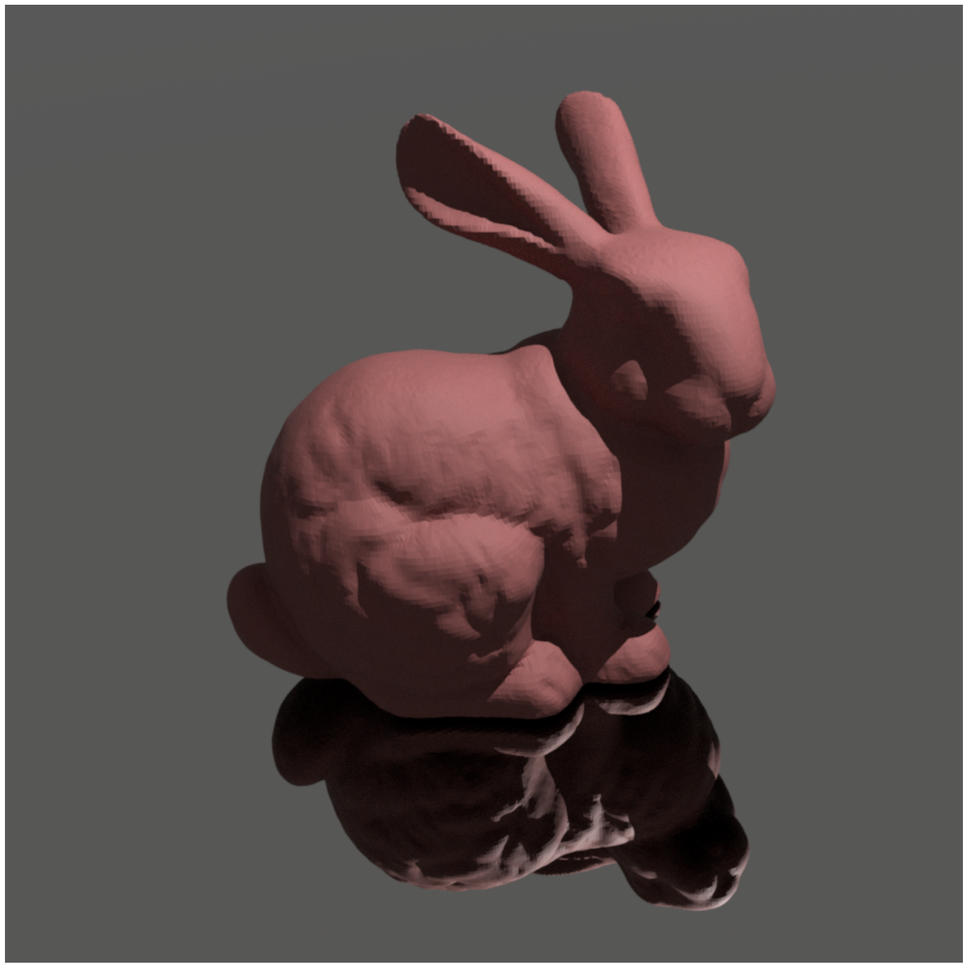
Whitted Ray Tracing



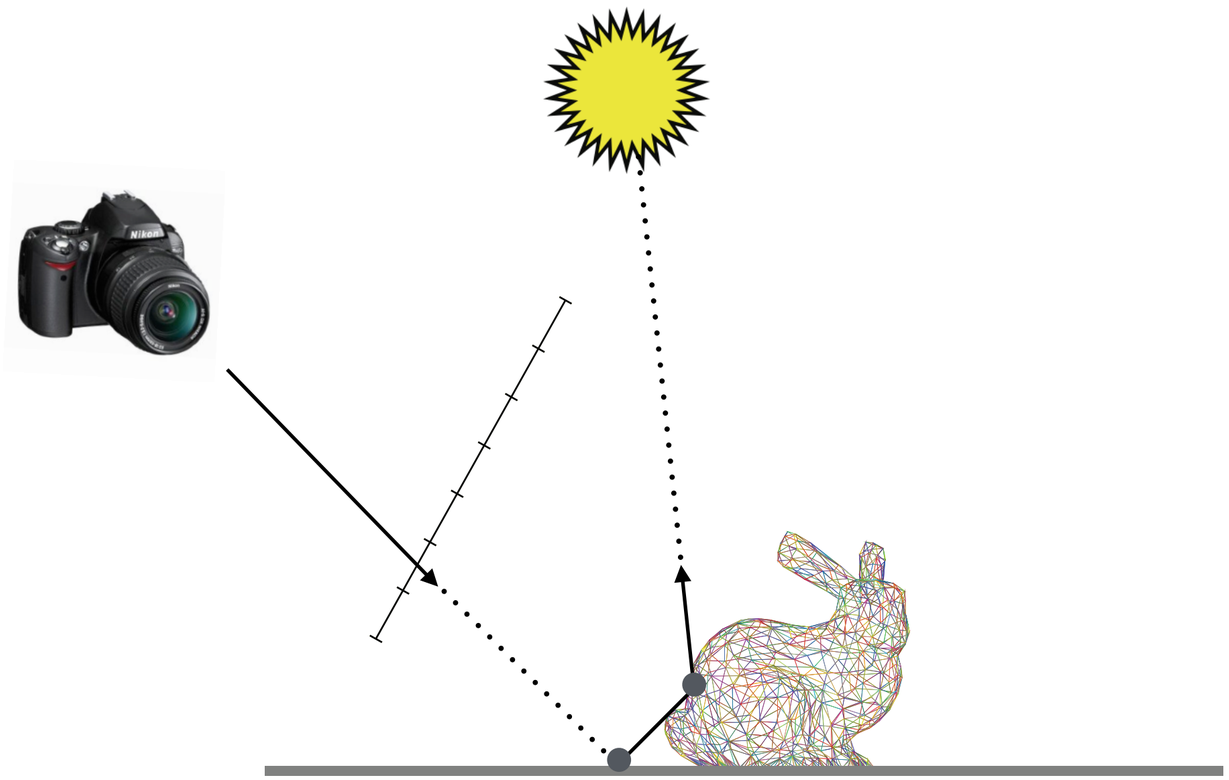
Whitted, *An Improved Illumination Model For Shaded Display*, 1979.

Whitted Ray Tracing





Whitted Ray Tracing

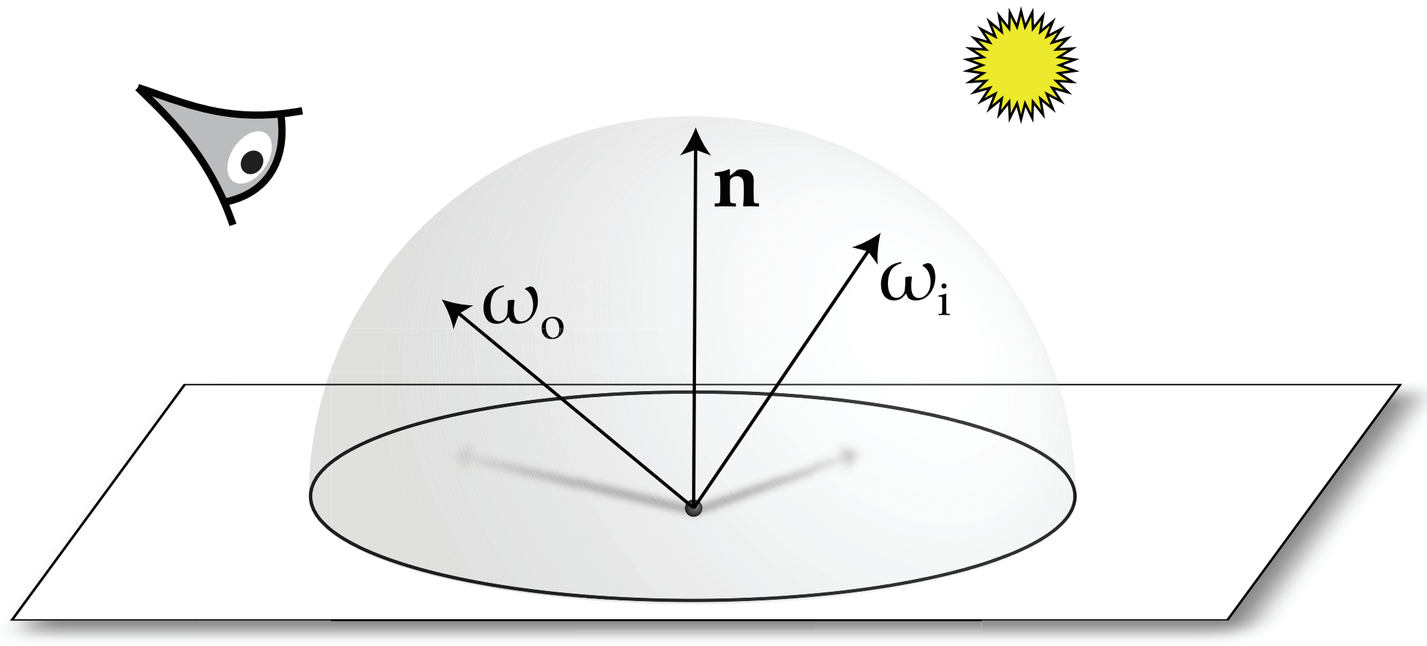


Recursive Expression:

