

Introduction to Ray Tracing



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Ray Tracing

Rajesh Sharma

Course Outline

- ✓- Intro, Model, Sampling
- ✓- Rays, Intersections
- ✓- Scene, Recursion
- ✓- Materials, BRDF
- ✓- BRDF-2
- ✓- Systems View: Integrators, Accelerators, BRDF-3
- Soft Shadows, Wrap up, Learn more

Eric Haines



[Eric Haines](#) is an expert in [computer graphics](#). Currently he is with [NVIDIA Corporation](#) as a Distinguished Engineer. He co-authored the book *Real-Time Rendering*, currently in its fourth edition.

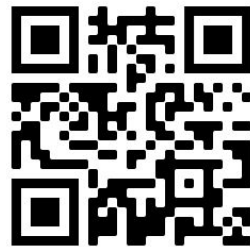
He created the [Massive open online course](#) *Interactive 3D Graphics* in 2013 with [Udacity](#). He authored a chapter in the book *An Introduction to Ray Tracing* by [Andrew Glassner](#) (ed), 1989. He has published a number of articles in computer graphics, some of which are included in the *Graphics Gems* series. He also maintains the Graphics Gems code repository.

Haines was on the editorial board of the *Journal of Graphics Tools* until 2012, at which time he helped found the *Journal of Computer Graphics Techniques*. He was the editor of the online forum of experts in [ray tracing](#), *Ray Tracing News* (1988-2010)^[4]

Today

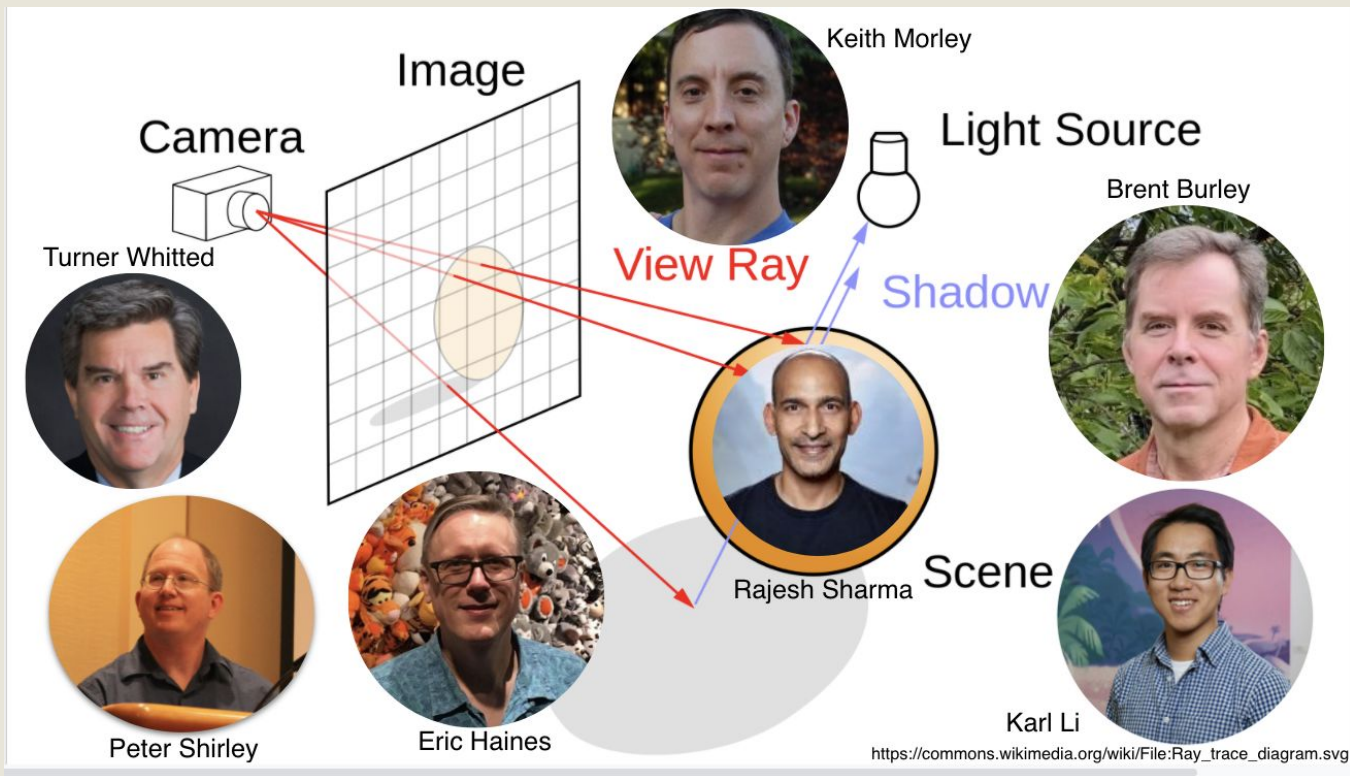
- Guest: Eric Haines
- Recap
- Soft Shadows (Area Lights)
- BRDF Sampling
- Wrap up
- Further Learning

