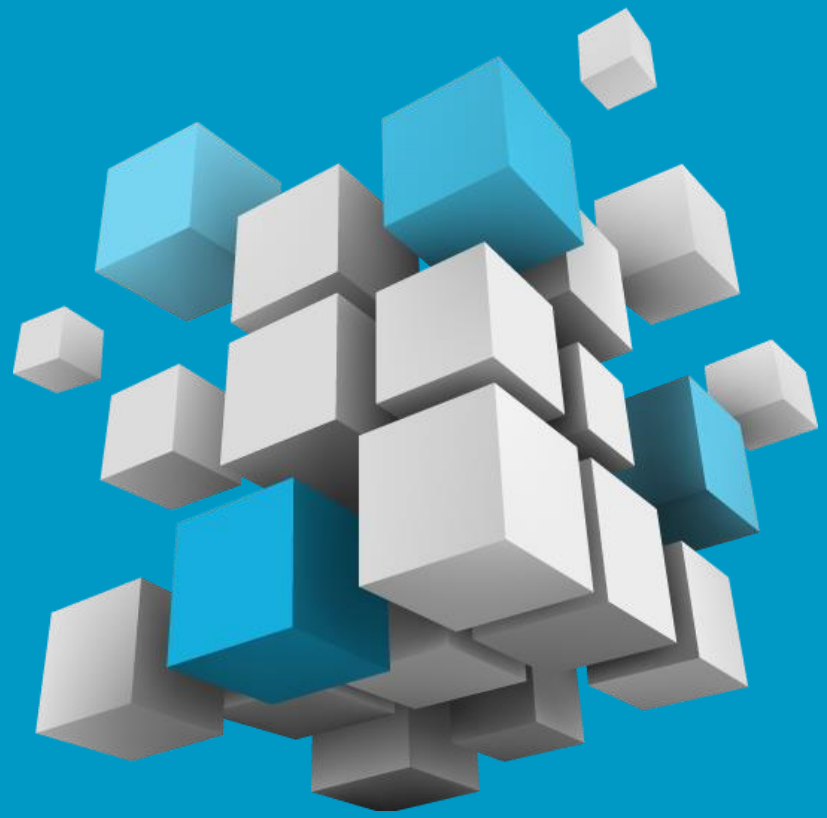
Illumination

Lighting

Environment mapping

Shadows



Direct Illumination Only?

Moon surface lit only by a direct light source, © NASA

Outdoor Lighting with Sun and Sky

3D Interior Lighting

https://youtu.be/UYOR-skFCoA

UE4 ARCH

Multiple Light Sources

(Elsa From Frozen)

Character Shader: RealToon
Elsa Model (PMX Type): WeFede (DA)
Elsa character and name: Disney

[MJQ Studio Works @ twitter]

Which light parameters affect lighting in a scene?

Light Sources

Chapters 10, 18
[Akenine-Möller 2018, chapter 10]

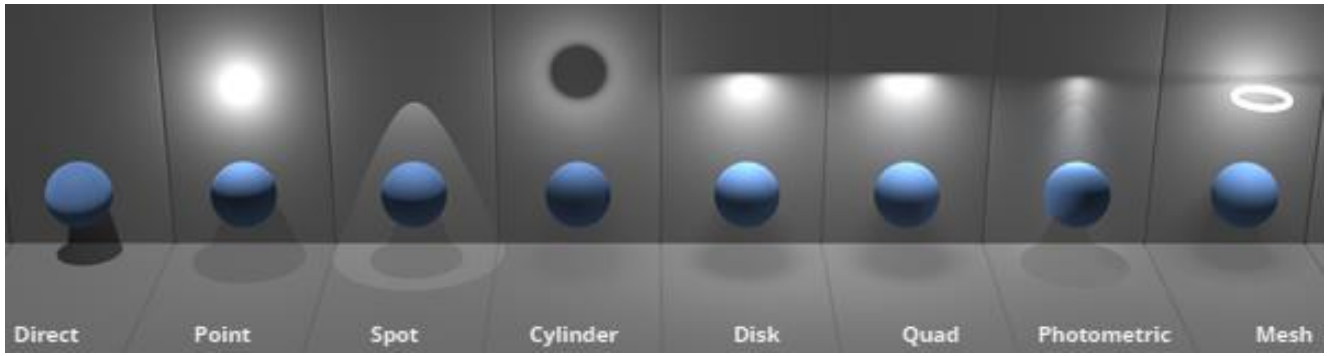
Contribute to the “mood” of the rendered image

- Color, intensity, and size of light sources
- Involves several light sources for dramatic effect
- Also affects shadows

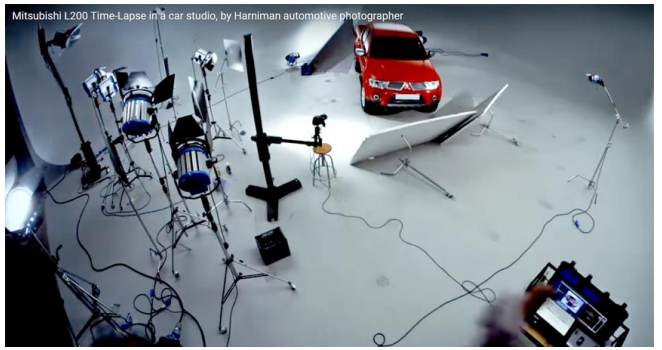
Not covered

- Underlying concepts such as radiometry & photometry
- Indirect lighting

Traffic Lights, © Lucas Zimmermann, 500px.com



[arnoldrenderer.com]

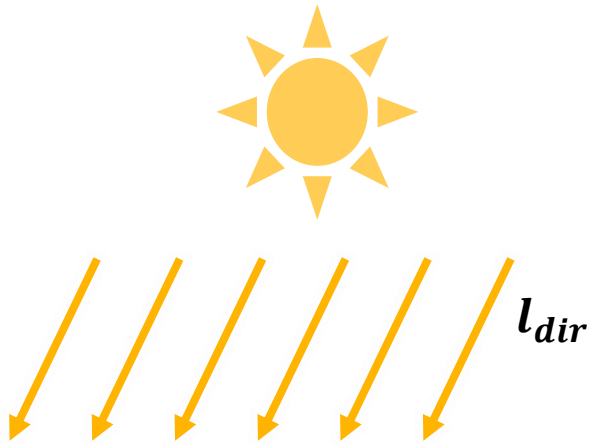


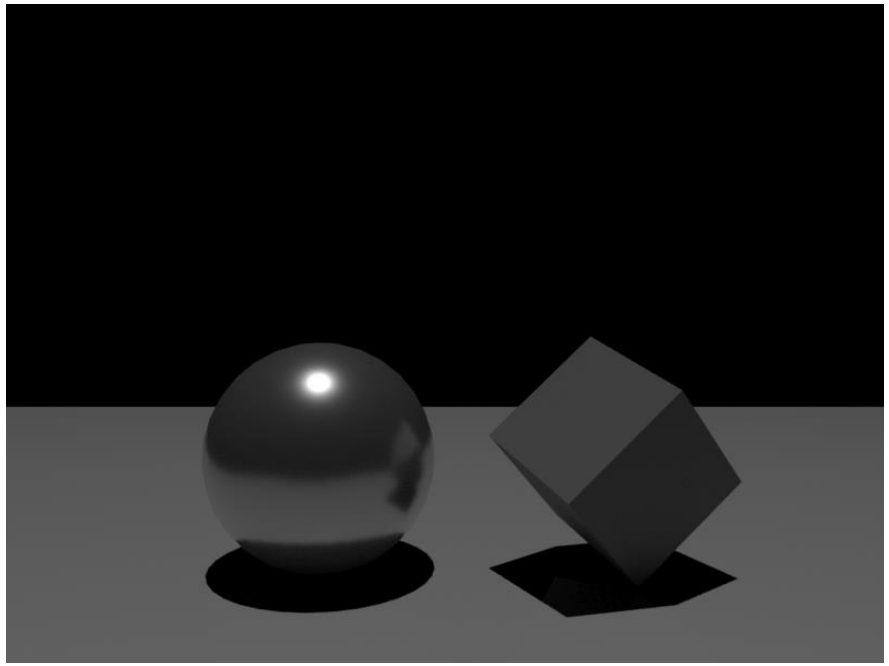
[www.lightmap.co.uk]

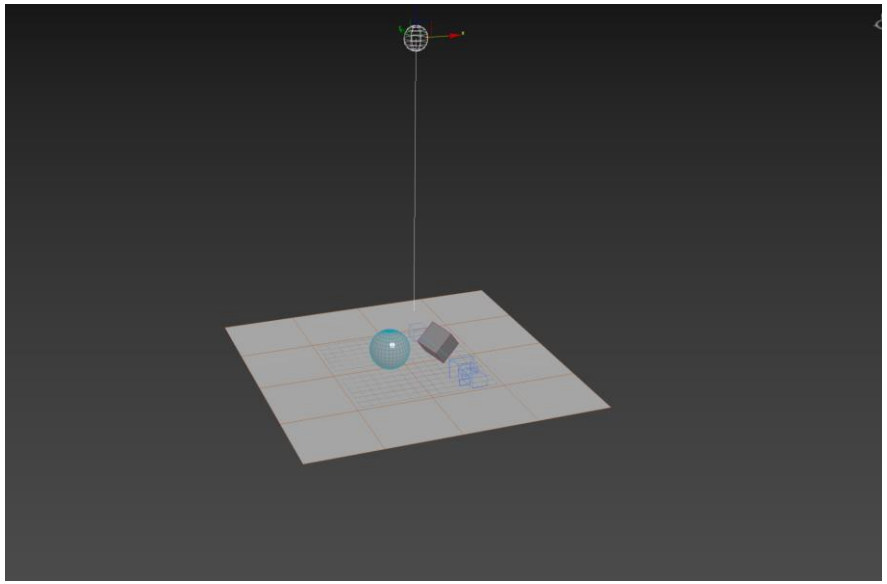
Directional Light

Described by directional vector

Example: Sun light on Earth (approx.)