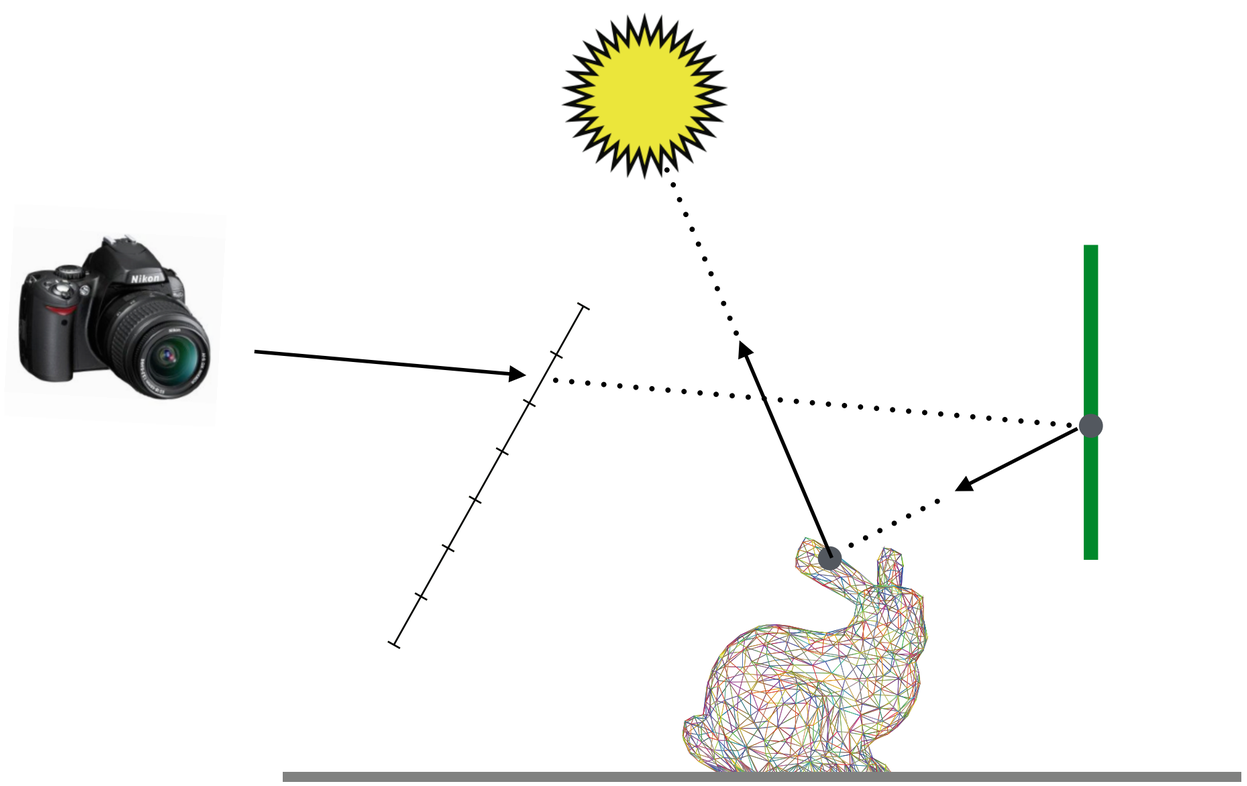
```
Whitted(ray) {
  L = 0;
  if (IntersectClosest(ray)) {
    if (SurfaceIsSpecular)
      return Whitted(specularRay);
    else if (LightIsVisible)
      L += scatteredIllumination;
  }
  return L;
}
```

The Rendering Equation

$$L_o(\omega_o) = L_e(\omega_o) + \int_\Omega f_r(\omega_i \rightarrow \omega_o)\, L_i(\omega_i)\, \cos\theta_i \, \mathrm{d}\omega_i$$



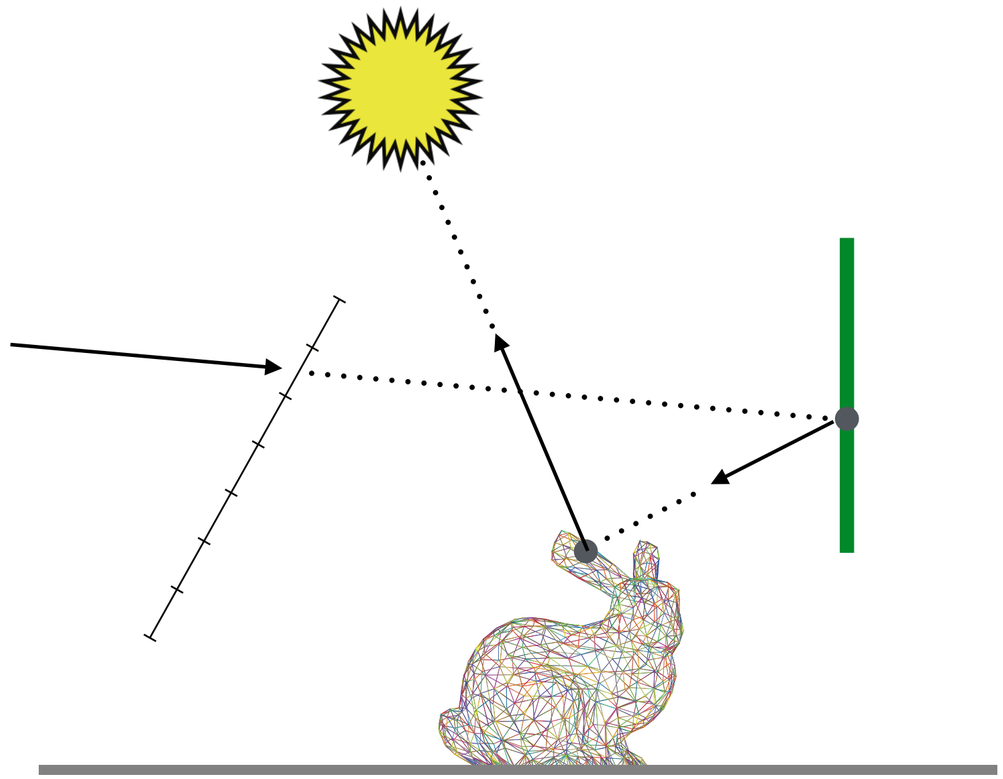
Random Walk—Path Tracing

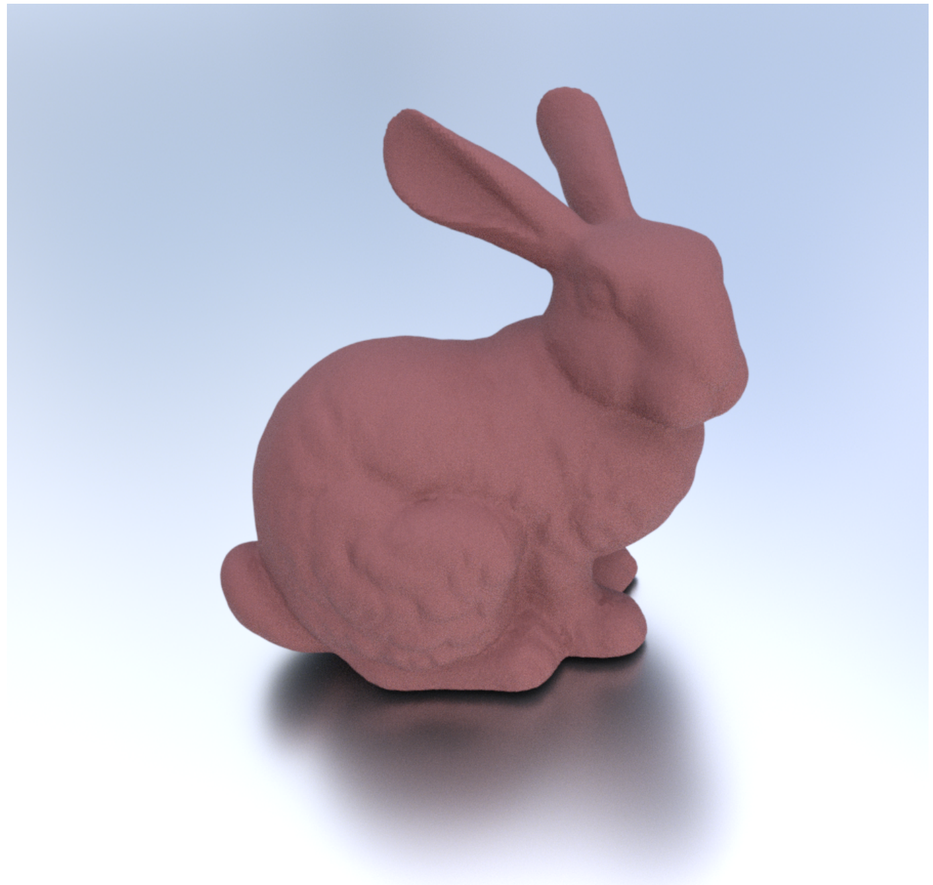


Recursive Expression:

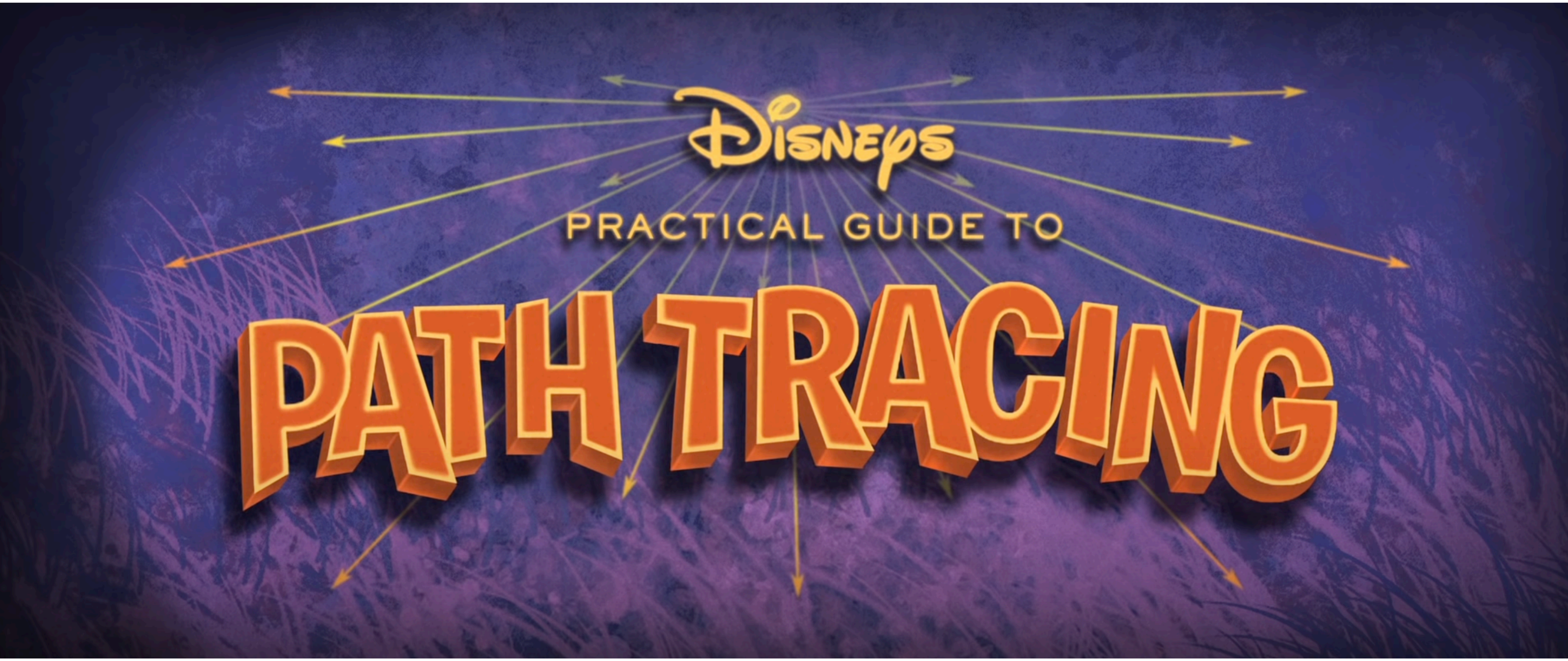
```
PathTrace(ray) {
  L = 0;
  if (IntersectClosest(ray)) {
    L += surfaceEmission;
    ray = randomDirection();
    L += reflection * PathTrace(ray);
  }
  return L;
}
```

Random Walk—Path Tracing





Disney's Practical Guide to Path Tracing



https://www.youtube.com/watch?v=frLwRLS_ZR0

Rendering as Physical Simulation

Models

- **Light**
- **Light sources**
- **Materials and shapes**
  - **Surfaces: Reflection and texture models**
  - **Media: Atmospheric scattering models**
- **Cameras**

Simulation

- **Light transport algorithms**
  - **Efficient ray-surface queries for many shapes**
  - **Sampling ray paths using Monte Carlo integration**

Measuring Light and Reflection

Cornell Box

Cornell Box Data

Cornell University Program of Computer Graphics

Photographic Images

We have made high-quality pictures of the Cornell box in its current configuration. The liquid-cooled Photometrics PXL1300L CCD camera has a precision of 12 bits. We used 7 narrow-band filters to get a coarse sampling across the visible spectrum. Dark current has been subtracted from the images, and flat-field correction has been applied to account for the cosine fall-off and the lens fall-off. The following data are available:

- **IPLab images** The images are collected in a compressed `tar` file (10 MB compressed, 18 MB uncompressed!). They are in IPLab format, which can be read using a simple Matlab function `iplab_read`.
- **TIFF images** The images are available in TIFF files, with 16 bits per pixel. This format can be read by a number of applications, including Photoshop. There is a choice of either a compressed `tar` archive (about 10MB compressed, 18MB uncompressed) or a ZIP archive (about 10MB).
- **OpenEXR images** The images are also available in the OpenEXR high-dynamic-range image format. Each pixel is represented as a 15-bit floating-point number with a 10-bit mantissa and 5-bit exponent. There is a choice of either an uncompressed `tar` archive (about 8MB, `gzip` compression shrinks it by only 0.4%) or a ZIP archive (about 8MB).
- **Transmission spectra** of the 7 corresponding filters, the lens system, and the response spectrum of the camera are available from our page with measurement data.

Synthetic Images

A synthetic image file, generated from the data below, is available in two formats:

- As a `jpeg` file
- As an `rgbe` file. RGBE is a floating point image format for which the specifications and I/O functions are available.

