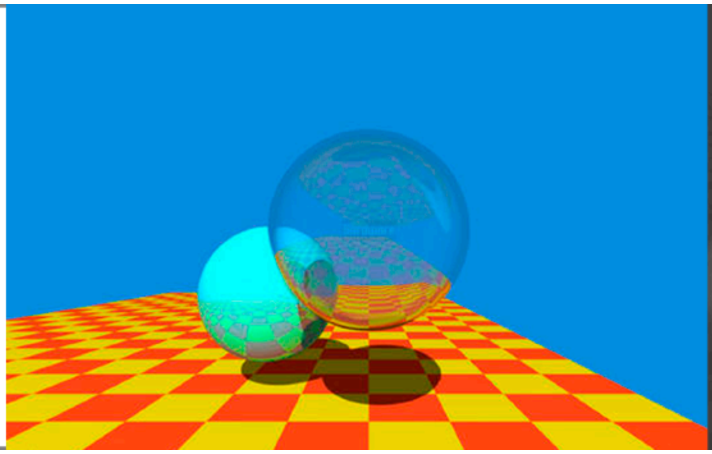
Introduction to Computer Graphics

GAMES101, Lingqi Yan, UC Santa Barbara

Lecture 7:
Shading 1 (Illumination, Shading and Graphics Pipeline)






http://www.cs.ucsb.edu/~lingqi/teaching/games101.html

Announcements

- Homework 1
    - 300+ submissions
    - Will start TA recruiting (from existing applications) soon
- Homework 2 will be out today
    - About Z-buffering
    - Much easier than HW1
- May need an additional lecture for shading

Last Lectures

- Rasterization
  - Rasterizing **one triangle**
  - Sampling theory
  - Antialiasing

Today

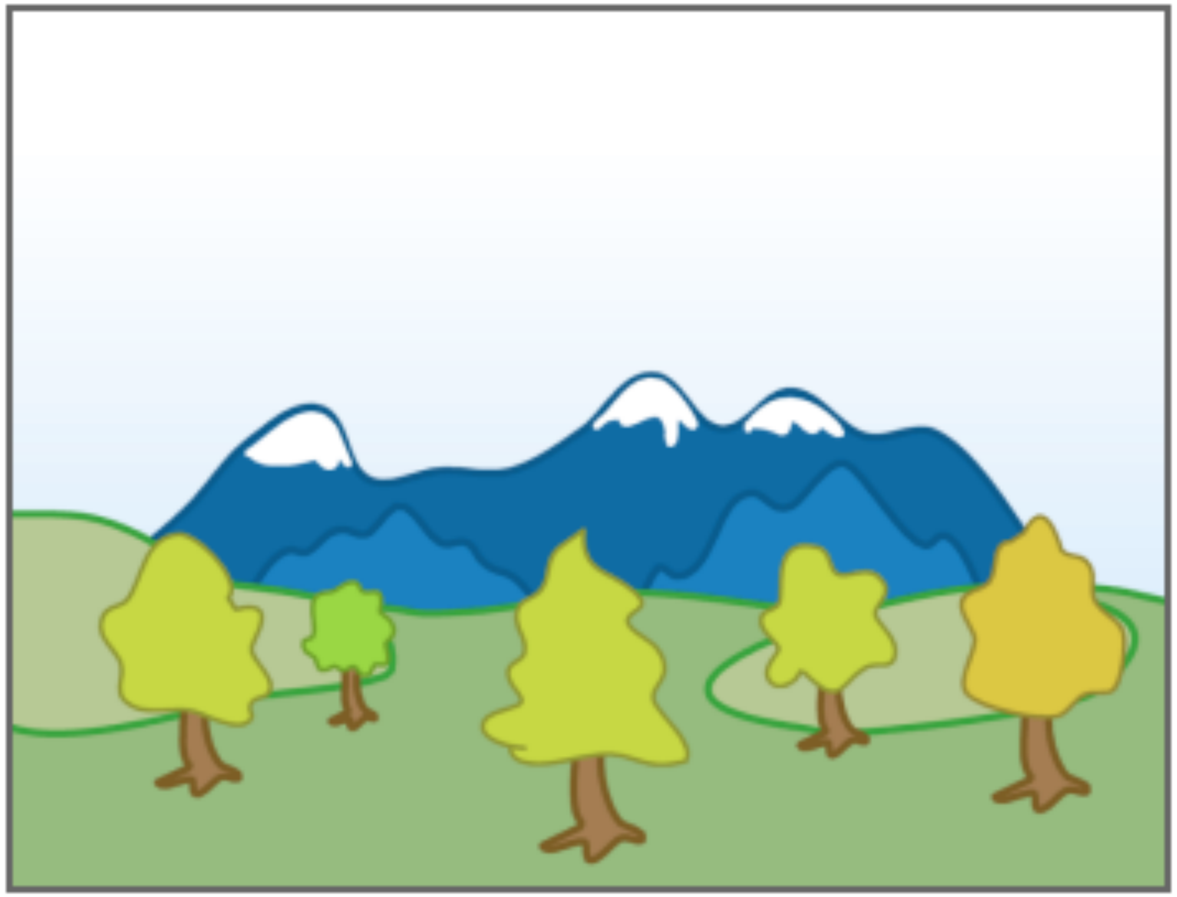
- Visibility / occlusion 可见性 / 遮挡
  - Z-buffering 深度缓存
- Shading 着色
  - 光照
    Illumination & Shading
  - Graphics Pipeline

Painter's Algorithm

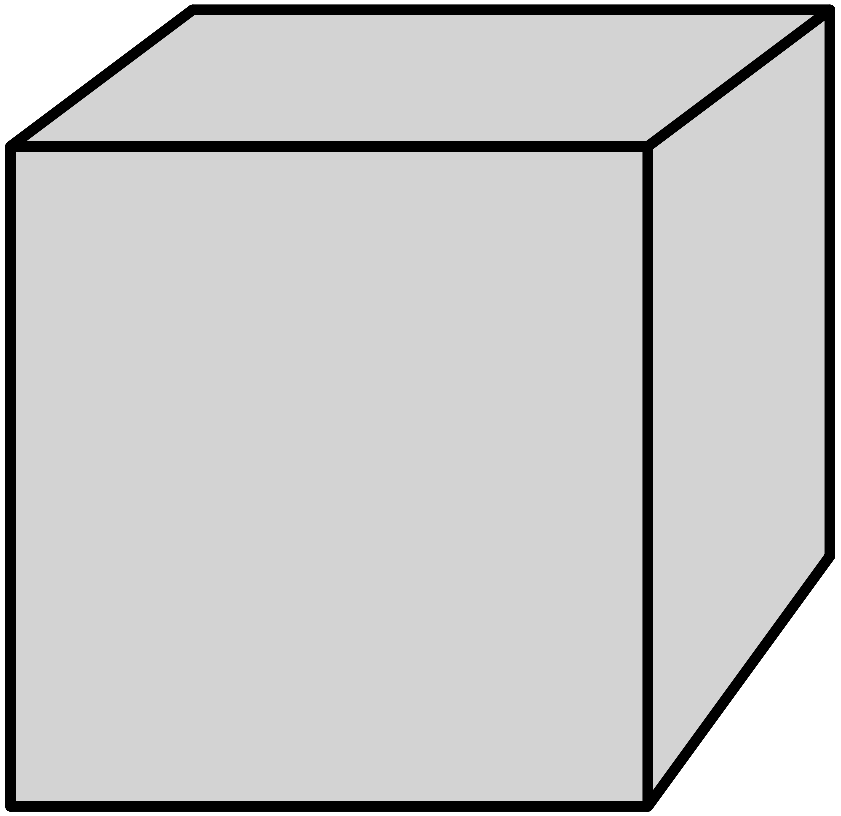
Inspired by how painters paint

由远即近

Paint from back to front, overwrite in the framebuffer



[Wikipedia]