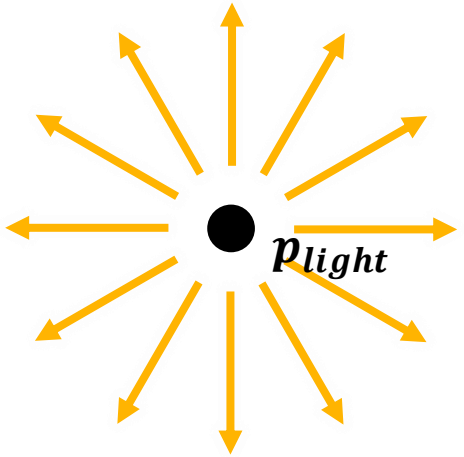


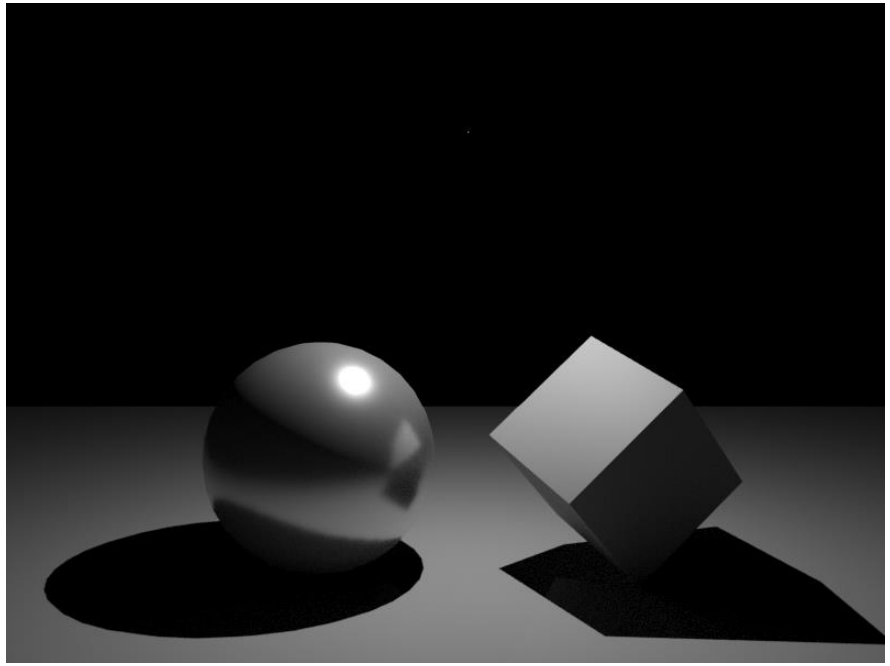


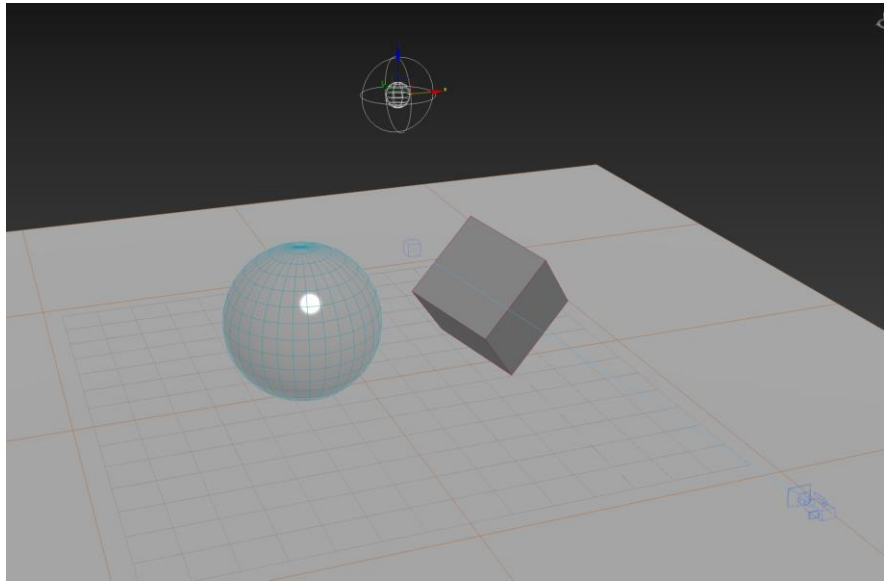
Point Light

Isotropic light source, described by position

Need to compute light direction $\mathbf{L}$ for each fragment



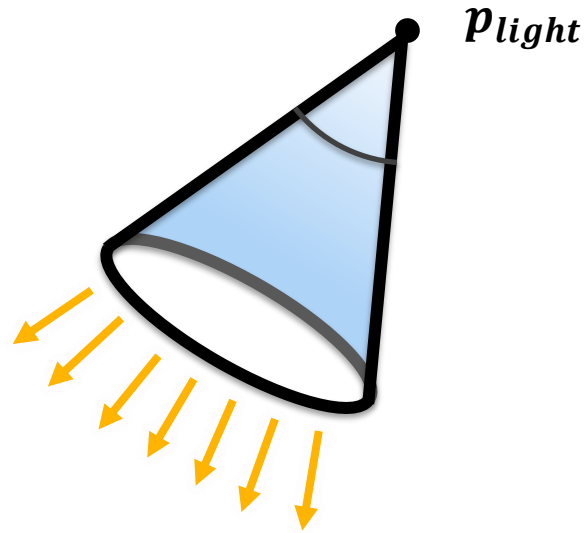




$$L = \frac{p_{light} - x}{|p_{light} - x|}$$

x

Spotlight



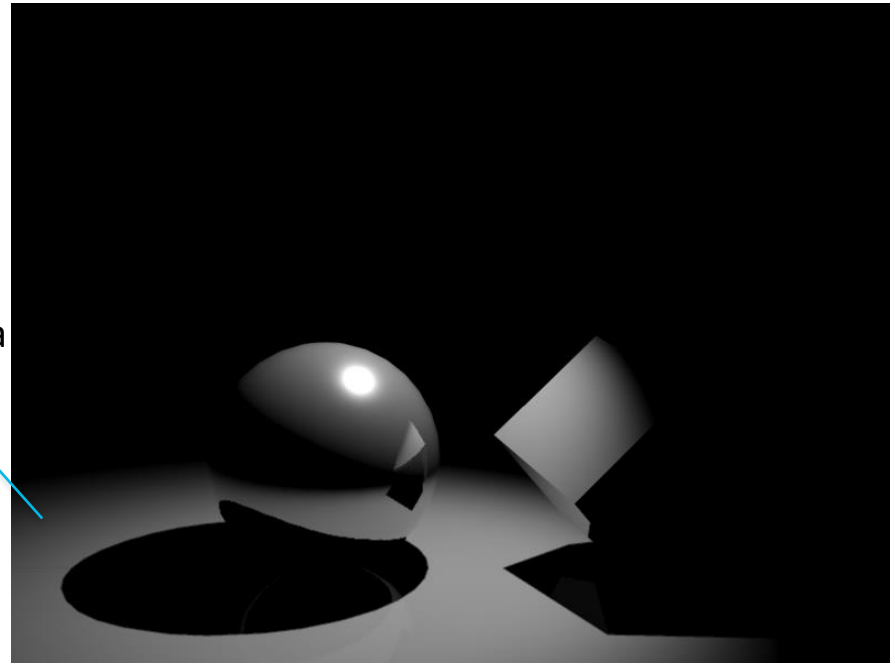
Results in penumbra, if inner < outer

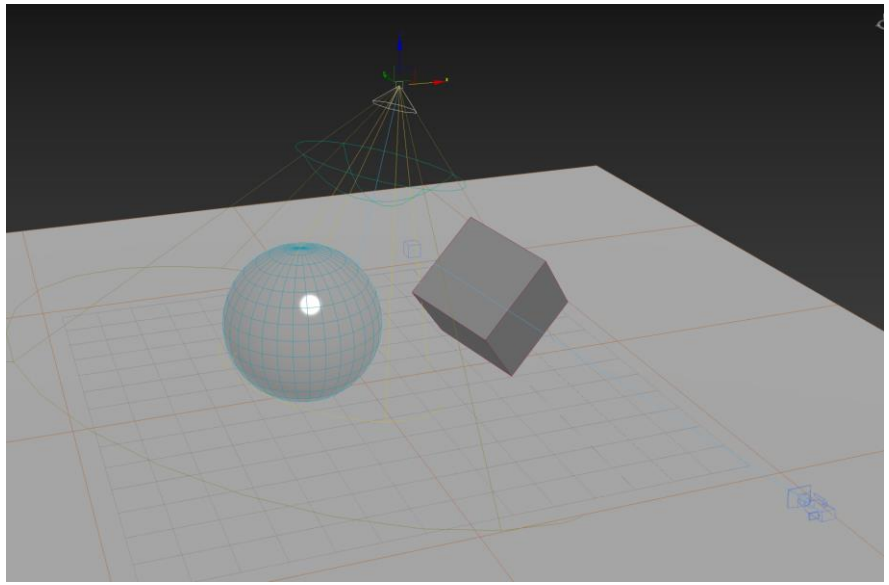
Light cone limits light direction

- Position, cone direction, opening angle (inner & outer)

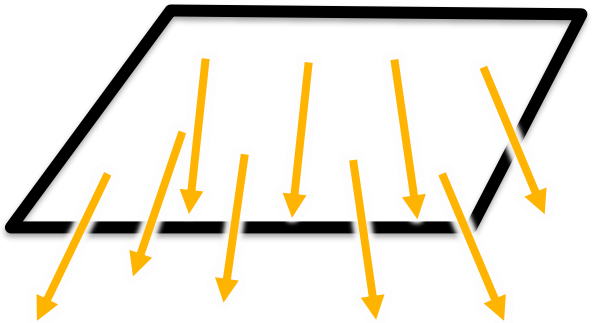
Can be used to project textures onto objects

Penumbra





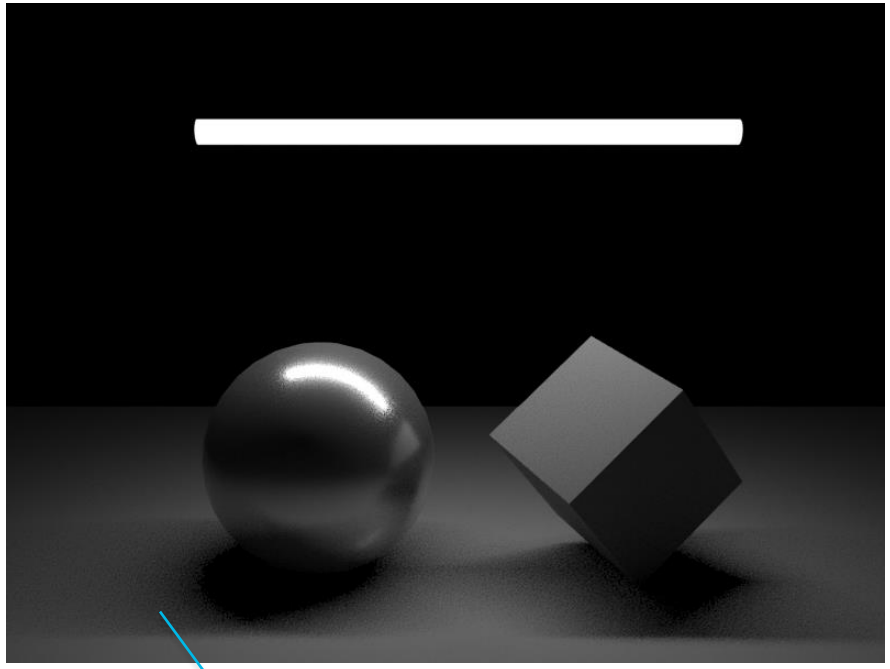
Area Light

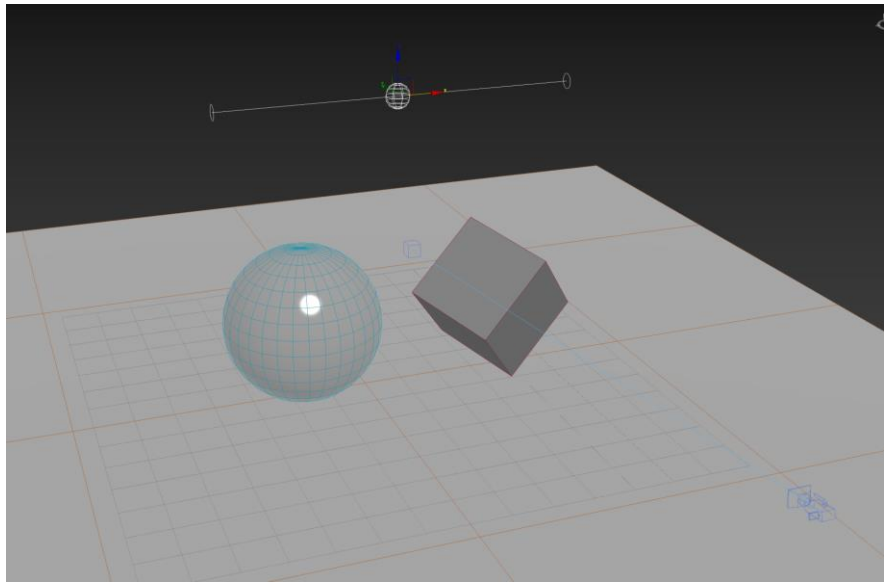


Real world lights are not small points!