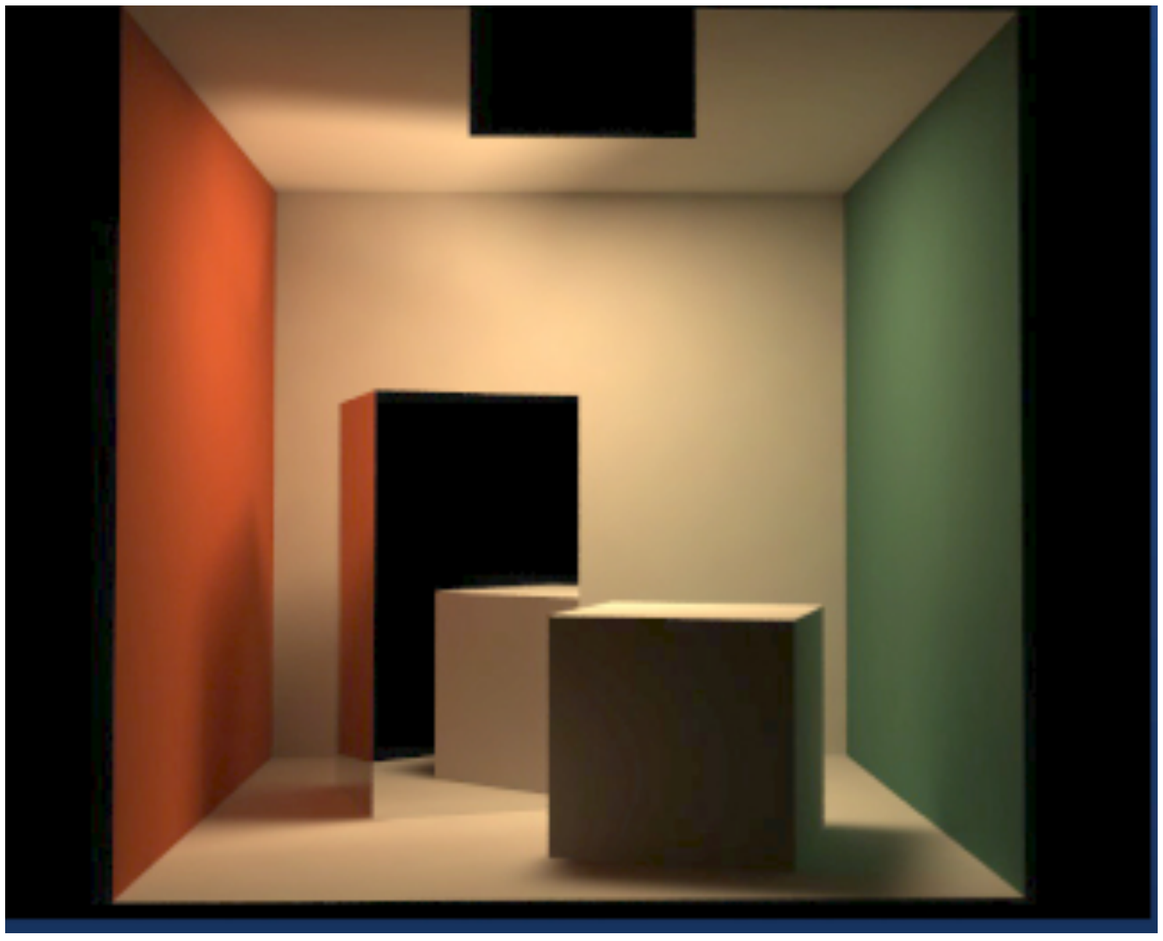
Scene Data

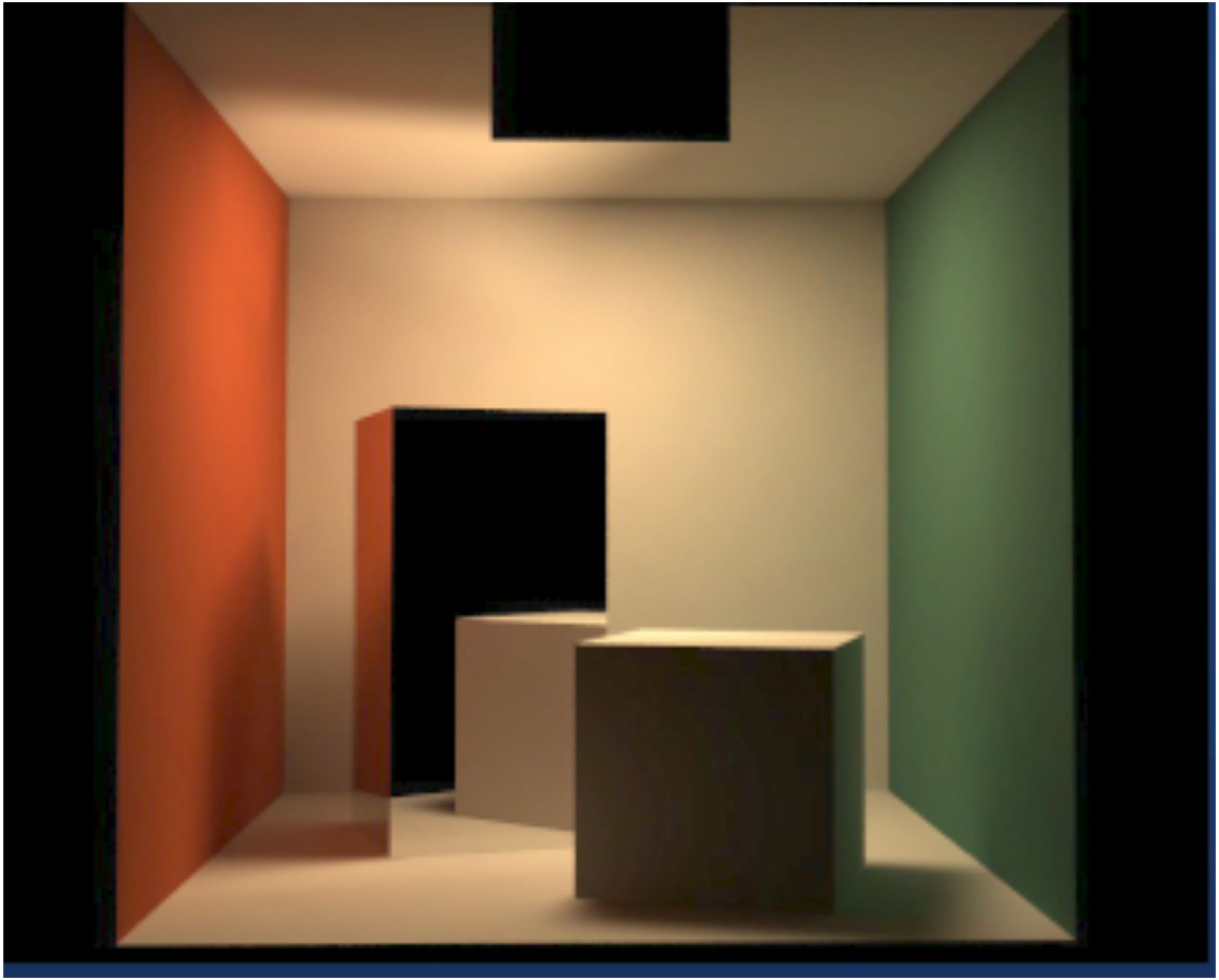
The reflectance data and the geometric data for the Cornell Box (with diffuse objects) are presented below. The data are also available in two other formats:

- As an `mdla` file. MDLA is a format defined at Cornell for scene descriptions, with specifications that are easily extendible.
- As an Inventor file. The RGB reflectance values in this file are for previewing purposes only; they do not correspond to the real spectral data.

http://www.graphics.cornell.edu/online/box/

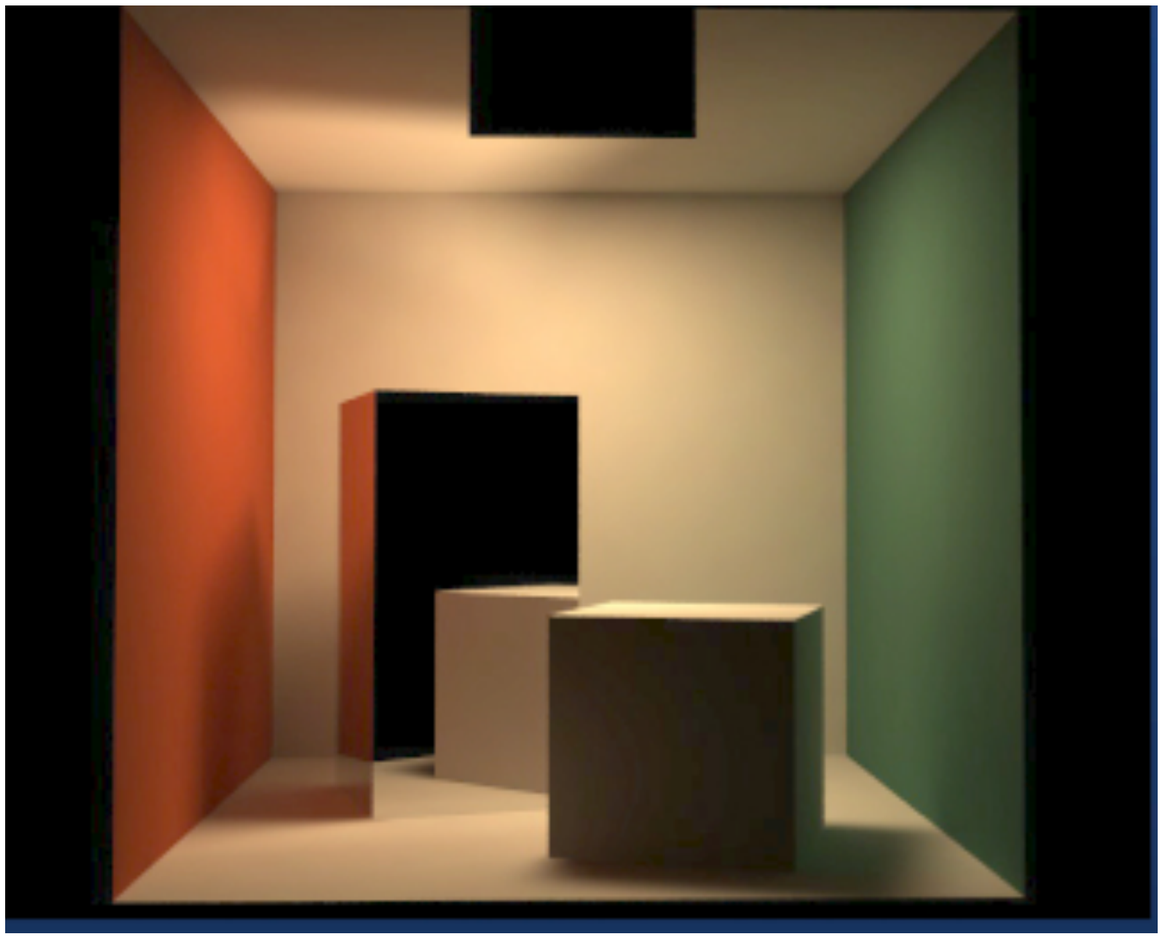
Which is Real?





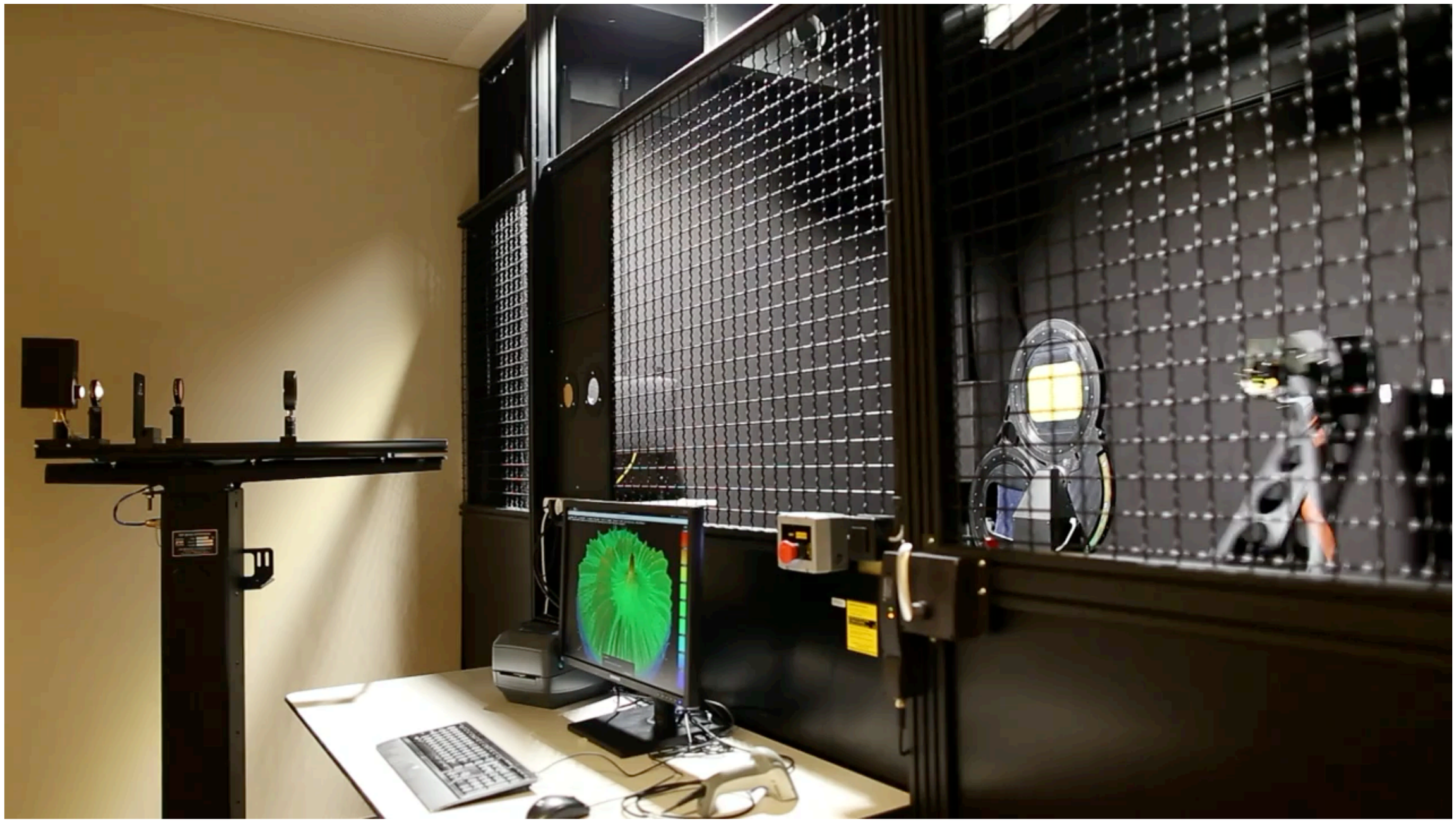
Which is Real?