Housekeeping



- Link to today's slides and shaderToys:
 - Log in to your google drive
 - Google drive folder: <https://bit.ly/3viTHez>
 - Code: <https://www.shadertoy.com/user/xarmalarma>
- Use the chat to ask questions, help others
- After the lecture: @xarmalarma, #siggraph2021

Thanks to the Guests!



Thank you to ACM SIGGRAPH!



Pol Jeremias-Vila : SIGGRAPH 2021 Chair

Tomasz Bednarz: Frontiers Program Chair

Alex Bryant: Student Volunteers Chair

Tim Hendrickson: Digital Marketing Manager

Student Volunteers:

Rogelio, Trinity, Aurora, Emily, Hunter & Kendra



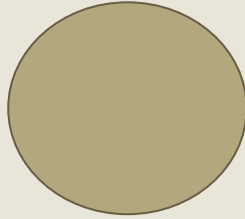
SIGGRAPH 2021

Shadows

Light



Object



Ground

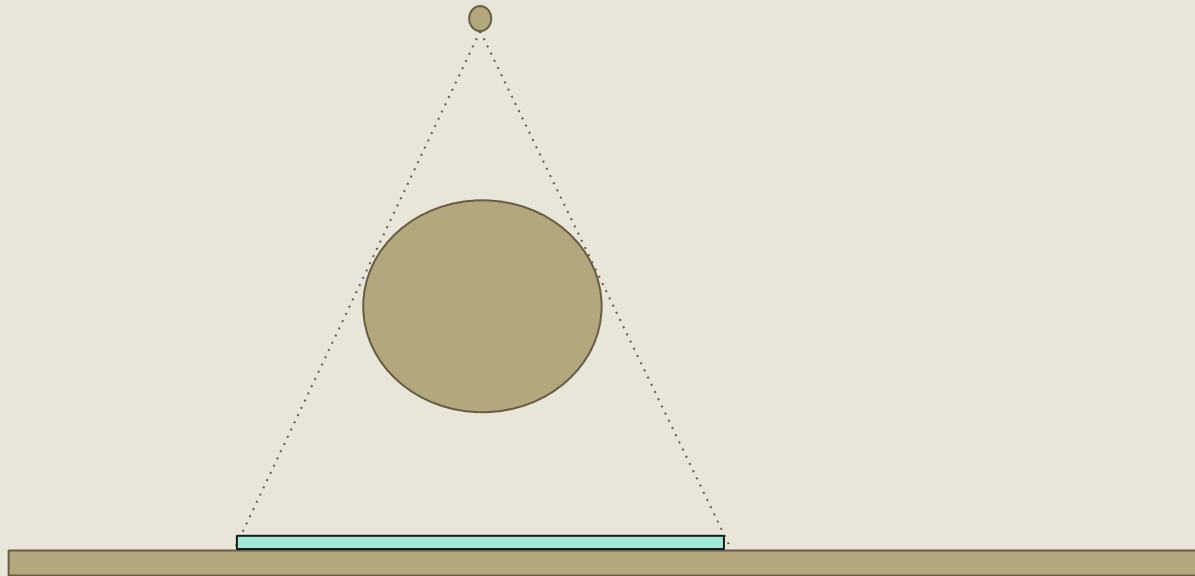


Shadows

Light

Object

Ground

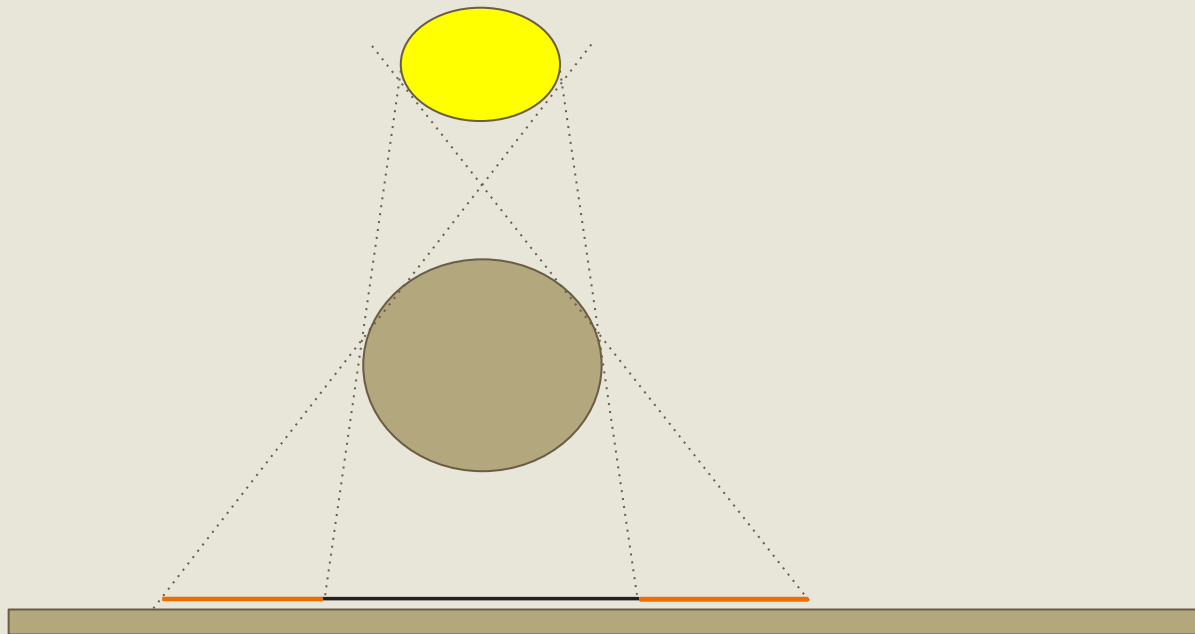


Shadows

Light

Object

Ground

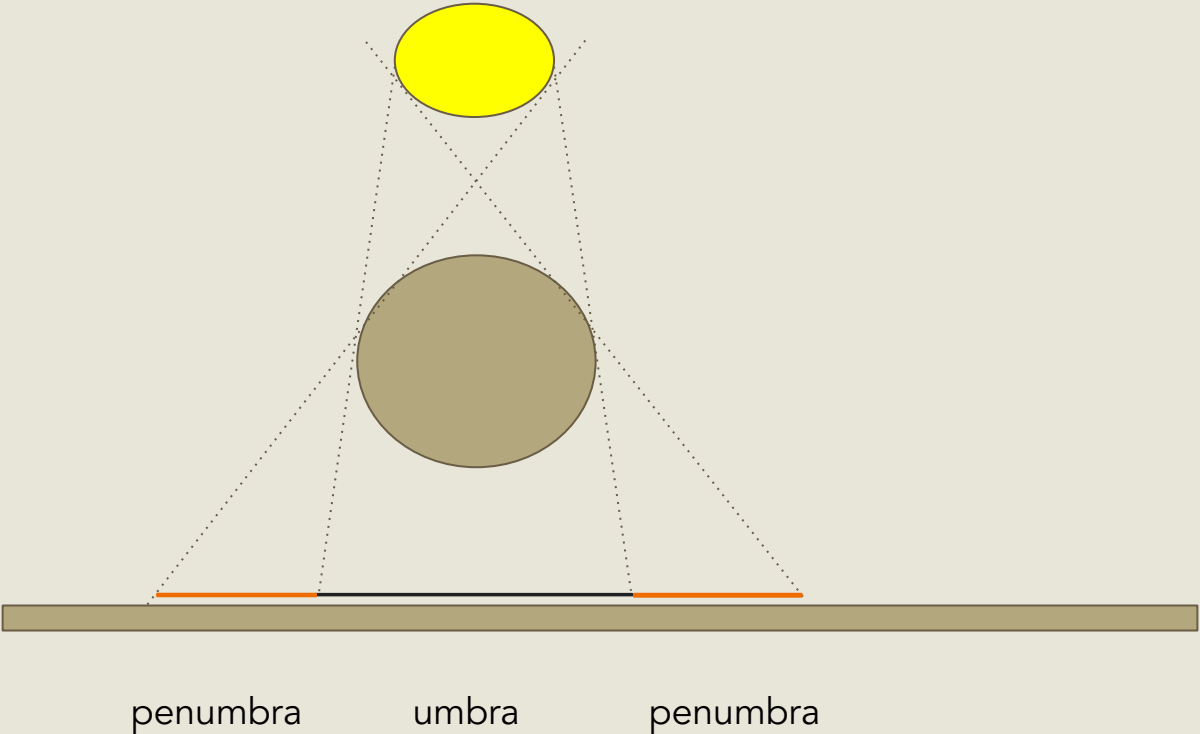


Shadows

Light

Object

Ground



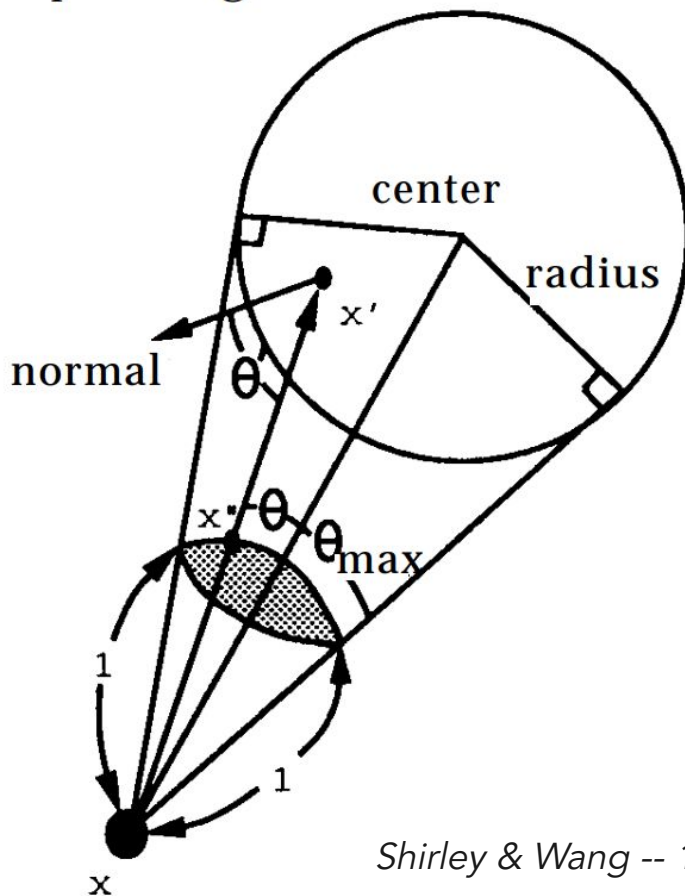
Sampling the Spherical Light