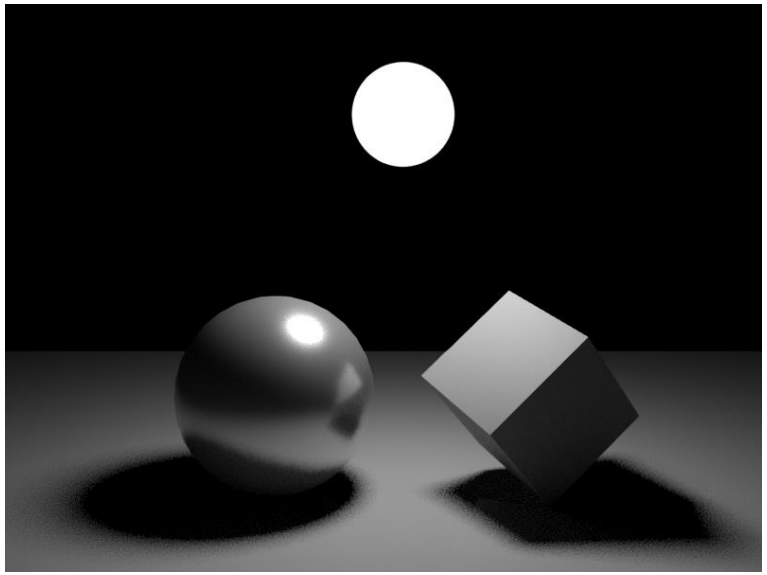
Use geometry to emit soft light in all directions

- More expensive to compute
- Can be roughly approximated with many point lights

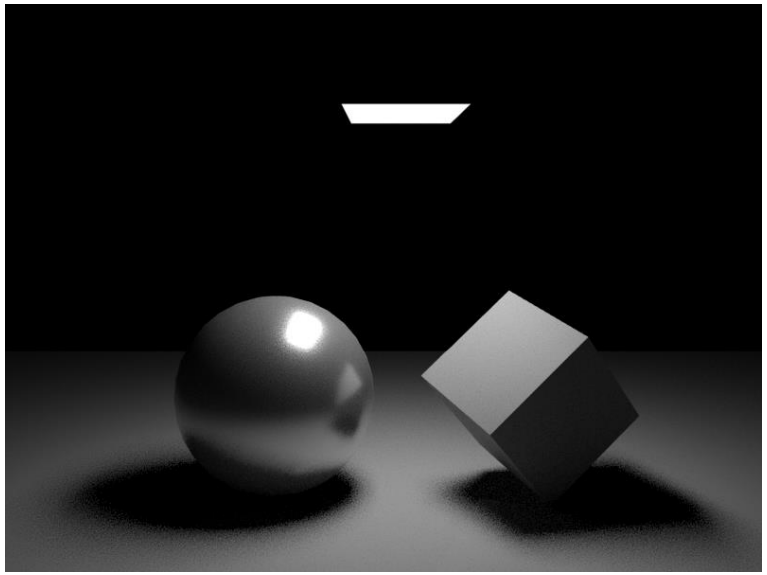




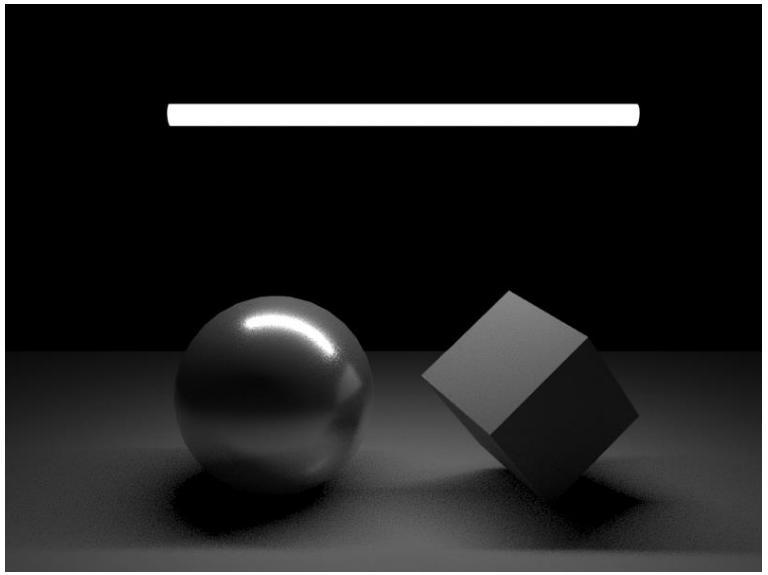
Area Light (cont.)



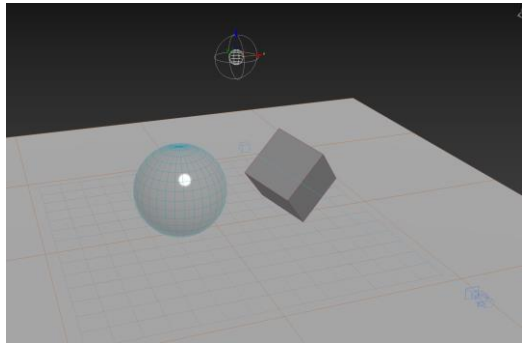
Sphere

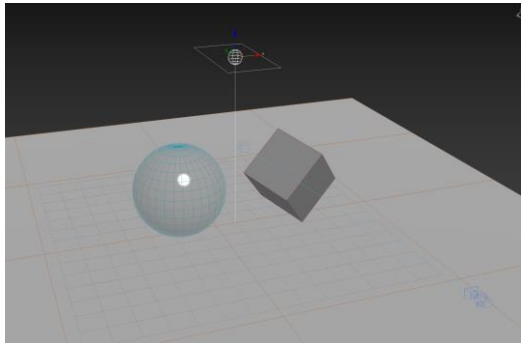


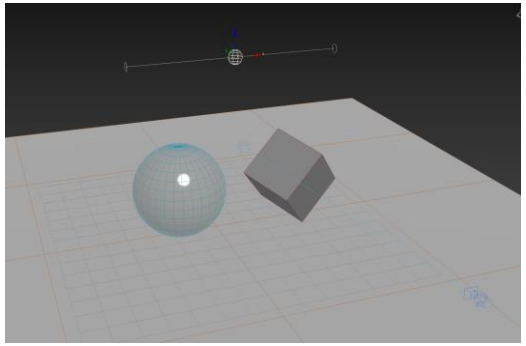
Rectangle



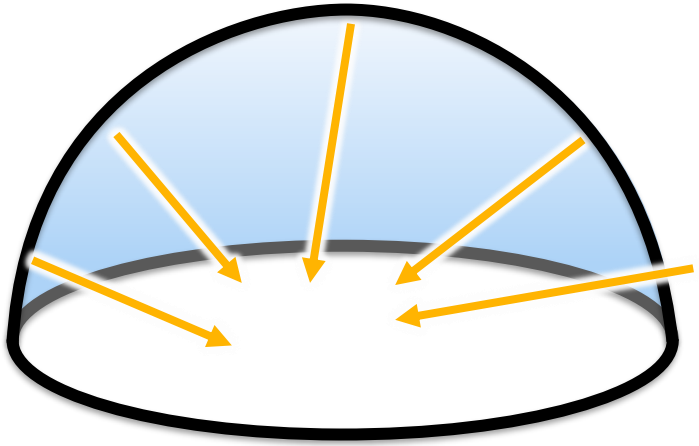
Cylinder







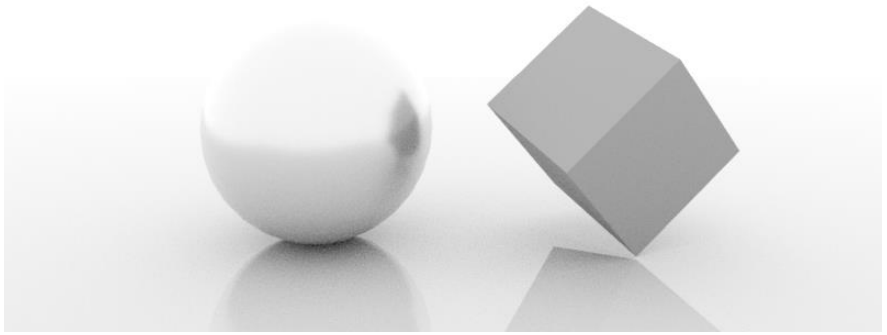
Skydome / Skylight

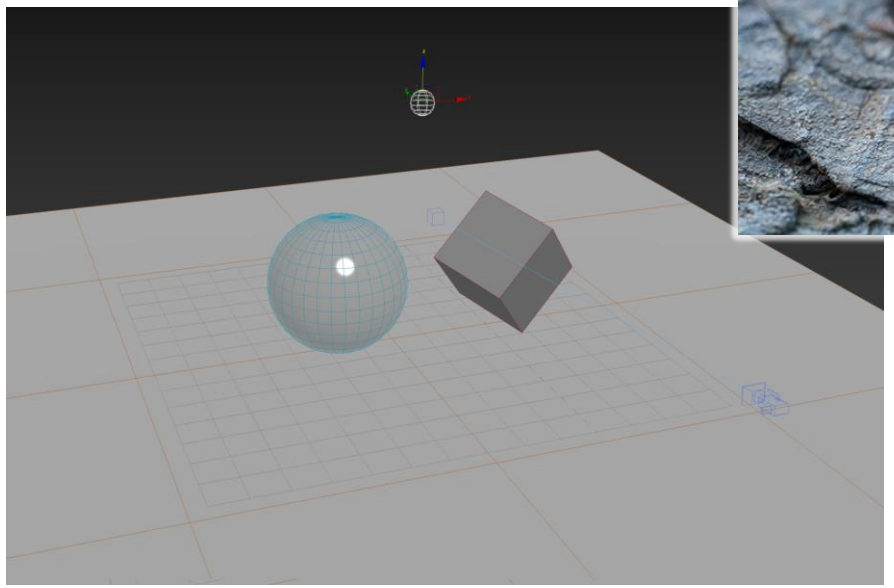


Simulates a bright environment around scene

- Sphere or dome above the scene

Use HDR images for environment lighting





[arnoldrenderer.com]

Other Light Parameters

Intensity

Color / color temperature

Affected objects

[ledsmaster.com]