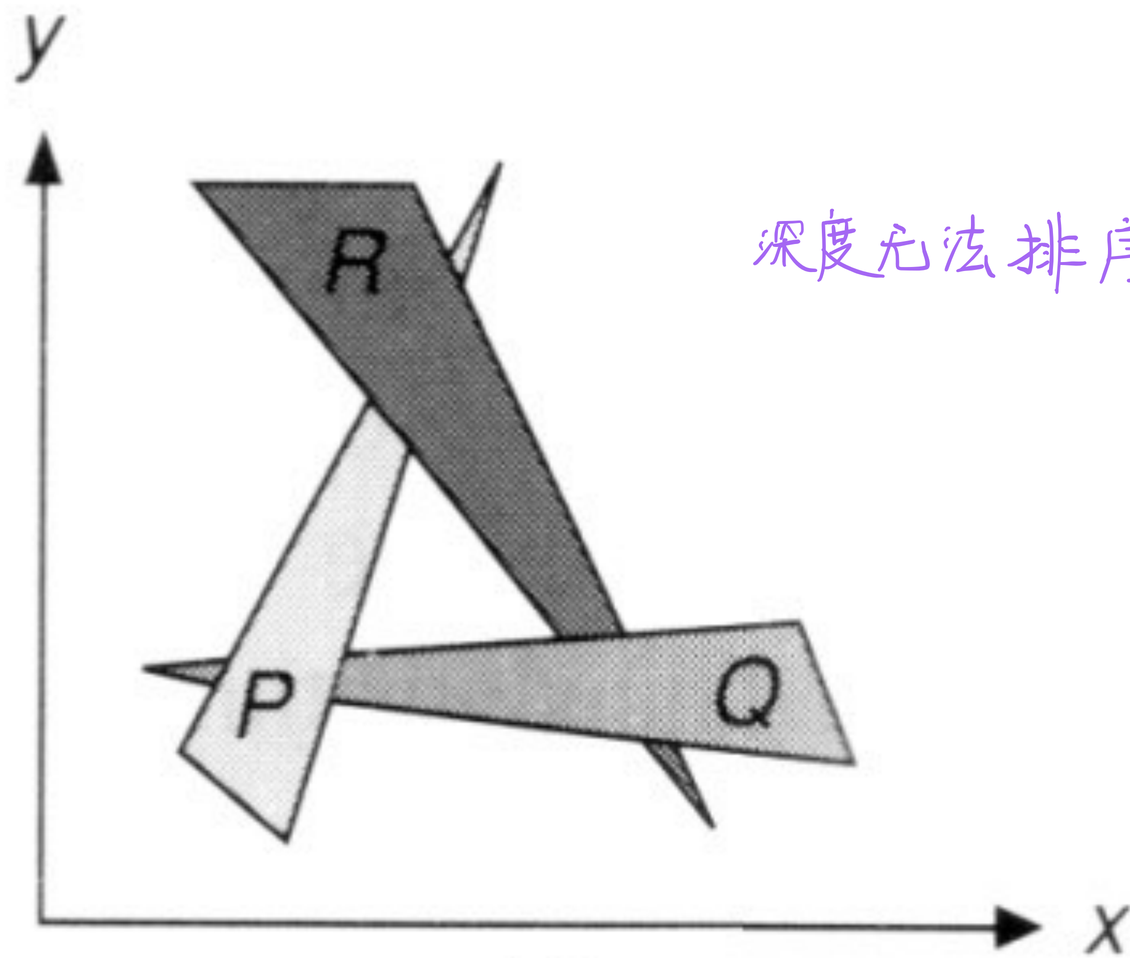


Painter's Algorithm

需要深度排序

Requires sorting in depth (O(n log n) for n triangles)

Can have unresolvable depth order



深度无法排序

[Foley et al.]

Z-Buffer

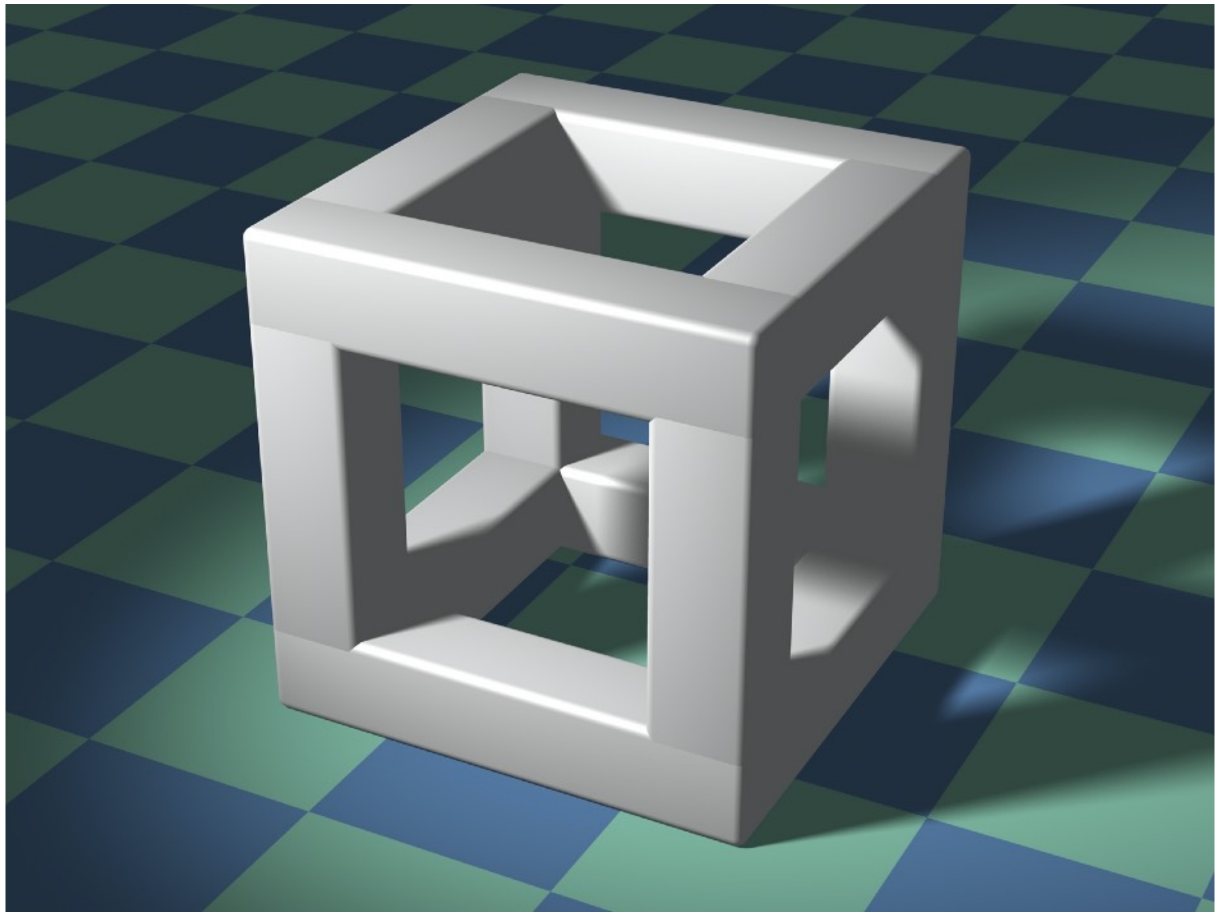
This is the algorithm that eventually won.