Light contribution is proportional to the visible area

```
vec3 SampleCone(vec2 u, float cosThetaMax) {  
    cosTheta = (1-u[0]) + u[0] * cosThetaMax;  
    sinTheta = sqrt(1 - cosTheta * cosTheta);  
    phi = u[1] * 2 *  $\pi$ ;  
    return vec3(cos(phi) * sinTheta,  
                sin(phi) * sinTheta,  
                cosTheta);  
}
```

From the PBRT book

sphere light



Shirley & Wang -- 1993

General Sampling Strategy

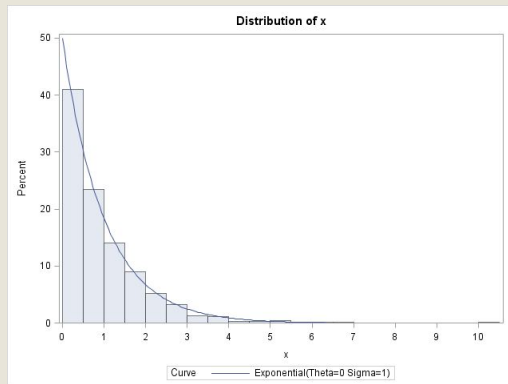
If you know the cumulative distribution function (CDF) of a probability distribution, then you can *always* generate a random sample from that distribution.

The *inverse CDF* technique for generating a random sample uses the fact that a continuous CDF, F , is a one-to-one mapping of the domain of the CDF into the interval $(0,1)$. Therefore, if U is a uniform random variable on $(0,1)$, then $X = F^{-1}(U)$ has the distribution F .

Example:

The exponential distribution has probability density (PDF): $f(x) = e^{-x}$, $x \geq 0$,