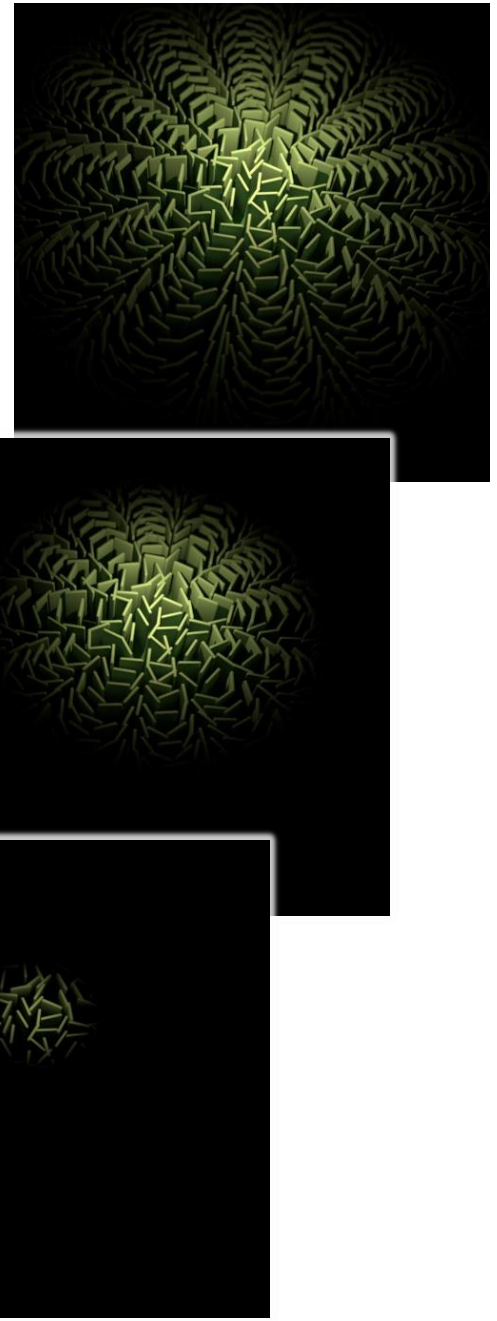
Color temperature

Light attenuation aka. light decay

- Light gets weaker with increasing distance to light source
- Physically correct:

$$I \propto \frac{1}{|\boldsymbol{L}|^2}$$

- Also possible: limit start and end



[arnoldrenderer.com]

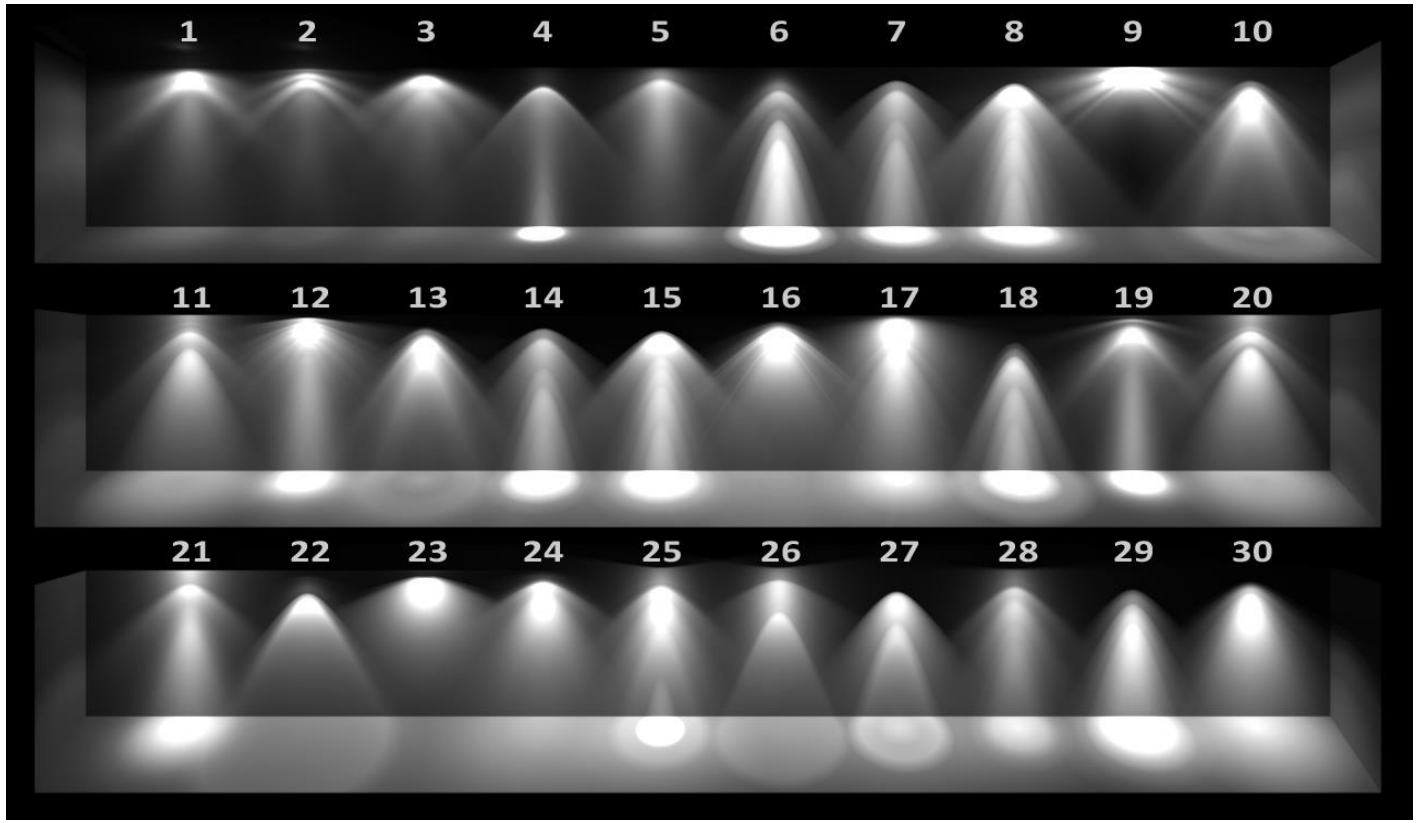
Increasing light attenuation

Photometric Light (Arnold Renderer)

[arnoldrenderer.com]

Use data from real-world light bulbs

- For example, Erco, Lamp, Osram, Philips



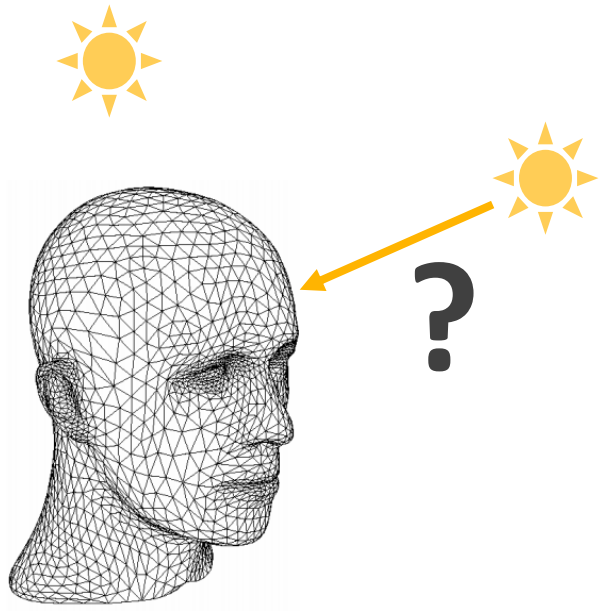
IES profiles available in the Arnold renderer [arnoldrenderer.com]

Group Assignment

How would you illuminate a person?

- Number and type of light sources
- Light positioning
- Difference between indoors vs. outdoors?
- …

Group discussion 5min



[rendernode.com]

Real-world Lighting (Studio)

Concepts applicable to Computer Graphics, too

Types of lights

- Main or **key light**
  primary light source
  natural lighting seen as secondary main light
- One or more **fill lights**
  for balanced appearance
  soften shadows
- **Back light**
  separate object from background
  highlight edges

[rendernode.com]

[Birn 2013]

Three-Point Lighting

Classic Hollywood lighting

1. Begin with no lights (not even ambient)
2. Add key light
   - Main illumination
   - Move 15-45° to side and up
3. Add fill light
4. Add back light

[Birn 2013]

Three-Point Lighting

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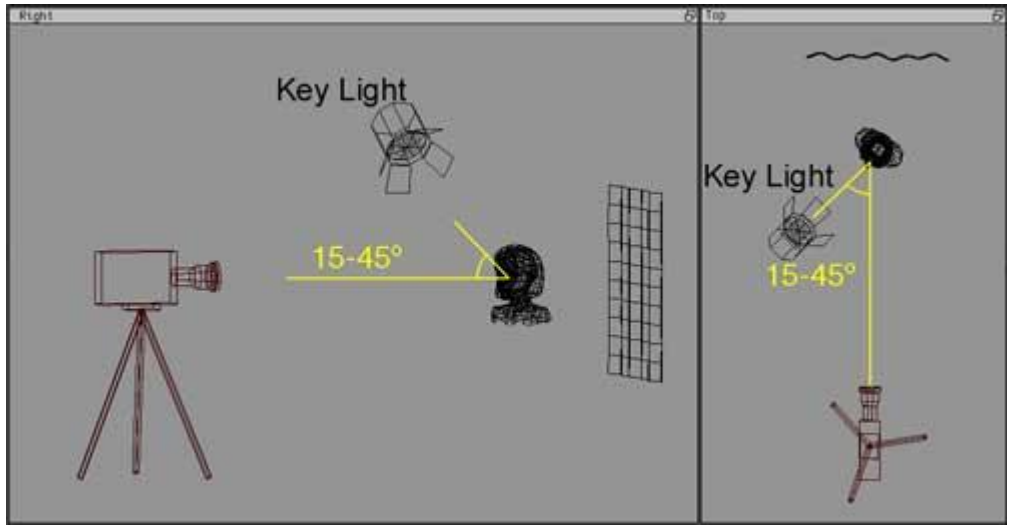

[3drenderer.com]

[Birn 2013]

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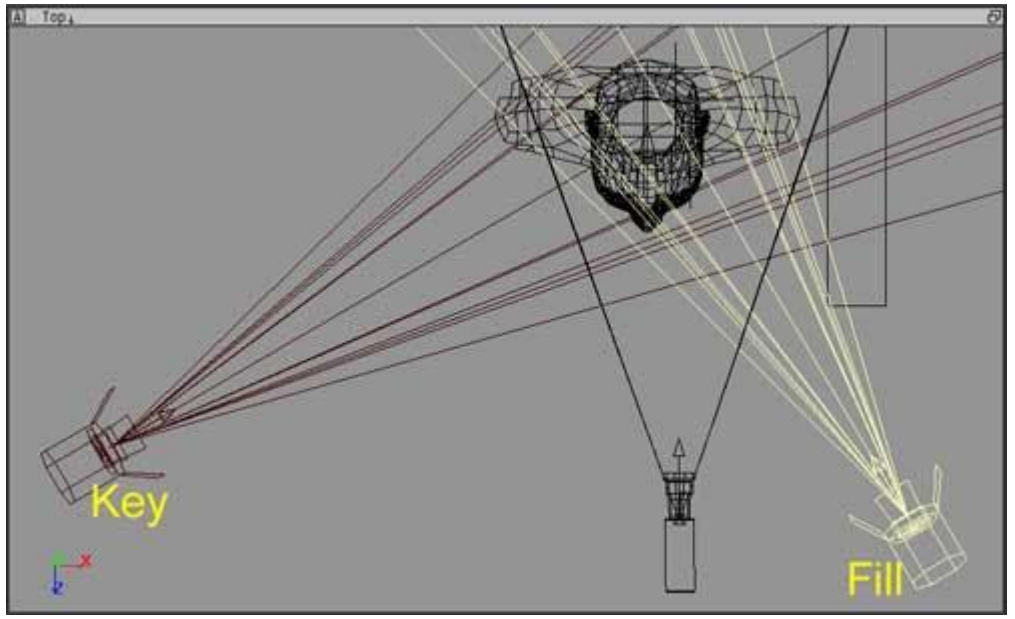