Idea:

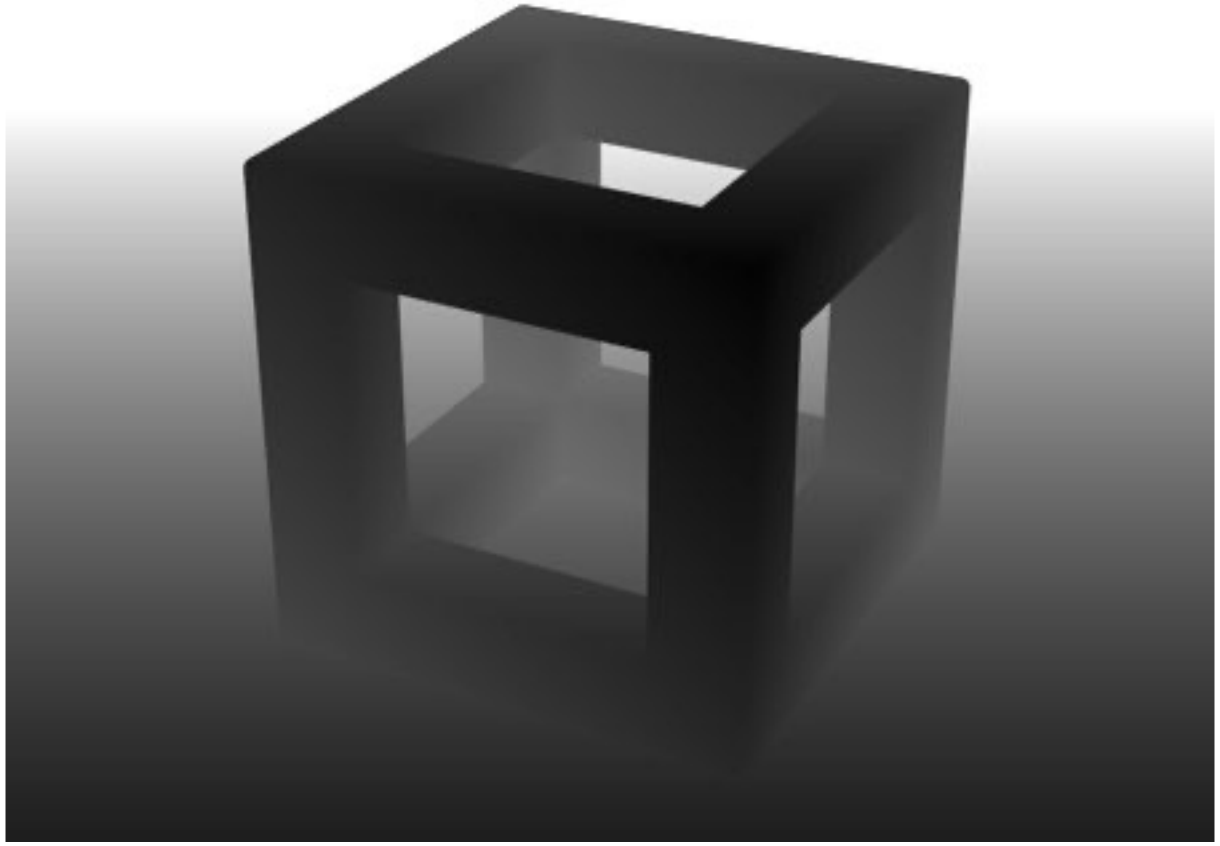
- Store current min. z-value for each sample (pixel)
- Needs an additional buffer for depth values
  - frame buffer stores color values
  - depth buffer (z-buffer) stores depth

IMPORTANT: For simplicity we suppose
z is always positive
(smaller z -> closer, larger z -> further)

Z-Buffer Example



Rendering



Depth / Z buffer

Image source: Dominic Alves, flickr.