Photograph



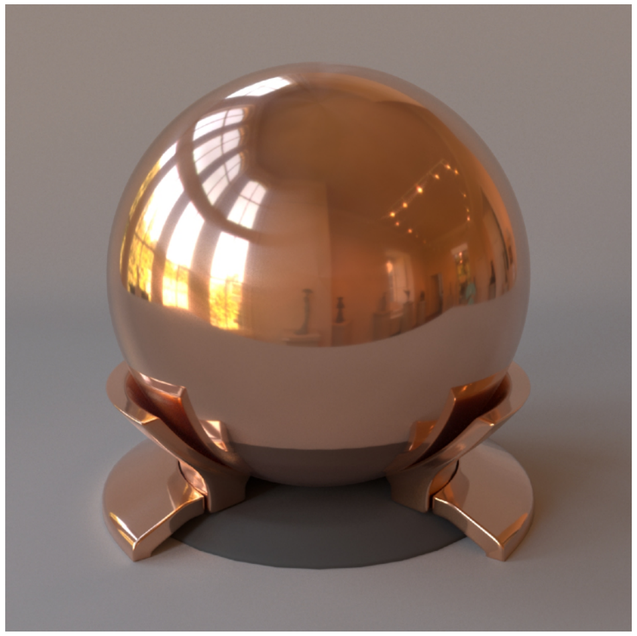
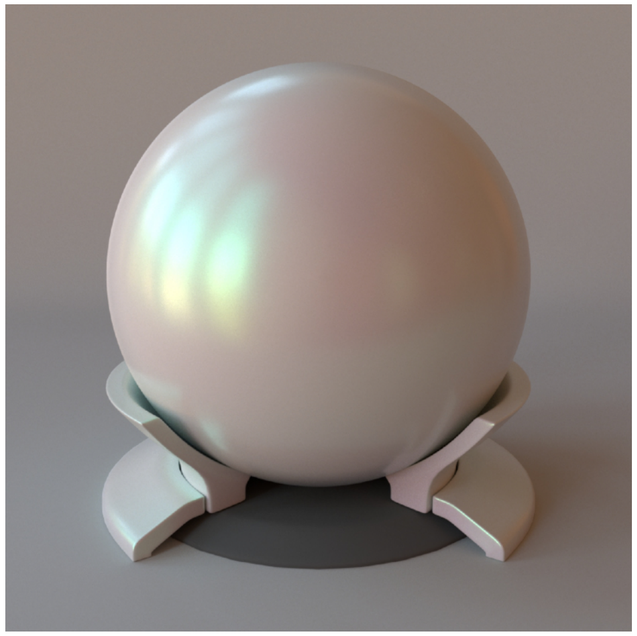
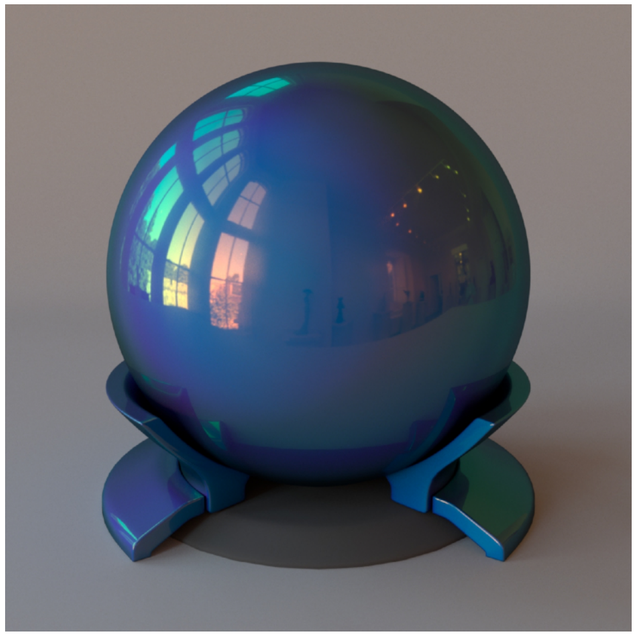
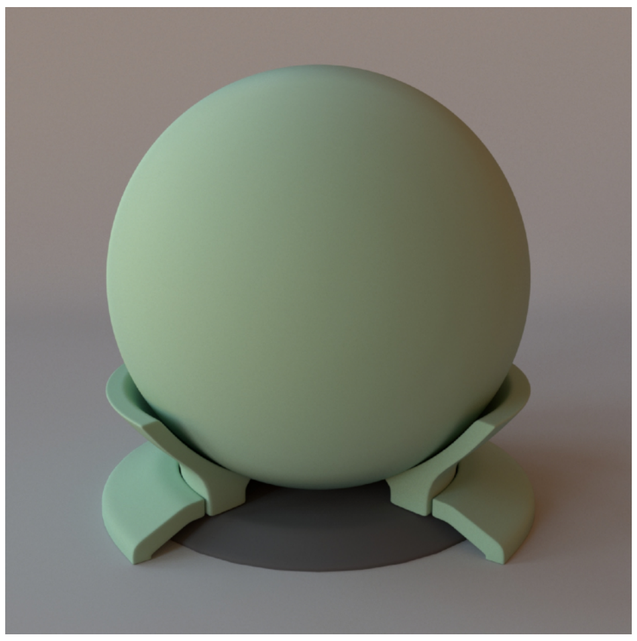
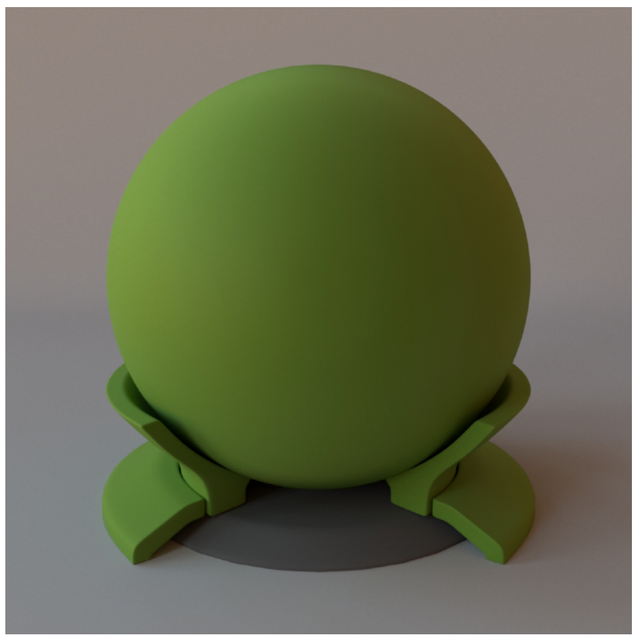
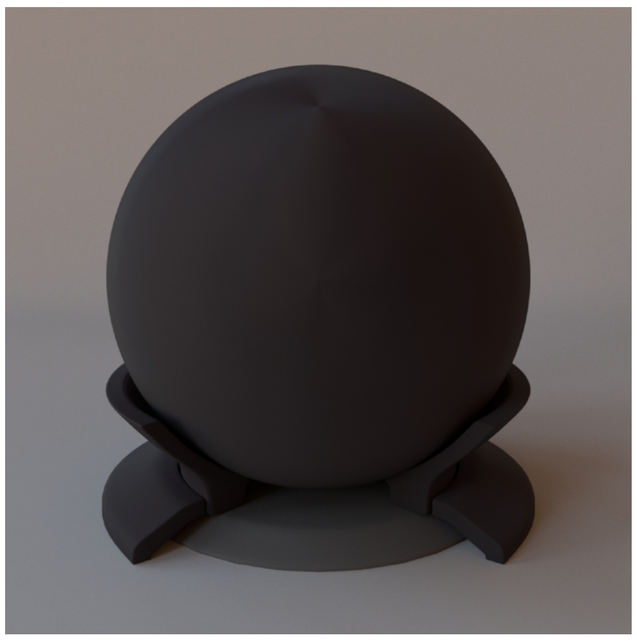
Rendering