[3drenderer.com]

[Birn 2013]

Three-Point Lighting

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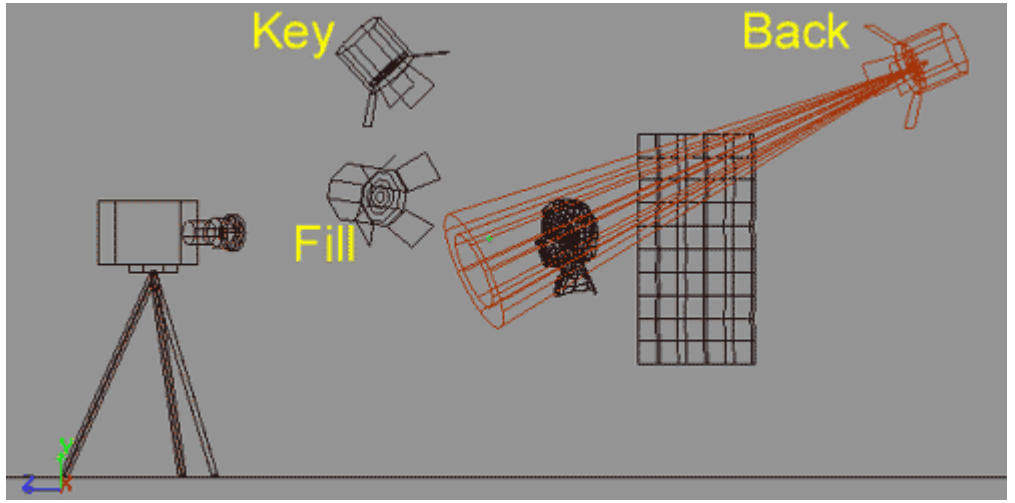

[3drenderer.com]

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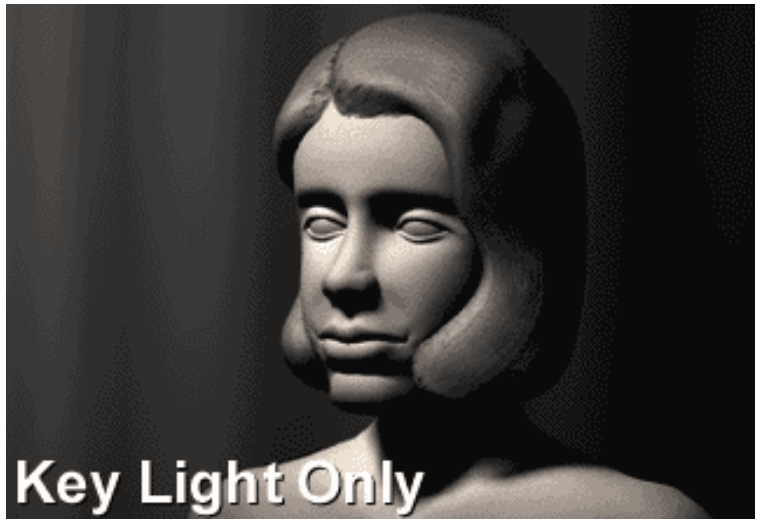
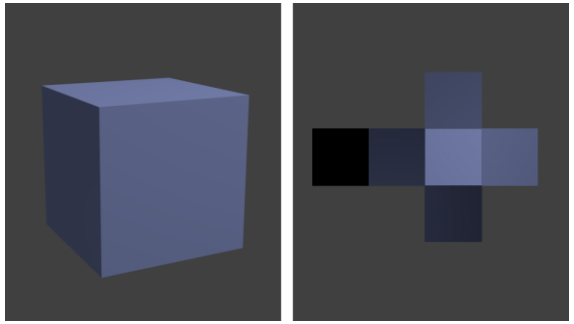


Lightmaps

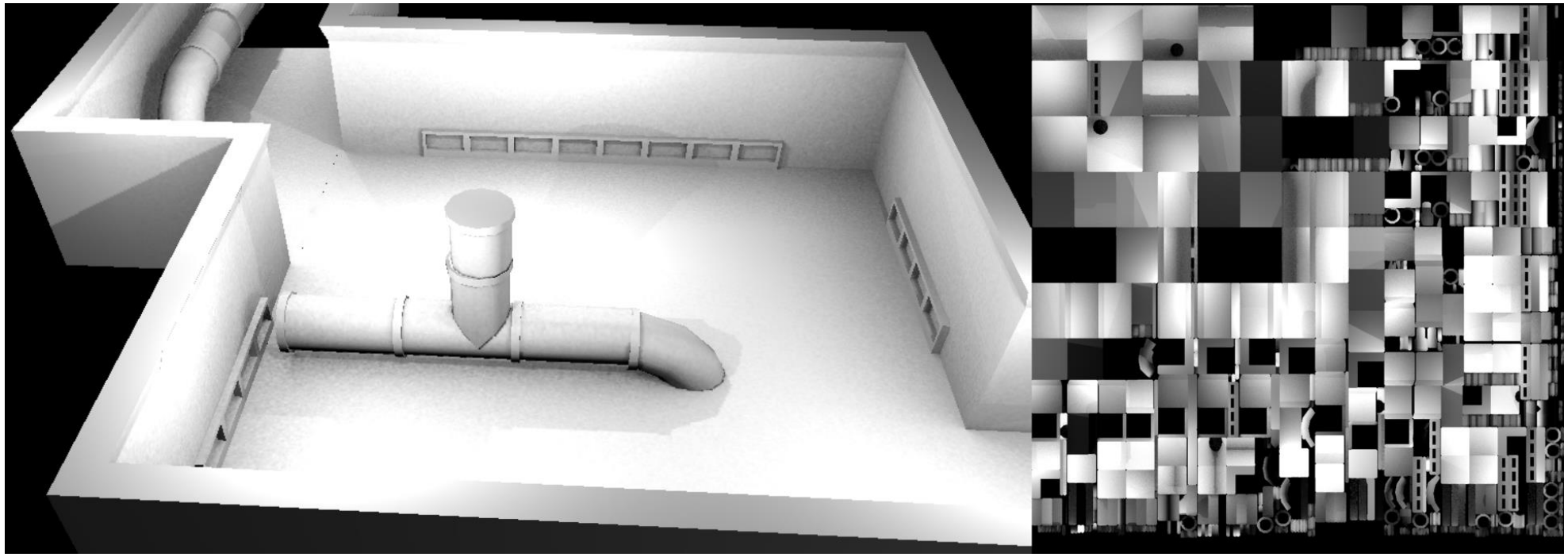
Lighting calculations can be expensive

- Pre-compute static illumination

Bake illumination into texture



Lightmap of a cube [wikipedia]



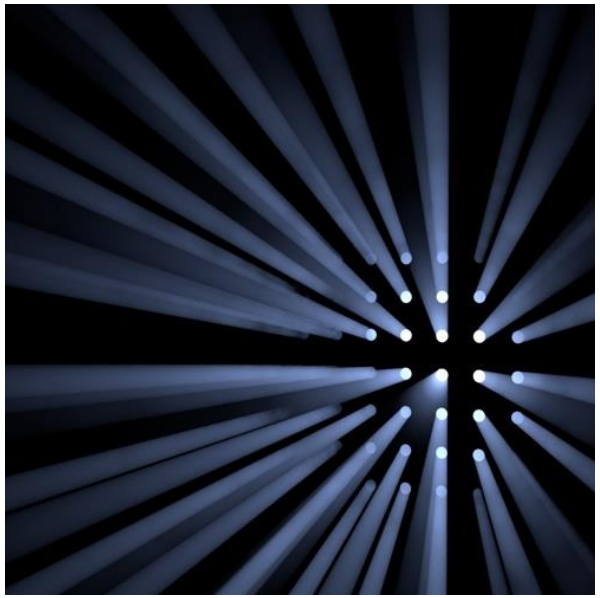
[wikipedia]

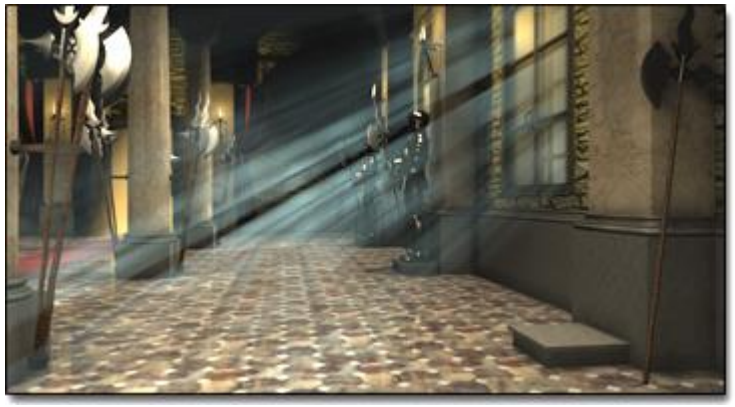
There is more…

Indirect lighting (global illum)

Participating media

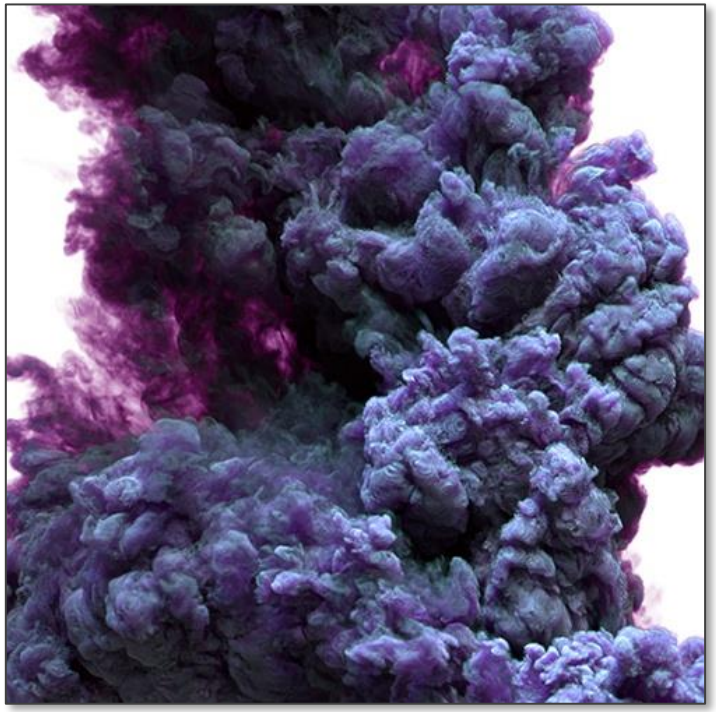
- Atmospheric effects
- Light scattering
- Volumetric effects
- Added as shaders