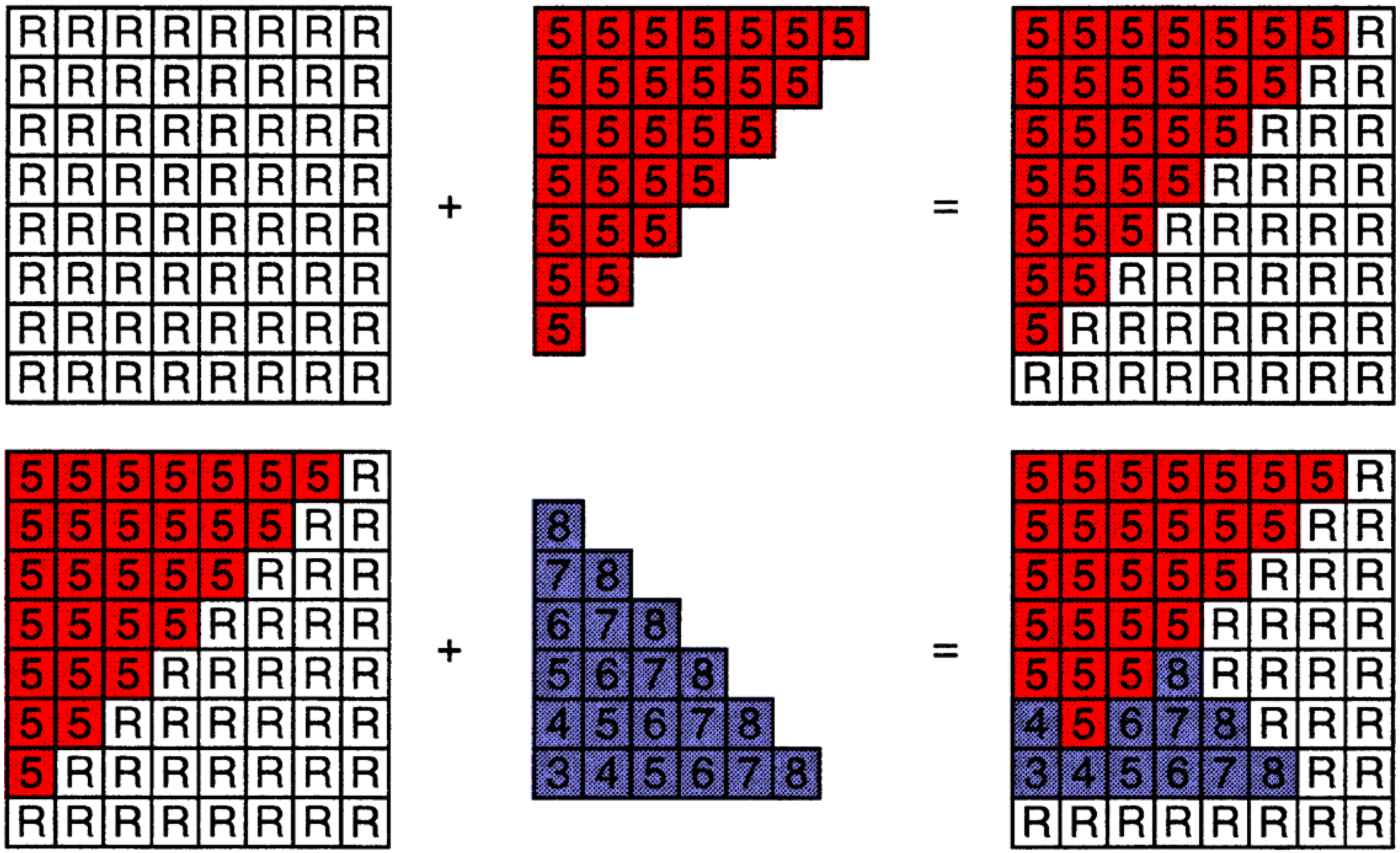
Z-Buffer Algorithm

Initialize depth buffer to ∞

During rasterization:

```
for (each triangle T)
    for (each sample (x,y,z) in T)
        if (z < zbuffer[x,y])                // closest sample so far
            framebuffer[x,y] = rgb;          // update color
            zbuffer[x,y] = z;                // update depth
        else
            ;                  // do nothing, this sample is occluded
```

Z-Buffer Algorithm



Z-Buffer Complexity

Complexity

- O(*n*) for *n* triangles (assuming constant coverage)
- How is it possible to sort *n* triangles in linear time?

没有在排序

Drawing triangles in different orders? 和顺序无关

Most important visibility algorithm

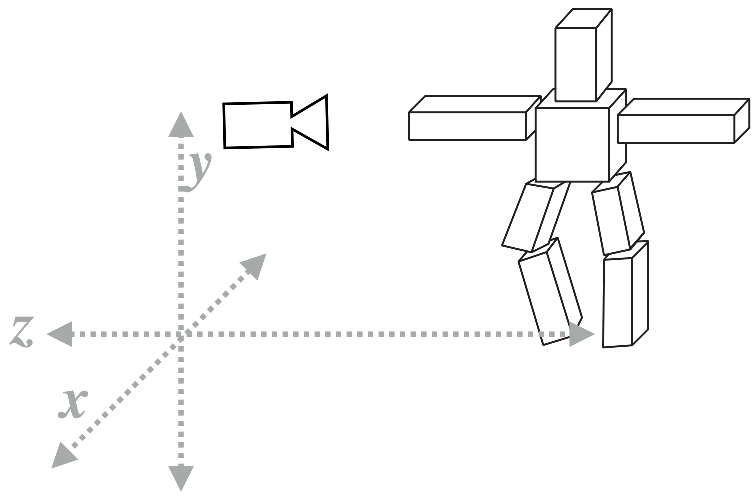
- Implemented in hardware for all GPUs

Questions?

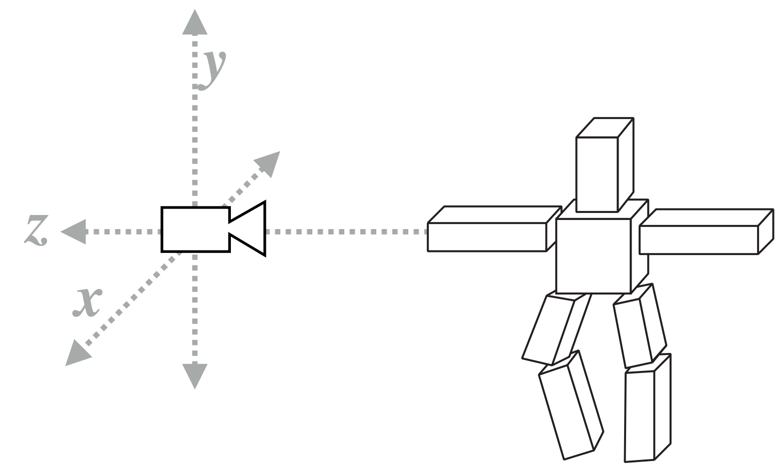
Today

- Visibility / occlusion
  - Z-buffering
- Shading 着色
  - Illumination & Shading
  - Graphics Pipeline

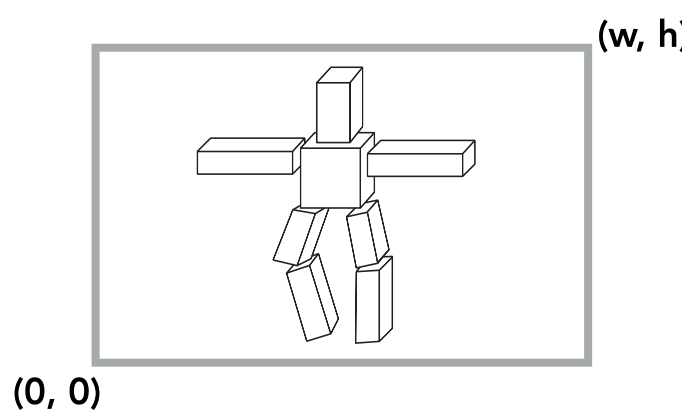
What We've Covered So Far



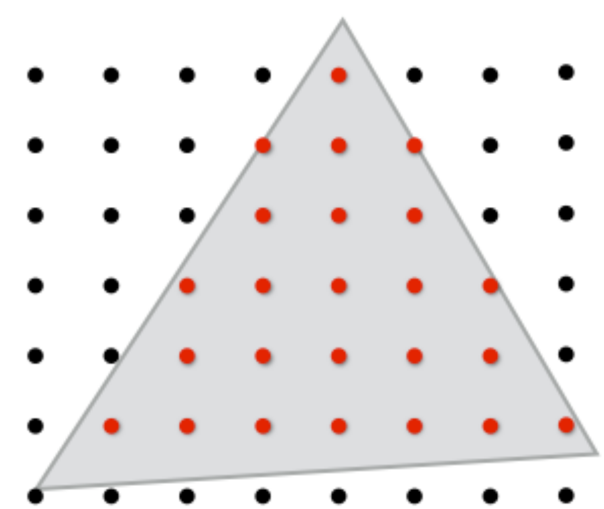
Position objects and the camera in the world