Data-Driven Rendering



EPFL Goniophotometer

Data-Driven Rendering

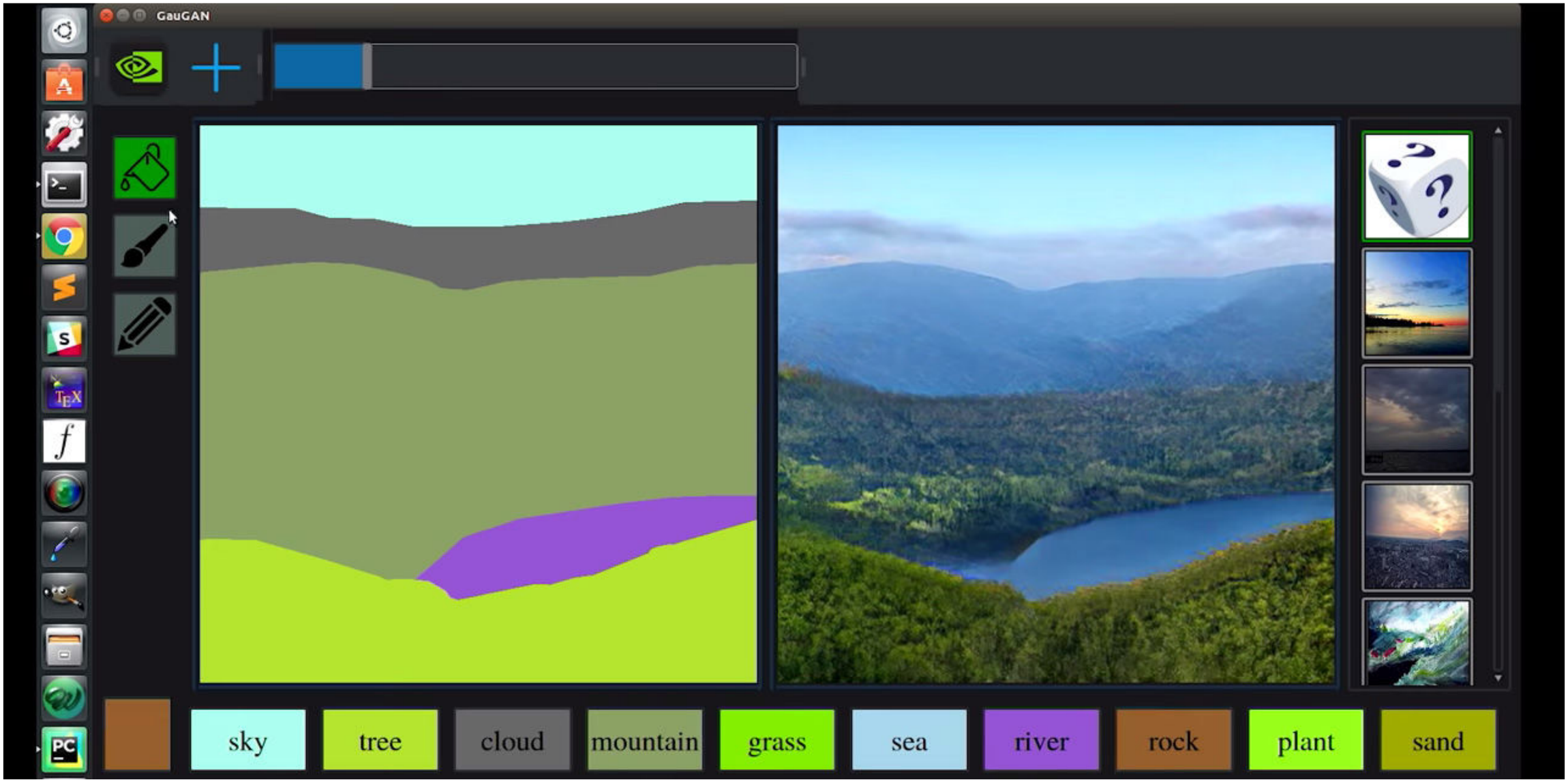







EPFL RGL Material Database

Data-Driven Rendering

Greg Zaal: https://polyhaven.com/a/rathaus

Data-Driven Rendering?



Gaugan [Park et al. 2019]

Algorithms and Architectures

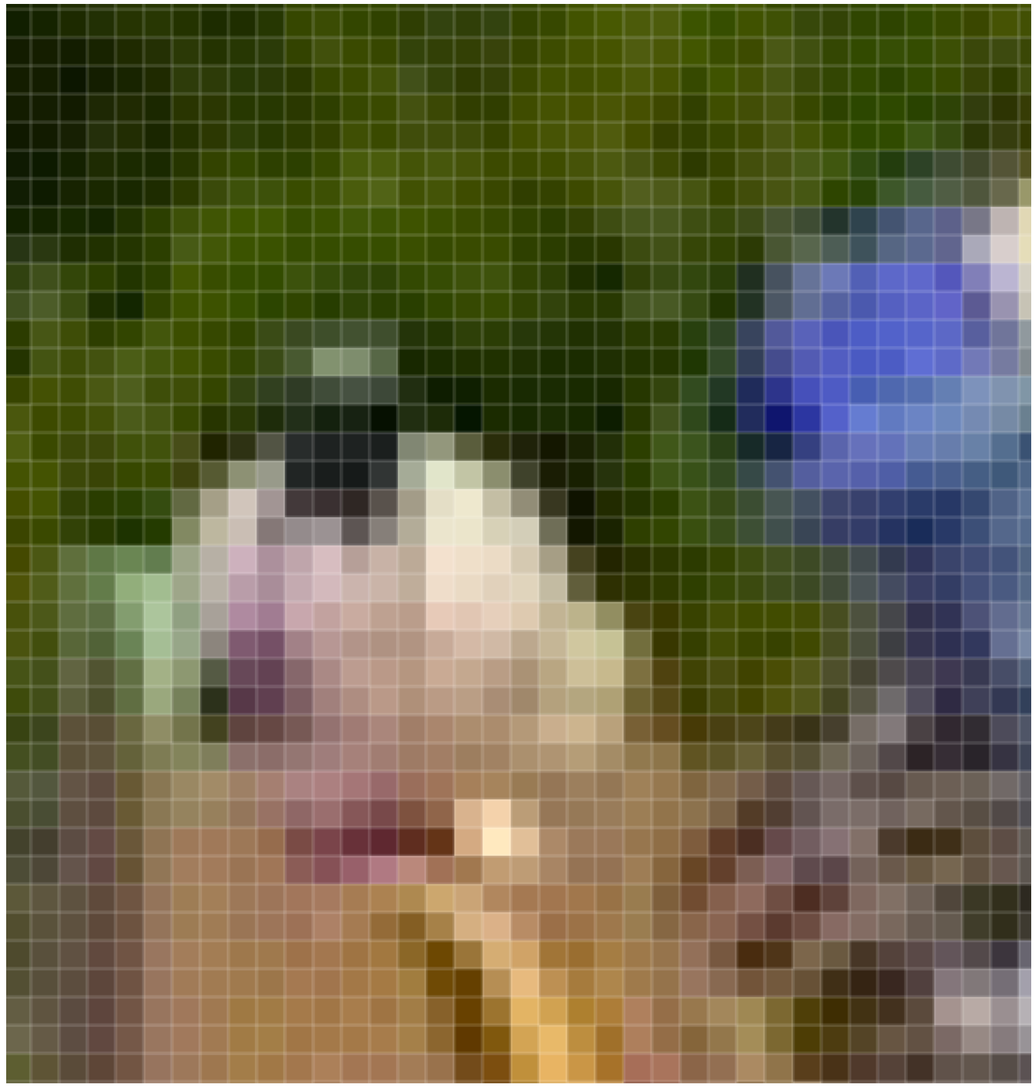

Welcome Freshme

Full Movie: 100 million hours of CPU time!

29 hours/frame =
29*60*60 seconds/frame
104,400 seconds/frame

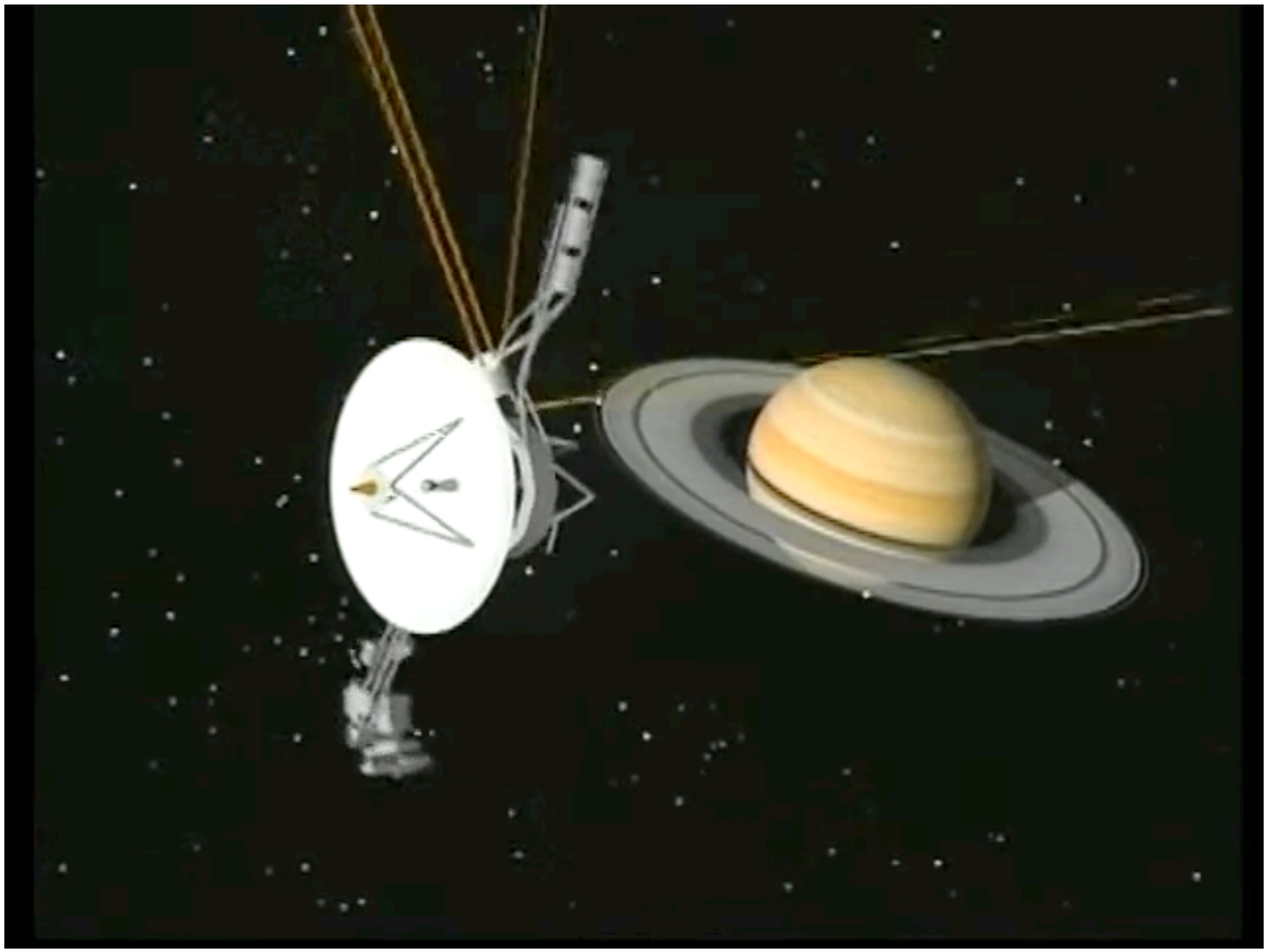
100K seconds/frame *
10 GFLOPs =
~1 PFLOP