CDF (cumulative distribution) is the integral of the density: $F(x) = 1 - e^{-x}$.

This function can be inverted by solving for x in the equation $F(x) = u$.
The inverse CDF is: $x = -\log(1-u)$.



Summary

Light coming in * Light Going to Viewer * angle to the normal

Over multiple samples/bounces

If objects were emitting light, we would add that too

Emitted Light + MultipleSamples [Light coming in * Light Going to Viewer * angle to the normal]

Summary

Emitted Light + MultipleSamples [Light coming in * Light Going to Viewer * angle to the normal]

$$L_r(x, \omega_r) = L_e(x, \omega_r) + \int_{\Omega} L_r(x', -\omega_i) f(x, \omega_i, \omega_r) \cos \theta_i d\omega_i$$

Rendering Equation Explained (Thanks to Julian Fong @ Pixar)

directions for making pictures using numbers
(explained using only the ten hundred words people use most often)

the light that comes from an interesting direction towards the position on the stuff

direction towards the eye

position on the stuff

light made by the stuff (sometimes because it is very hot)

the answer to how much light from an interesting direction that will keep going in the direction towards the eye, after hitting stuff at the position (this is easy for mirrors, not so easy for everything else)

how much the light becomes less bright because the stuff leans away from the interesting direction

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

light that leaves the position on the stuff and reaches the eye

light can be added said a man who sat under a tree many years ago

for lots of interesting directions inside half a ball facing up from the stuff, add up all the answers in between

this idea came from <http://xked.com/1133/>

@levork

Learning More

- [Peter Shirley's Ray Tracing Series](#)
- [PBRT Book](#)
- [Embree](#), [OptiX](#), [Vulkan](#), [DirectX](#)
- Papers, Conferences (SIGGRAPH)

QUESTIONS?

- Chat
- #xarmalarma