Compute position of objects relative to the camera

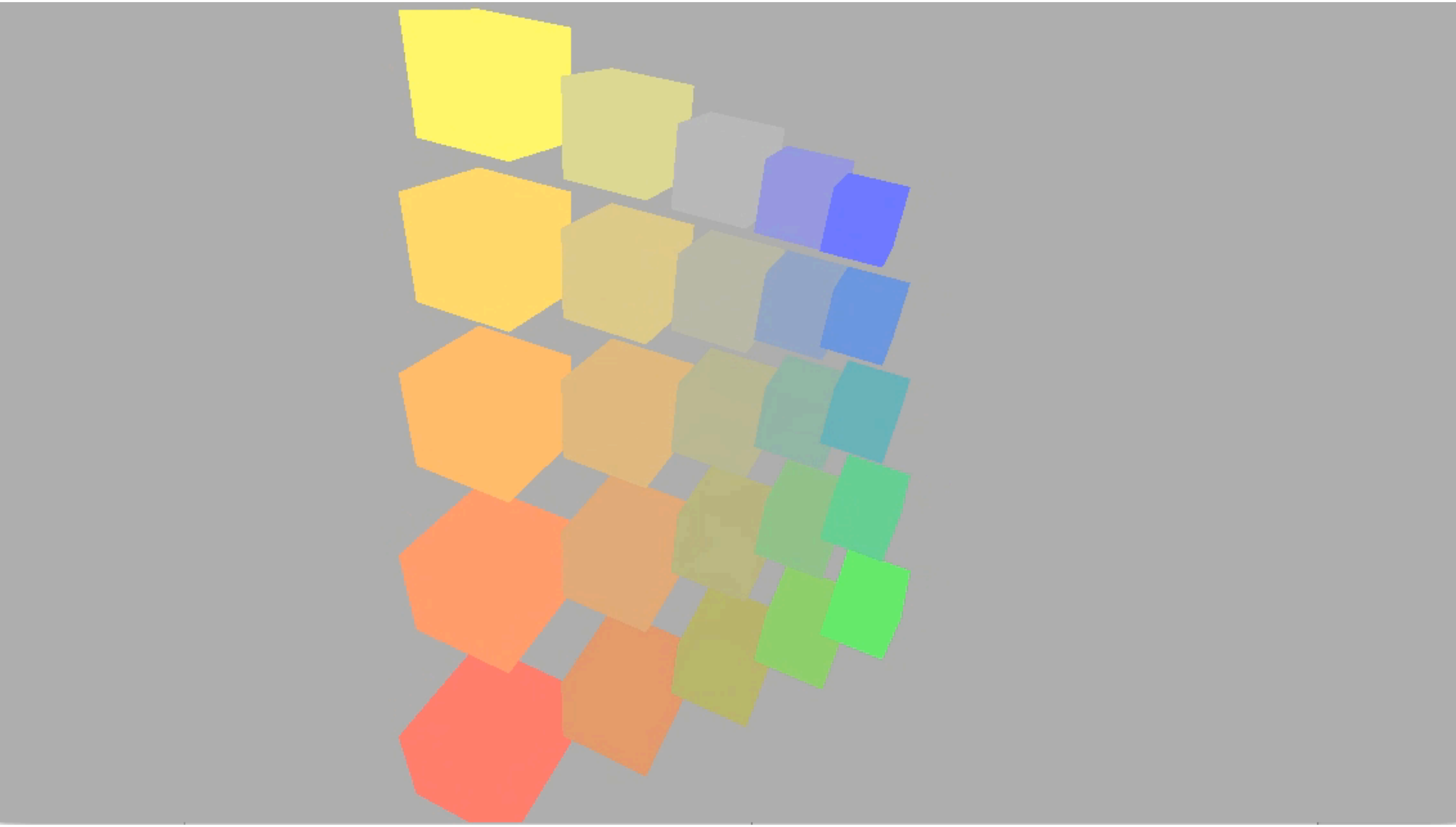


Project objects onto the screen

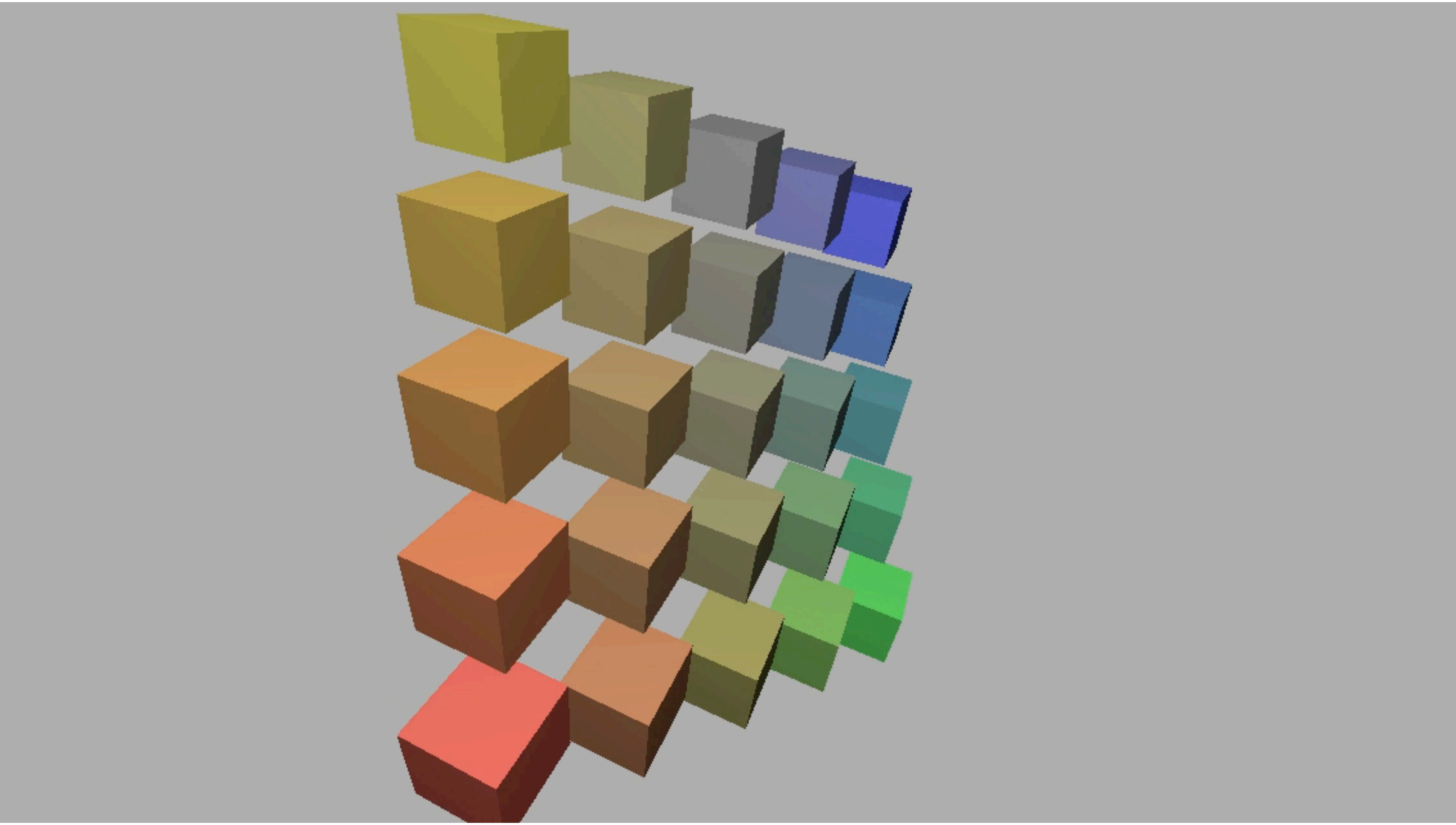


Sample triangle coverage

Rotating Cubes (Now You Can Do)



Rotating Cubes (Expected)



What Else Are We Missing?

Credit: Bertrand Benoit. "Sweet Feast," 2009. [Blender /VRay]

Shading

Shading: Definition

- In Merriam-Webster Dictionary

  shad·ing, [ˈʃeɪdɪŋ], noun
  明暗 颜色