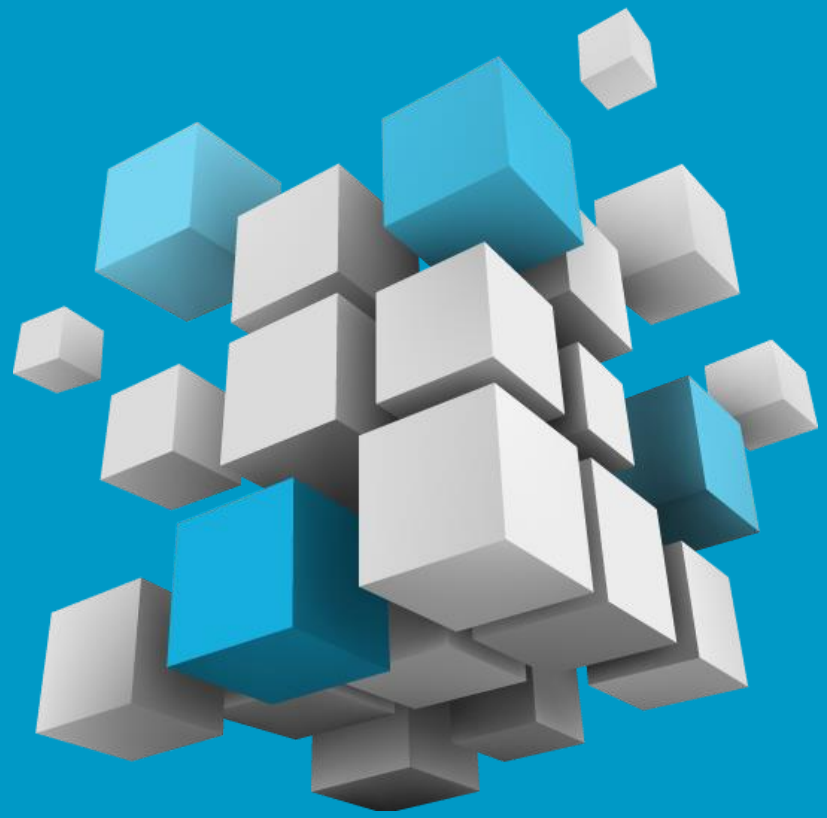
[knowledge.autodesk.com]

[arnoldrenderer.com]



Illumination

Environment lighting & mapping

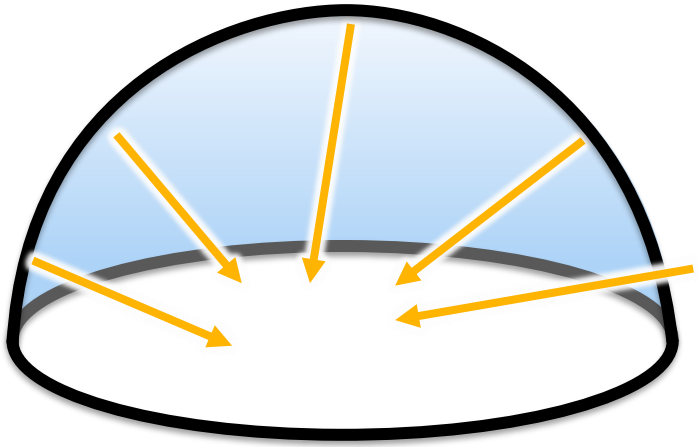


Environment Lighting

Chapter 11.4.5
[Akenine-Möller 2018, chapter 10]

Incoming light does not need to come from light sources

- Capture “far-away” light from entire 360° environment



Use image as skydome

- Preferably high dynamic range (HDR)

Source can be a photograph or rendering

Also known as **Image-based lighting**

[Akenin-Möller 2018]

[arnoldrenderer.com]

Environment/Reflection Mapping

Cheap way to create reflections

- Both diffuse and/or specular

Reflect view direction $\mathbf{V}$ at normal

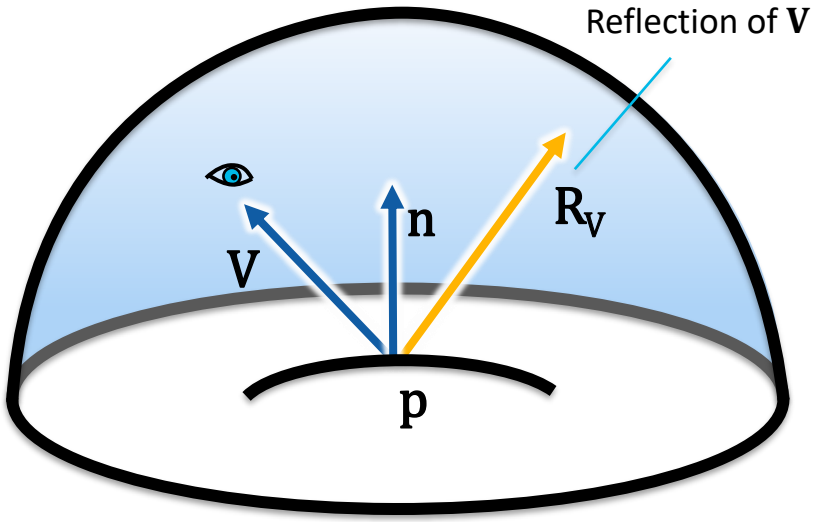
- Use result $\mathbf{R_V}$ to look up environment map

Method is just an approximation!

- No self-reflection, linear interpolation

Possible to use pre-filtered mipmap for different levels of roughness

[learnopengl.com]



See also three.js envmaps example

Spherical Mapping

Entire environment captured on a small chrome sphere

- View-dependent
- Circular image also called **light probe**

Singularity at border

Photograph a shiny sphere to create a sphere map

Original images of sphere mapping [Miller 1984, pauldebevec.com]

[Akenine-Möller 2018, chapter 10.4.3]

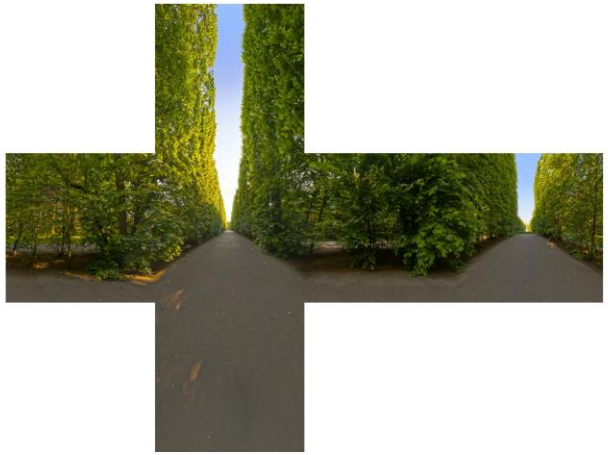
Cube Map

Map environment to six sides of a cube

- View-independent

Supported on GPU

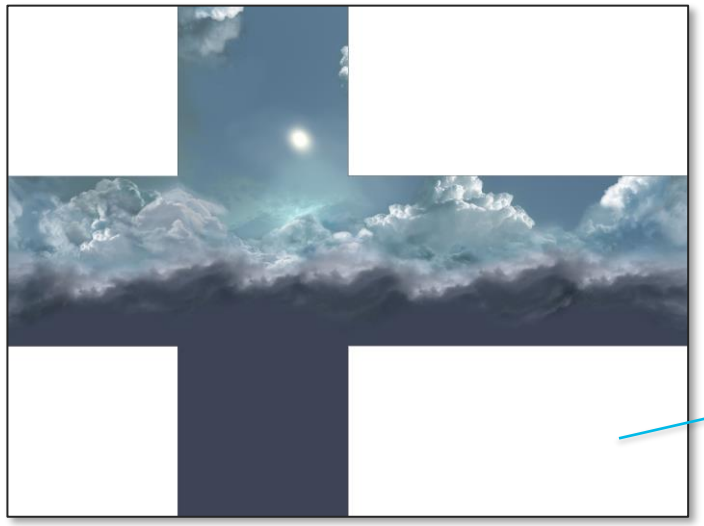
- Pass $\boldsymbol{R_V}$ directly to cube map sampler
- Largest component picks cube side



Standard cubemap

Irradiance cubemap

[indidb.com]

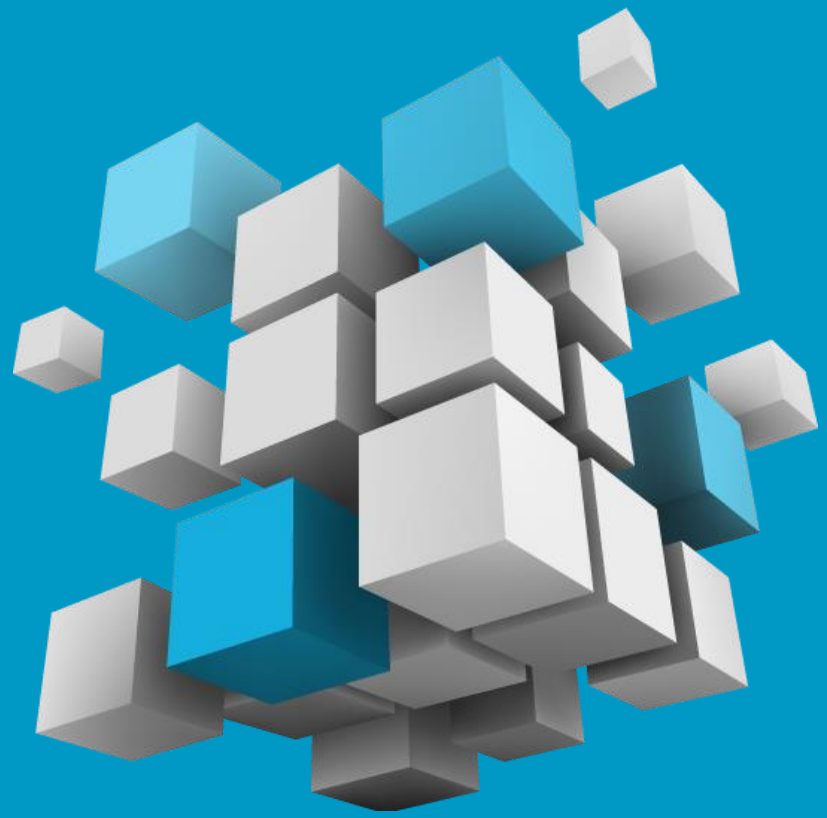


[Stefan Roettger]

Usually stored as 6 separate textures to avoid wasting space.