1 PFLOP / 1 Megapixel =
~ 1 GFLOP / pixel



Blinn's Law

"As technology advances, rendering time remains constant"



***Voyager 2 Saturn Flyby* (1981)**

Blinn's Law in Action

Monsters, Inc. (2001)

Blinn's Law in Action

Monsters University (2013)

Blinn's Law in Action

Monsters, Inc. (2001)

Blinn's Law in Action

Monsters University (2013)

Modeling and Simulating the World...

With a Computational Budget

Interdisciplinary Topics

Computer science

- **Computational geometry**
- **Computer architecture**

Physics

- **Bidirectional reflectance distribution functions**
- **Radiometry and light fields**
- **Radiative transport**

Mathematics

- **Integral equations**
- **Monte Carlo methods**

Perception

Art and design

[Walt Disney Animation Studios]

Course Mechanics

https://cs348b.stanford.edu/

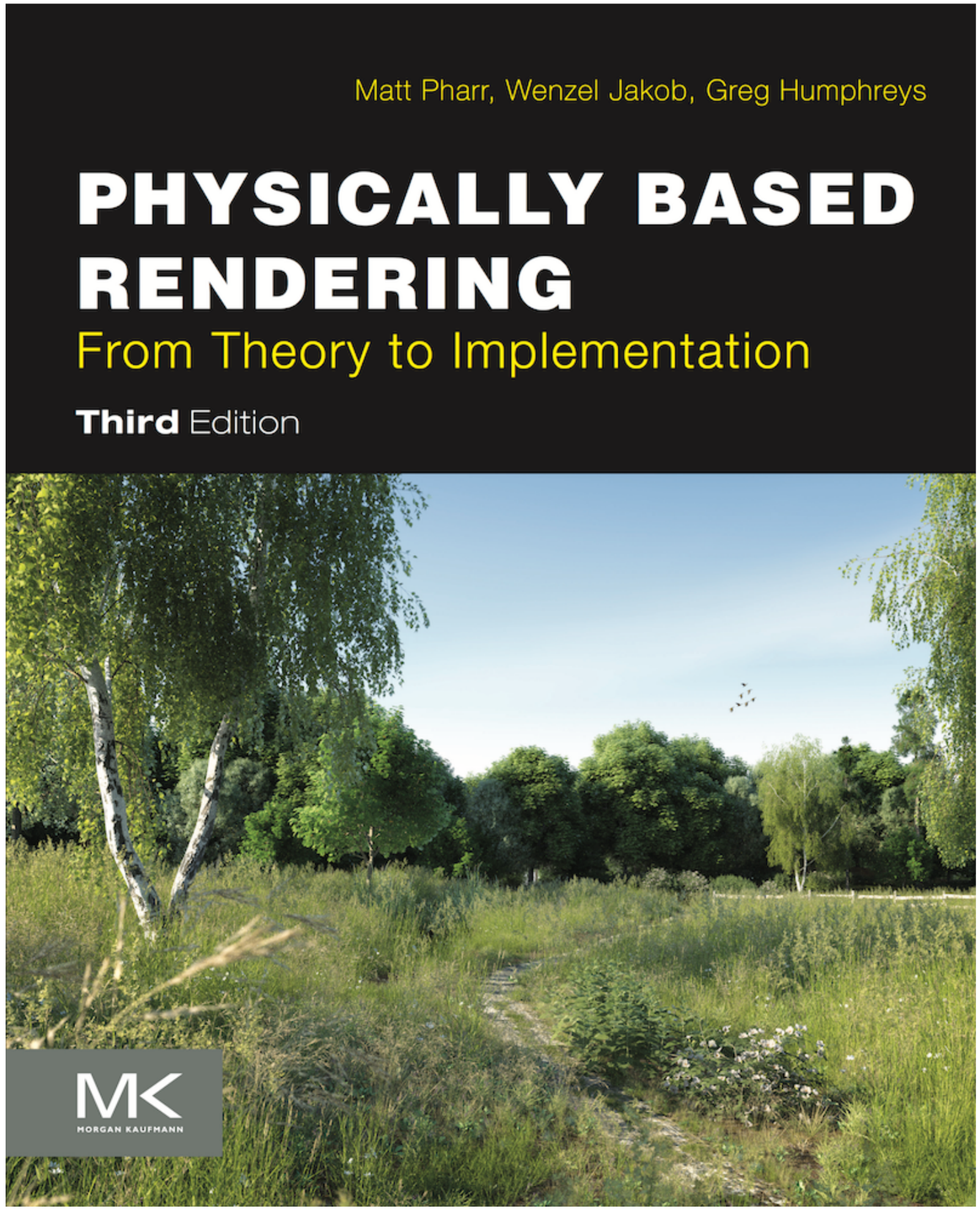
(https://gfxcourses.stanford.edu/cs348b/spring22/)

https://edstem.org/us/courses/21377/discussion/

DRAFT (2 July 2002) — Do Not Distribute

A LITERATE RAY TRACER

Matt Pharr and Greg Humphreys



http://www.pbr-book.org/

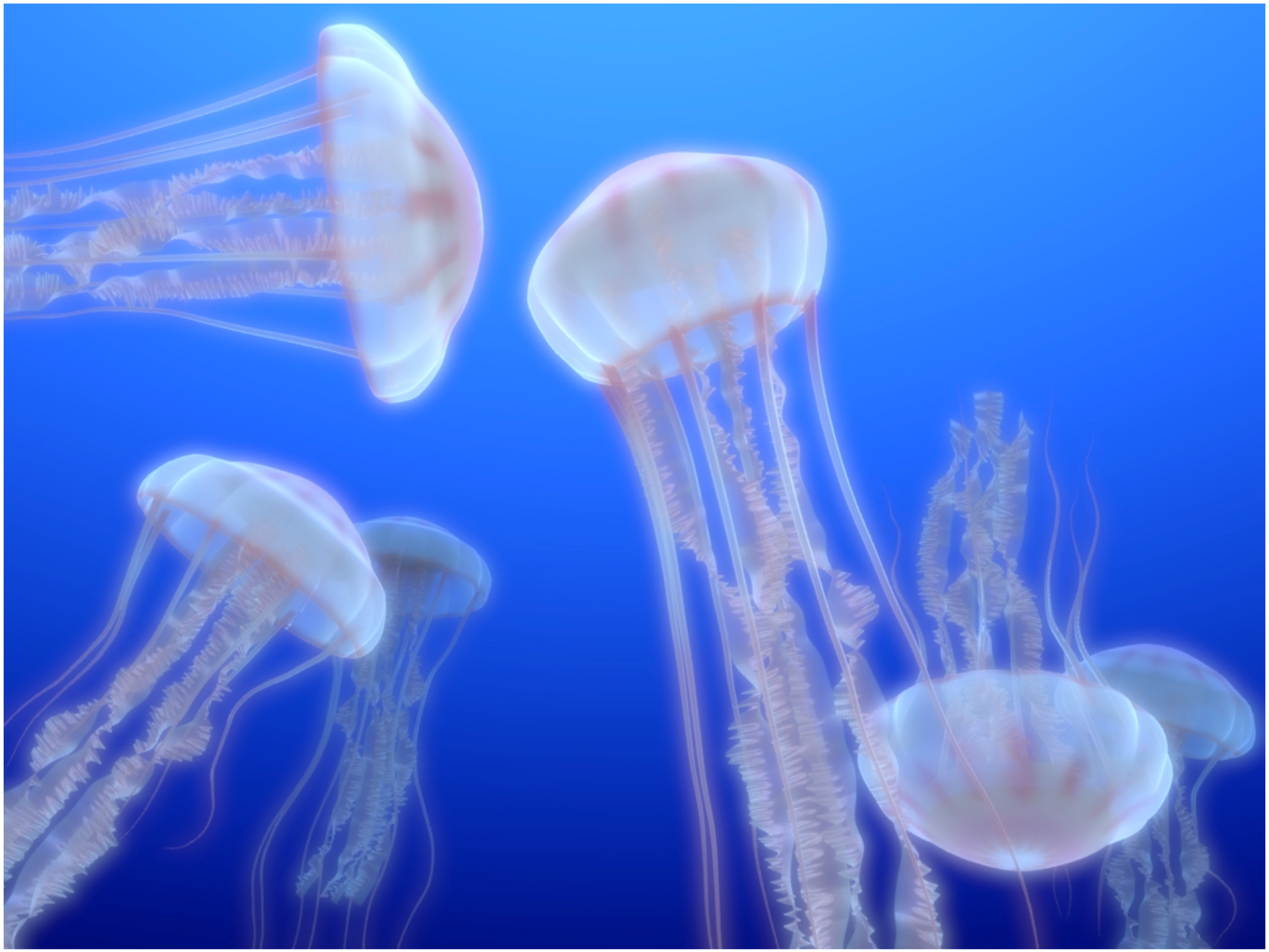
Logistics

- Slide comments (10%)
  - 2 per lecture, due before next lecture
- 4 Assignments (10% each)
  - Lighting design
  - Sphere tracing distance estimators
  - Light field cameras
  - Monte Carlo sampling
- Final project (50%)
  - Reproduce a scene or image
  - Explore advanced rendering algorithms