  The darkening or coloring of an illustration or diagram with parallel lines or a block of color.

- In this course

  The process of applying a material to an object.

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A Simple Shading Model
(Blinn-Phong Reflectance Model)

Perceptual Observations

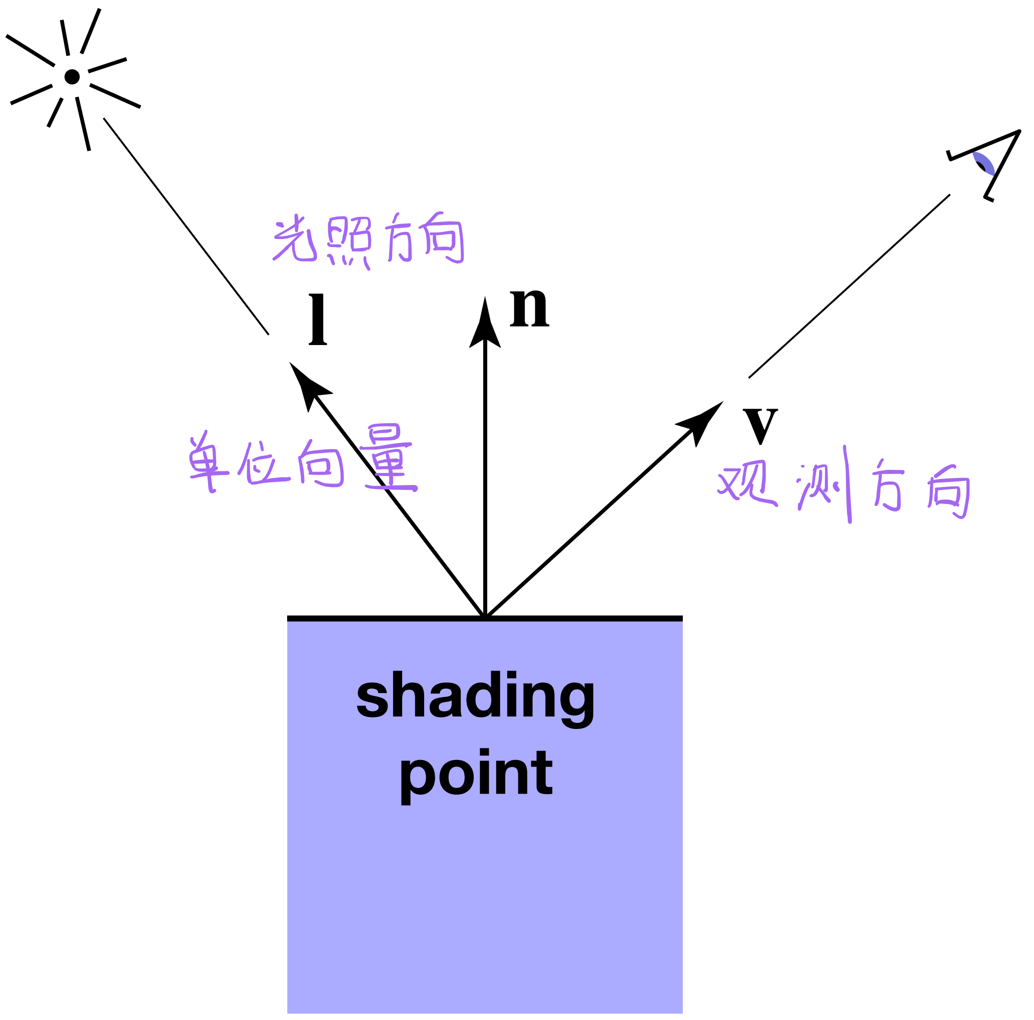
Photo credit: Jessica Andrews, flickr

Shading is Local

Compute light reflected toward camera at a specific shading point

Inputs:

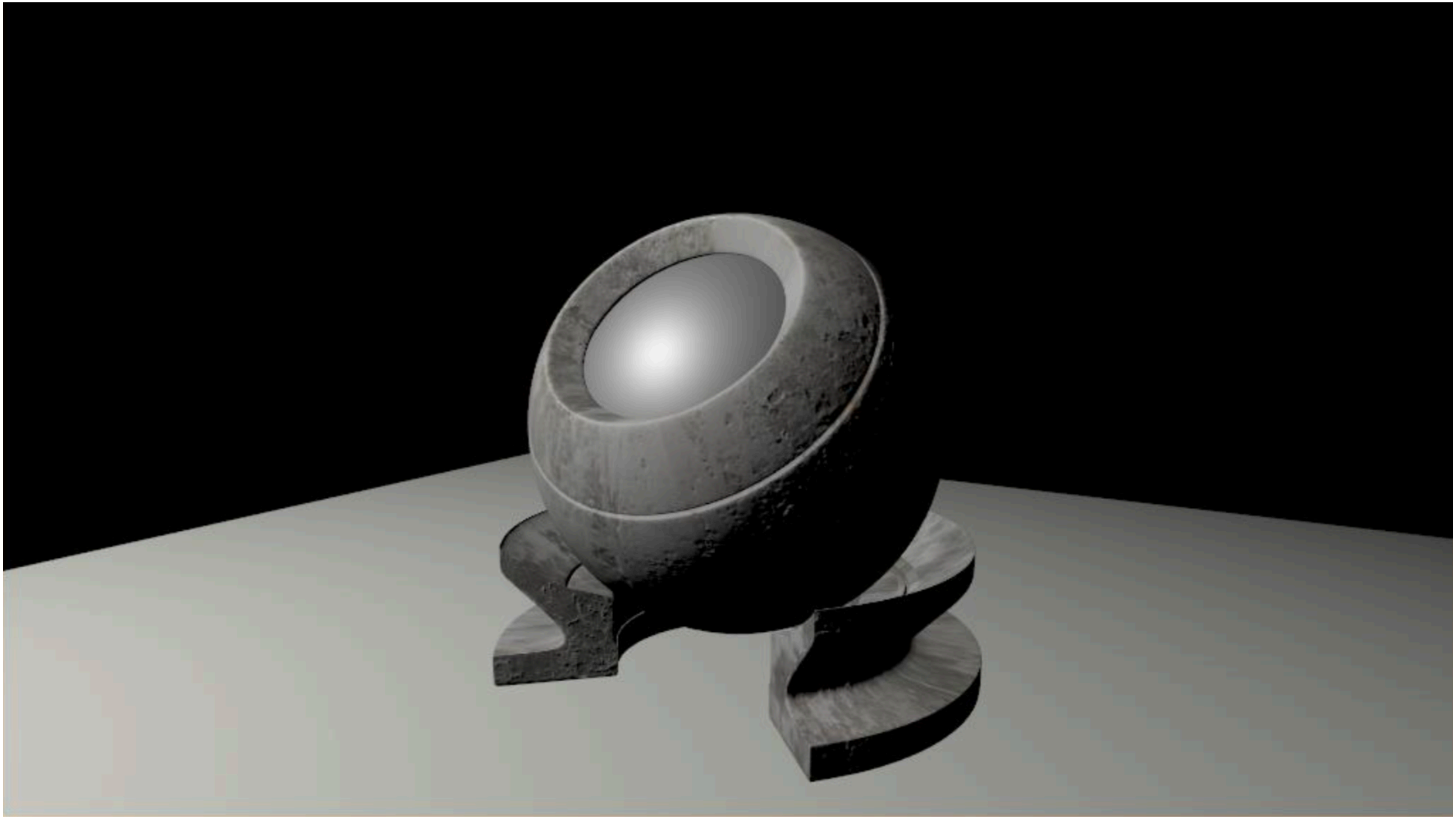
- Viewer direction, v
- Surface normal, n
- Light direction, l (for each of many lights)
- Surface parameters (color, shininess, …) 表面参数



Shading is Local 局部

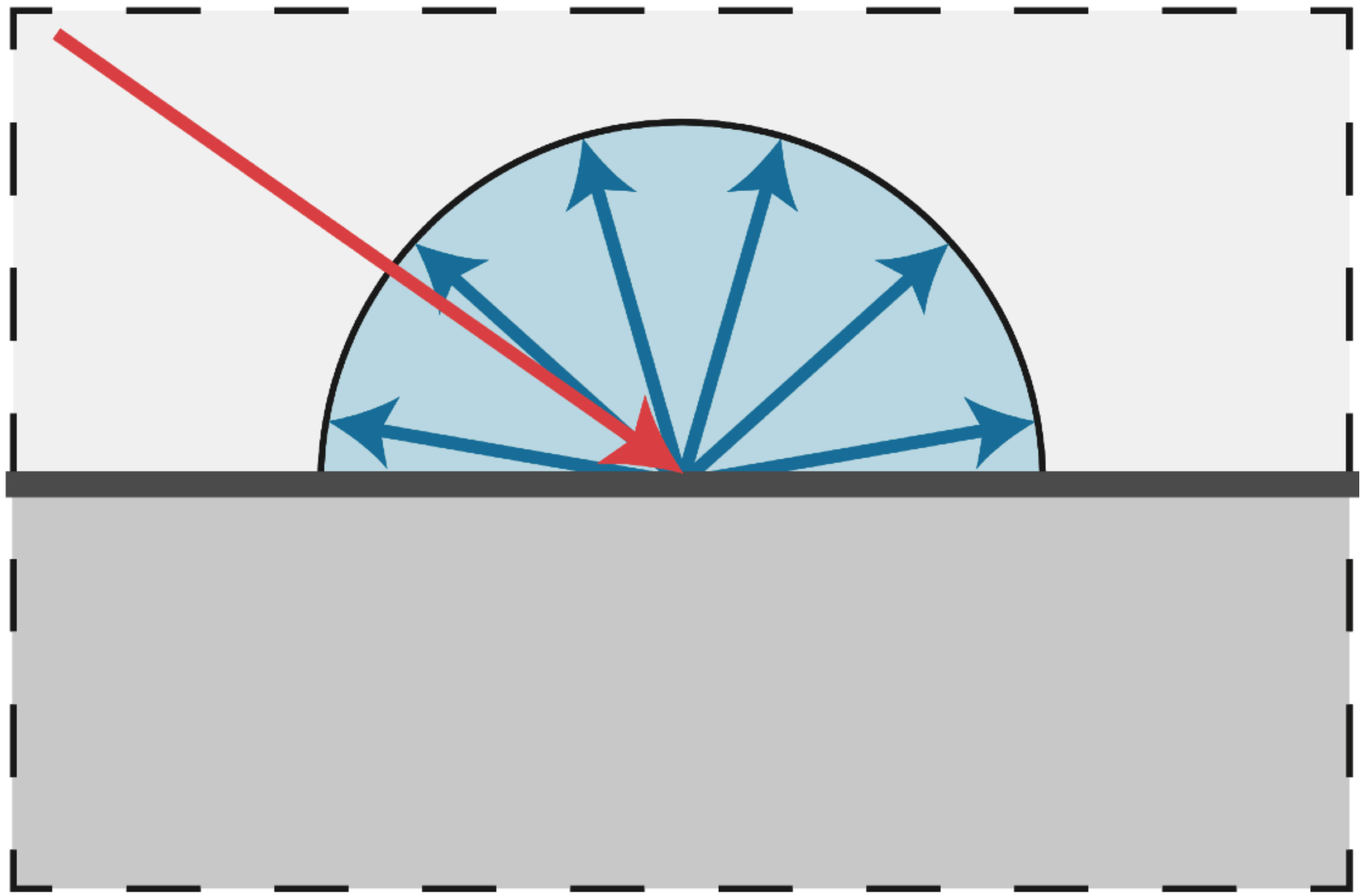
不考虑阴影

No shadows will be generated! (**shading ≠ shadow**)