Illumination

Shadows



Shadows

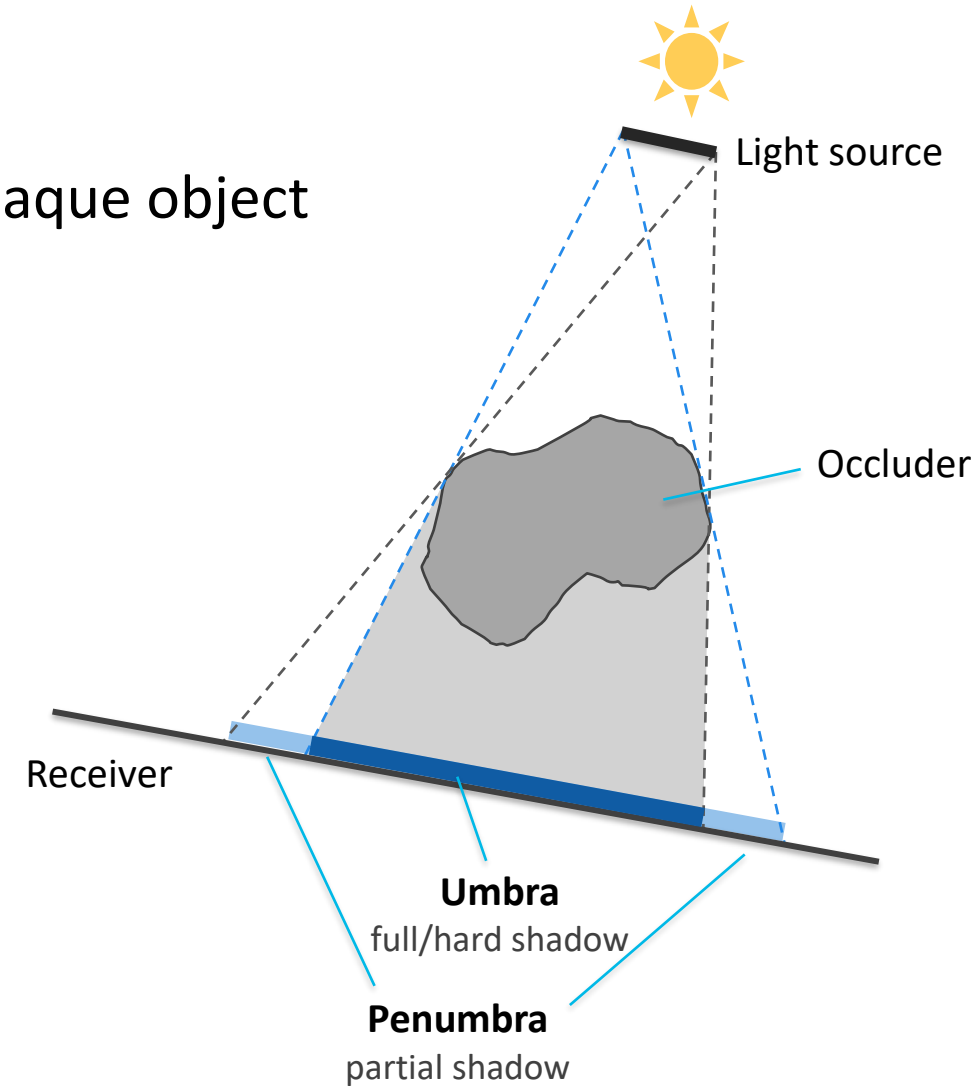
Dark area where light is blocked by opaque object

Provide important visual cues

- Depth perception & distance

[imgur.com]

Real photograph, no shadows during Lahaina Noon (solstice on Hawaii)



After [Akenine-Möller 2018]

Soft Shadows

Point lights, spotlights, and directional light create hard shadows

- Infinitesimal points or directions

Requires light source with area > 0

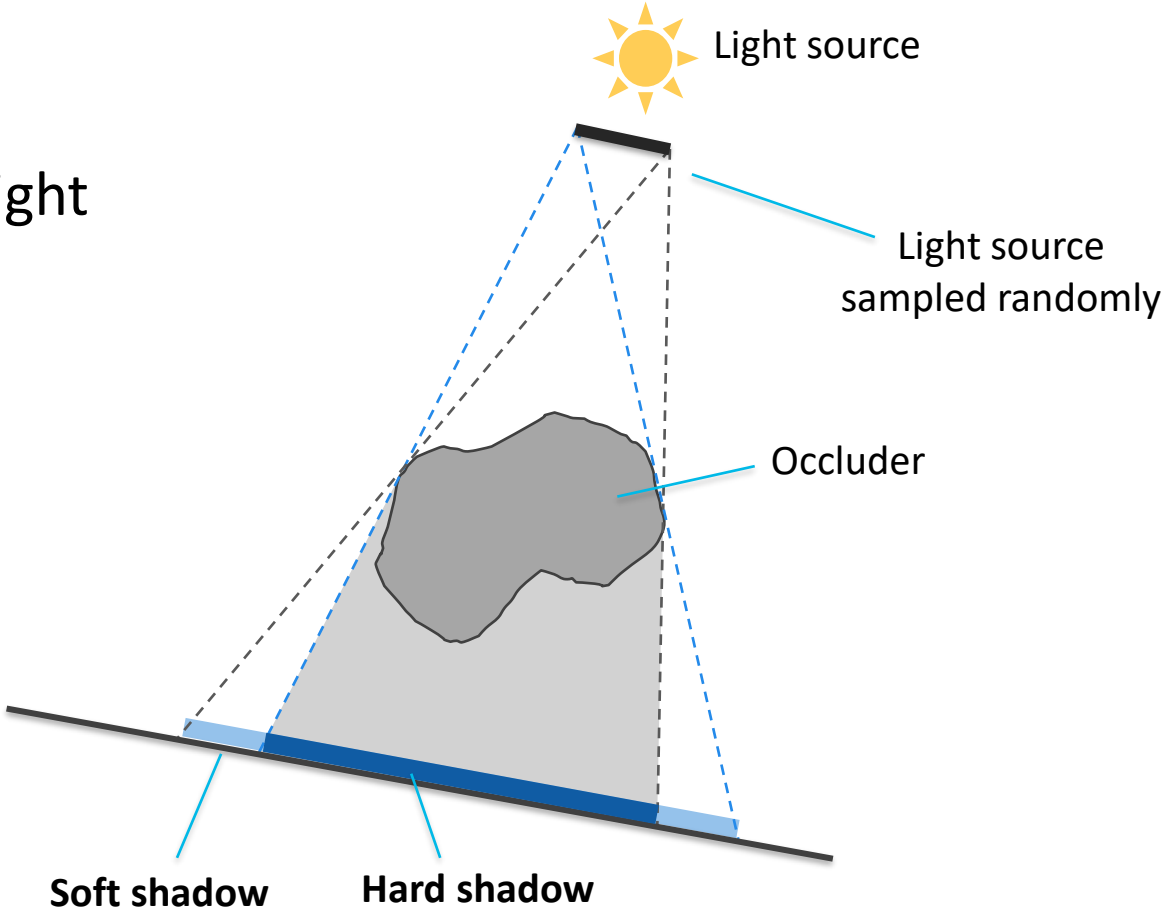
- Light can be partially visible

➔ Area light source

Test multiple points in light source for illumination

- Random sampling
- Shadow determined by average light visibility

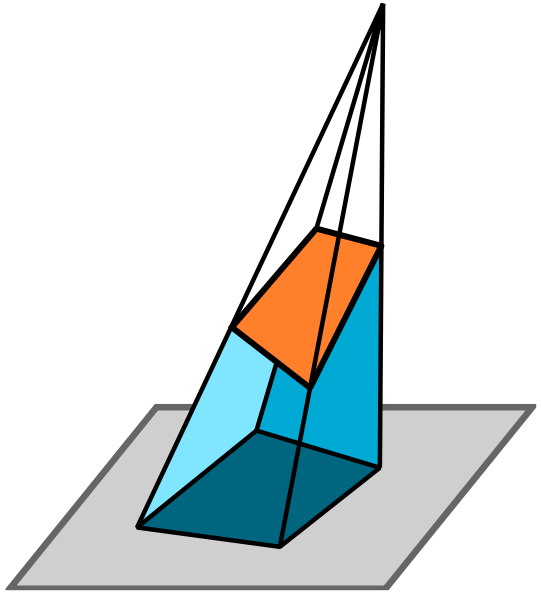
For hard shadows only: multi-pass rendering + average



Soft & Sharp Shadows

GTA 5 [NVIDIA]

Local Shadow Methods

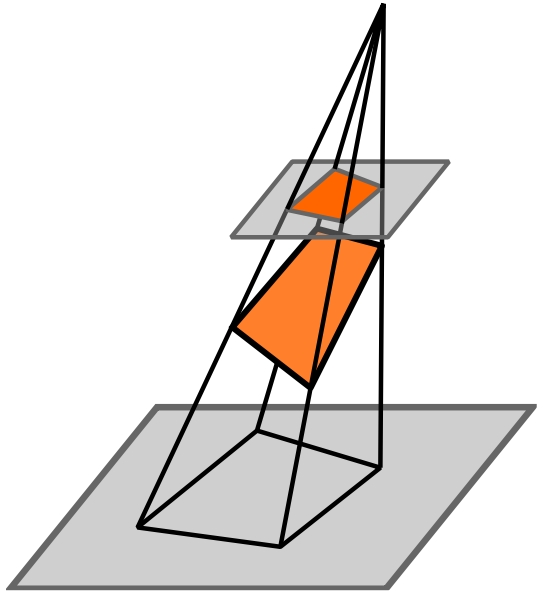


Shadow volumes

Object-space approach

Each object casts an infinite shadow volume

Stencil test on GPU with multi-pass rendering

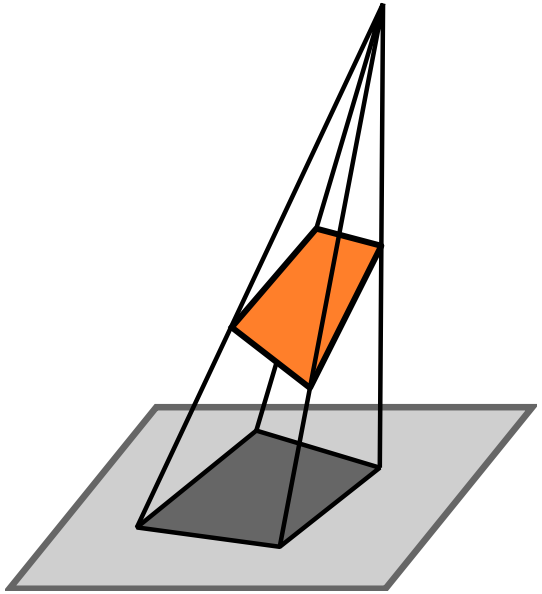


Shadow maps

Image-space approach

2-pass rendering

No real soft shadows



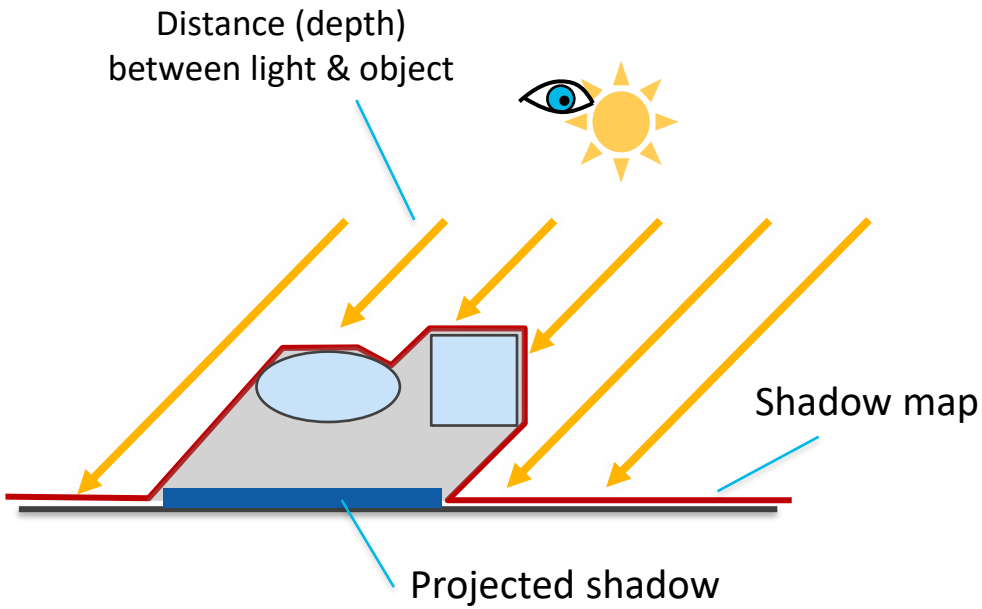
Projective shadows

Only shadows on planes

Compute and render shadow as separate object

Shadow Mapping

Idea: things not visible from a light are shadowed



Render scene from light perspective

- Create a shadow map for each light source
- Render only depth
- Orthographic projection for directional light source