Final Projects

The Rendering Competition

Artistic Art Glass
Georg Petschnigg and Inam Ur-Rahman Malik



Jellyfish

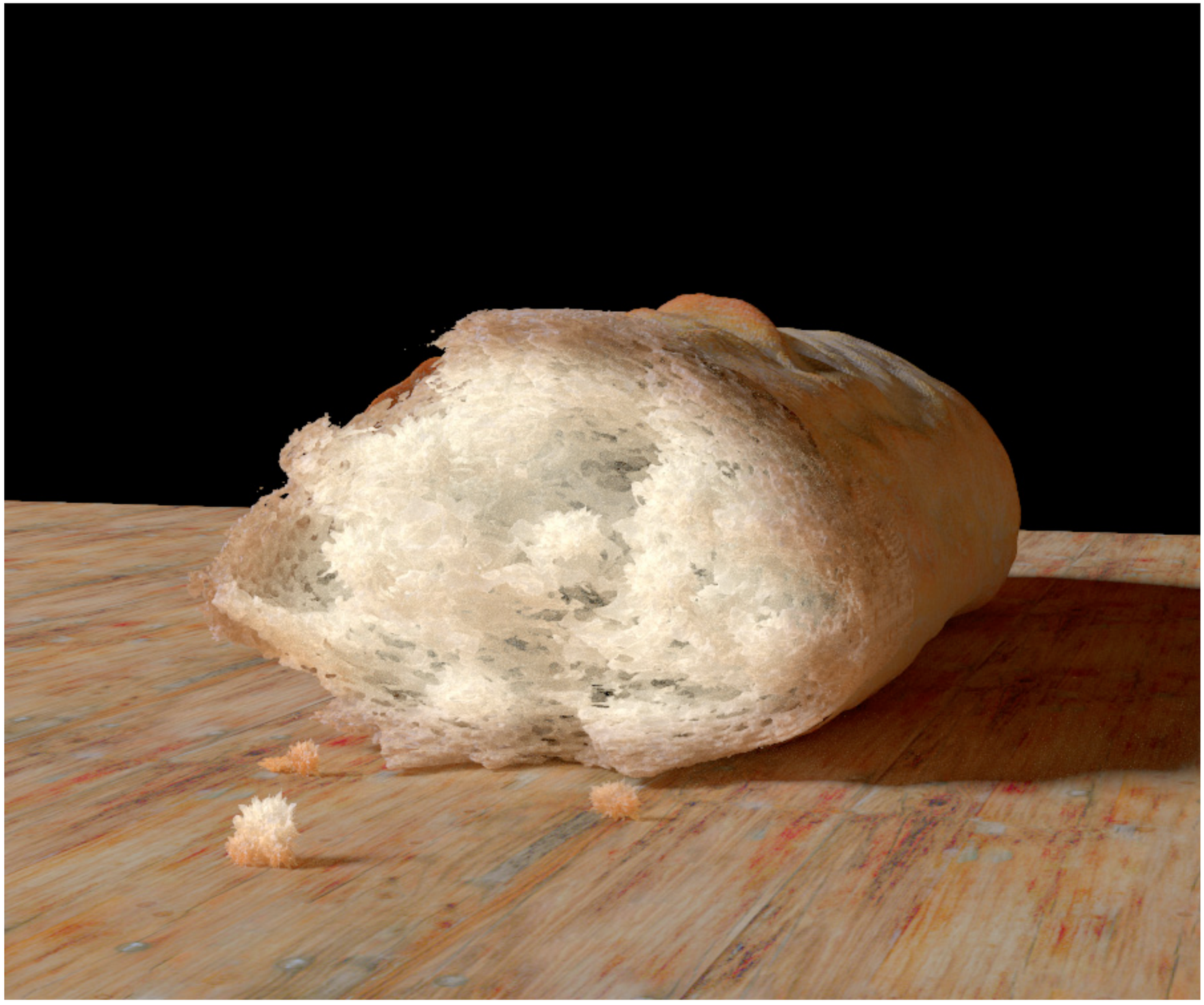
Kayvon Fatahalian and T. Foley

Lily Pads
Tom Brow and Ranjitha Kumar

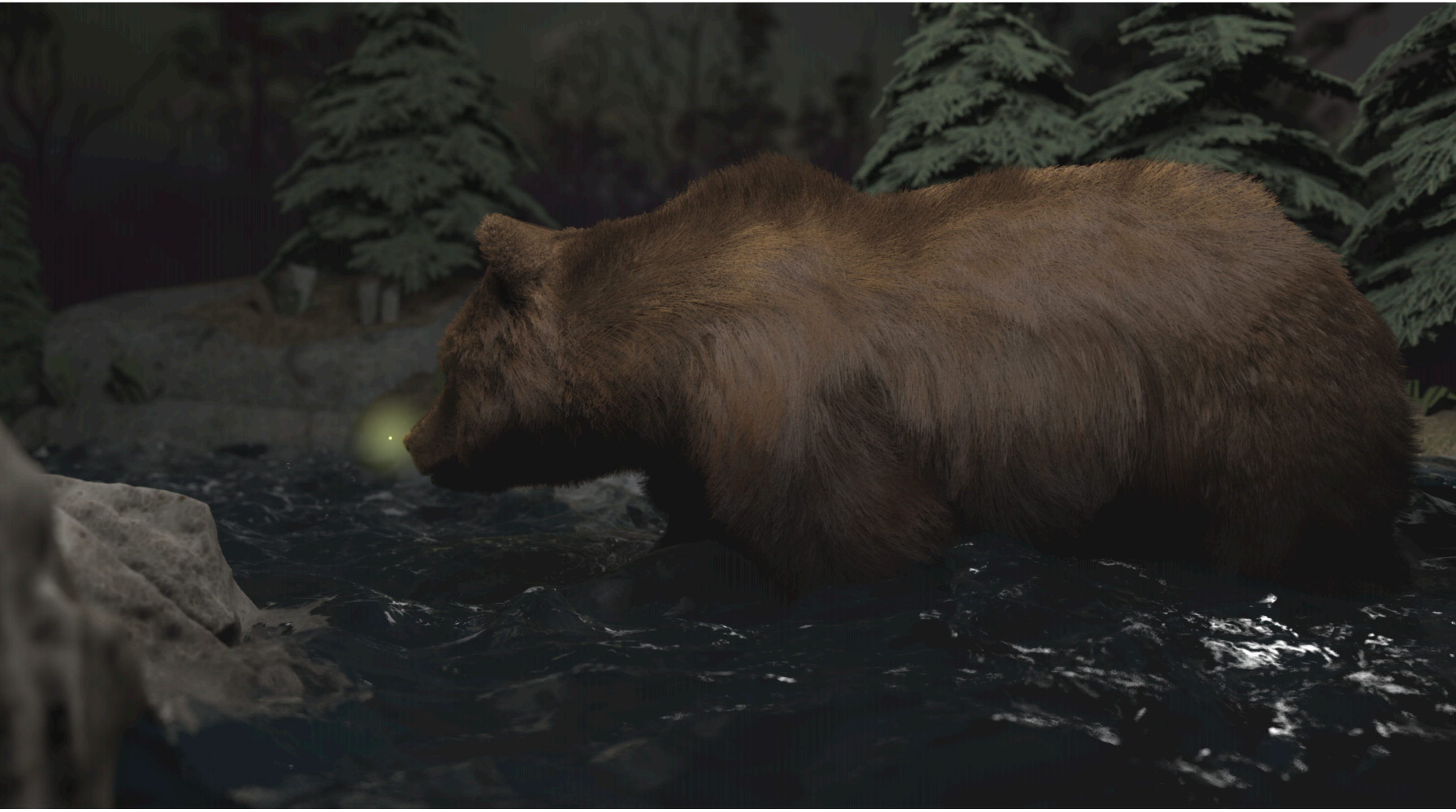
Cherry Pi

Luke Anderson, Kate Swanson, and Nora Willett

Citrus Marmalade
Sonny Chan and Phaedon Sinis



French Bread
Alexis Haraux



Bear and River

David Hyde, Lingxiao Li, Tushar Paul

Cotton Candy

Chenlin Meng, Hubert Teo, Jiren Zhu

Summertime Iridescence
Jennifer Tao and Cynthia Jia