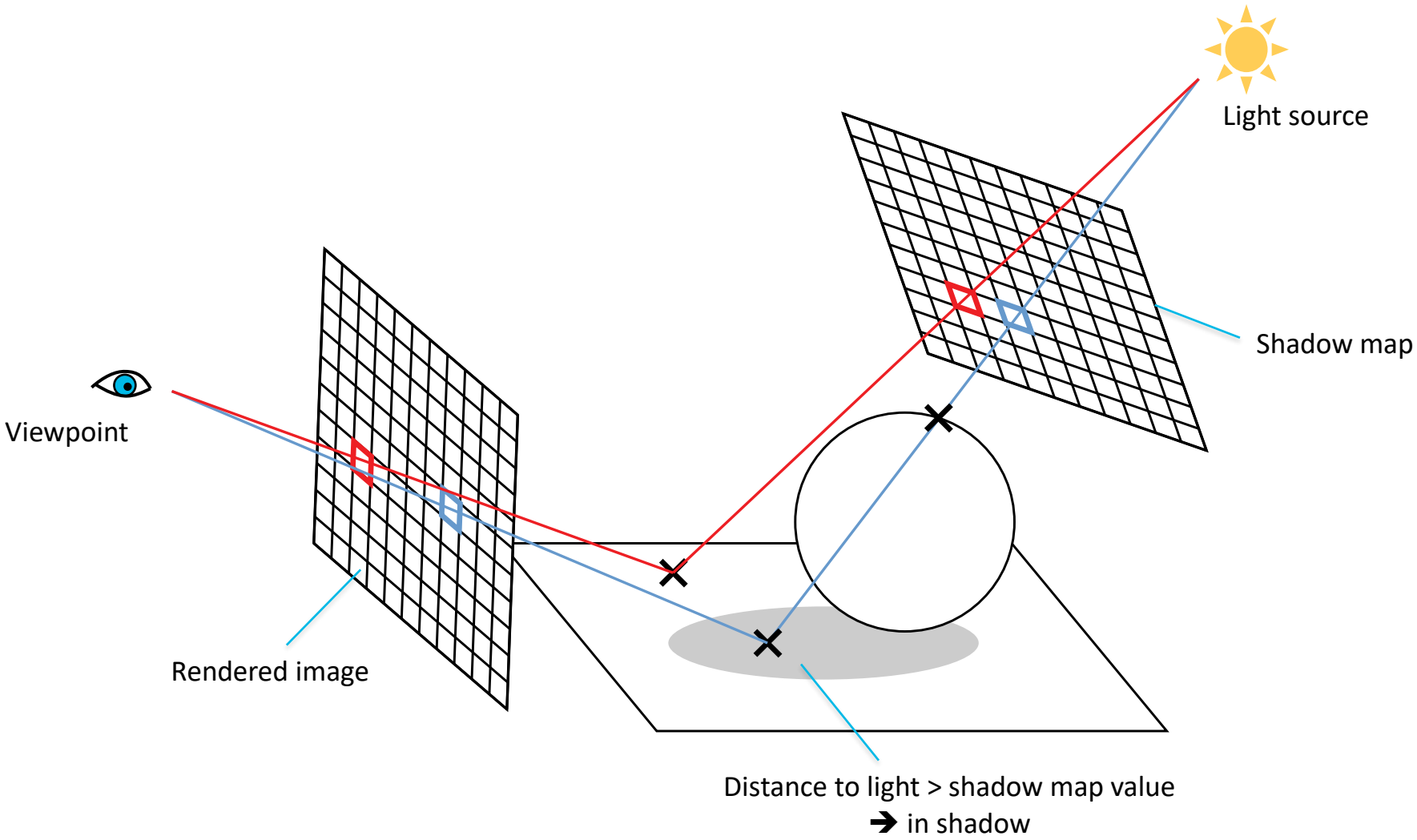
Render regular scene

- Transform fragment position into light space
- Query shadow map and compare light depth

Soft shadows:

- Sample shadow map multiple times and filter result

Shadow Mapping (cont.)



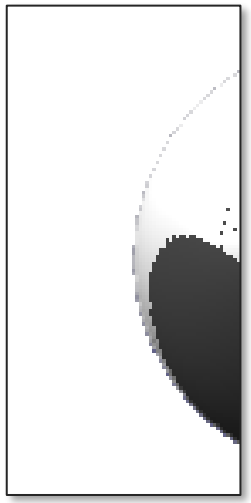
Shadow Map Problems

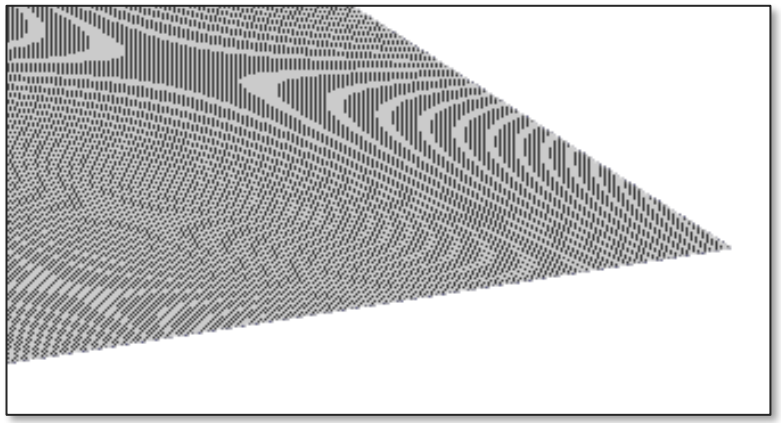
Limited precision of matrix transformations

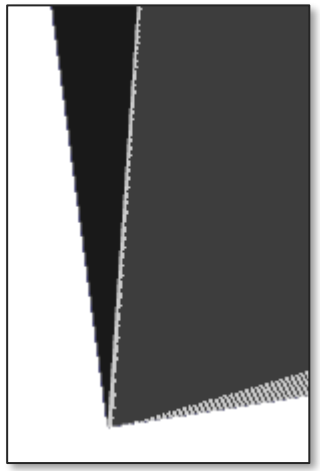
Limited resolution of shadow map

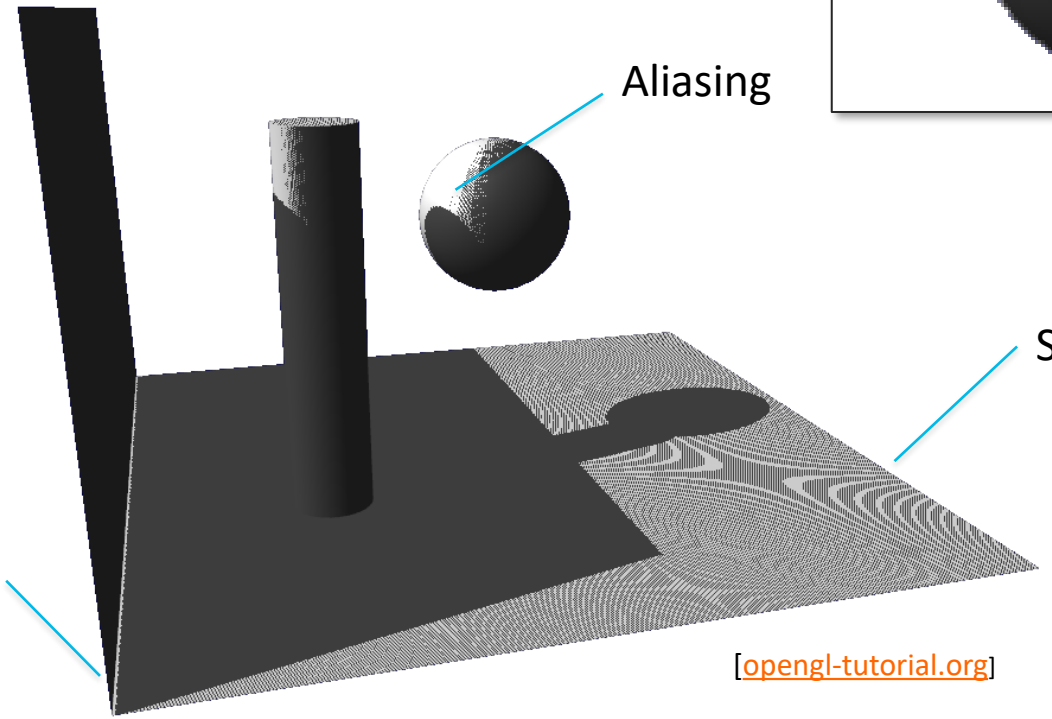
➔ shadow map bias (small offset)

➔ improved sampling like PCF (`sampler2DShadow`)









Peter Panning
floating shadows
(bias too large)

[opengl-tutorial.org]

Summary

– Illumination –

Light sources

- Different types: directional, point, spotlight, area light, skydome
- Basic lighting setup (3-point lighting)

Environment lighting & mapping

- Using HDR environmental maps for illumination & reflection
- Sphere maps, cube maps

Shadows

- Volumetric shadows, shadow maps, soft shadows

References – Illumination

[Akenine-Möller 2018] Tomas Akenine-Möller, Eric Haines, Naty Hoffman, Angelo Pesce, Michał Iwanicki, and Sébastien Hillaire. *Real-Time Rendering*, Fourth Edition, CRC Press, 2018.

[rendernode.com] Studio Lighting Setup in 3ds Max + VRay, https://www.rendernode.com/studio-lighting-setup/

[Birn 2013] Jeremy Birn. Digital Lighting & Rendering, third edition, New Riders Pub, 2013. http://3drender.com/light/index.html

[Miller 1984] Gene S. Miller and C. Robert Hoffman. *Illumination and Reflection Maps: Simulated Objects in Simulated and Real Environments*, SIGGRAPH Advanced Computer Graphics Animation course, 1984. http://www.pauldebevec.com/ReflectionMapping/miller.html

Coming up next

Ray Tracing

- Whitted ray tracing
- Path tracing