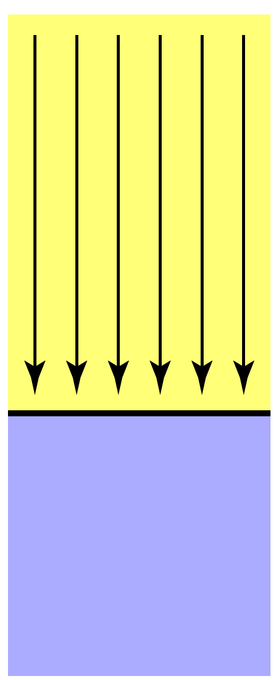
Diffuse Reflection

- Light is scattered uniformly in all directions
  - Surface color is the same for all viewing directions

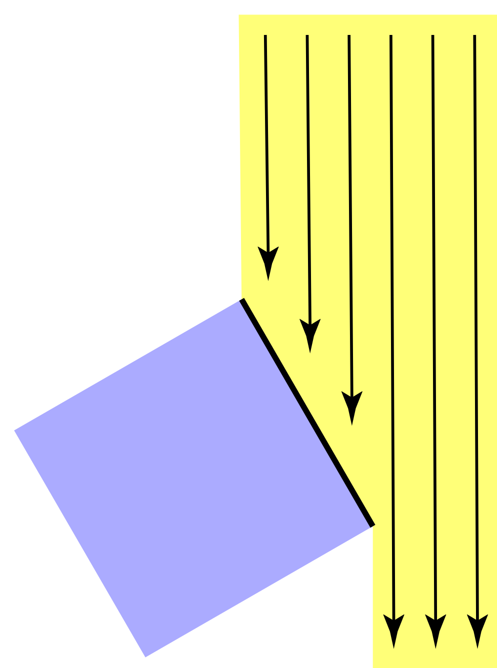


Diffuse Reflection

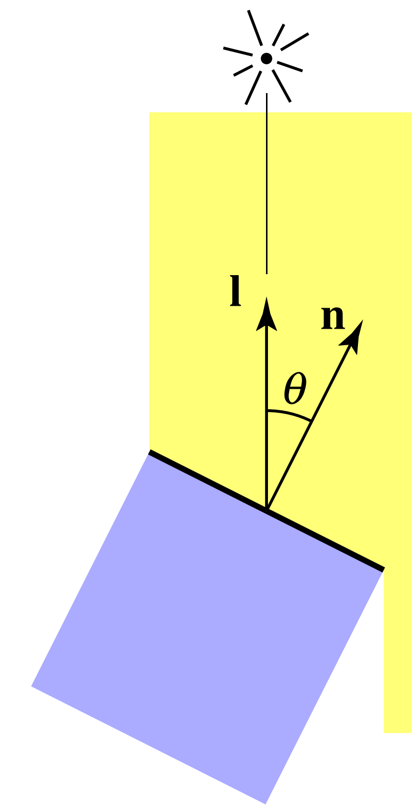
- But how much light (energy) is received?
  - Lambert's cosine law



Top face of cube receives a certain amount of light



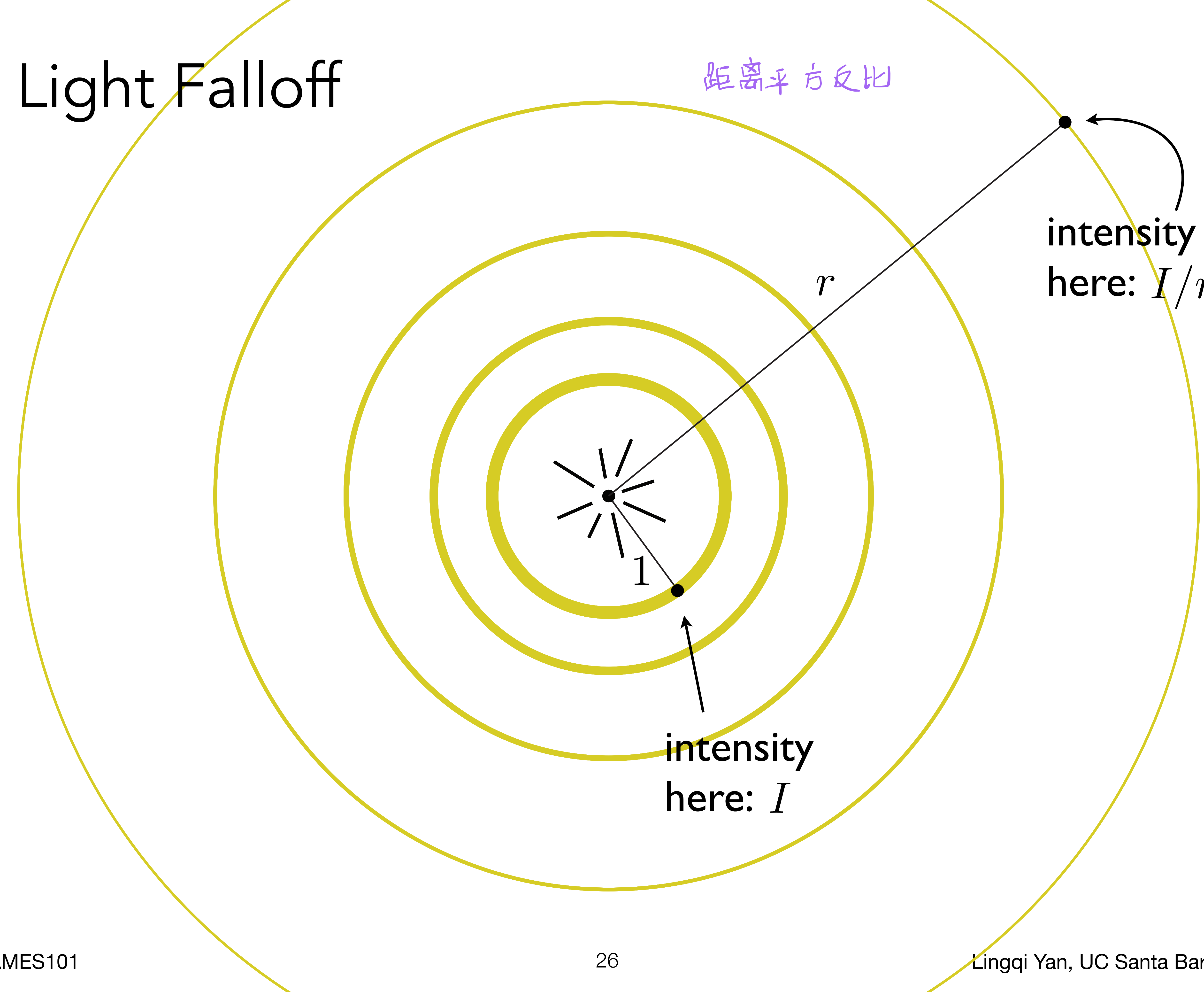
Top face of 60° rotated cube intercepts half the light



In general, light per unit area is proportional to $\cos\theta = \mathbf{l} \cdot \mathbf{n}$

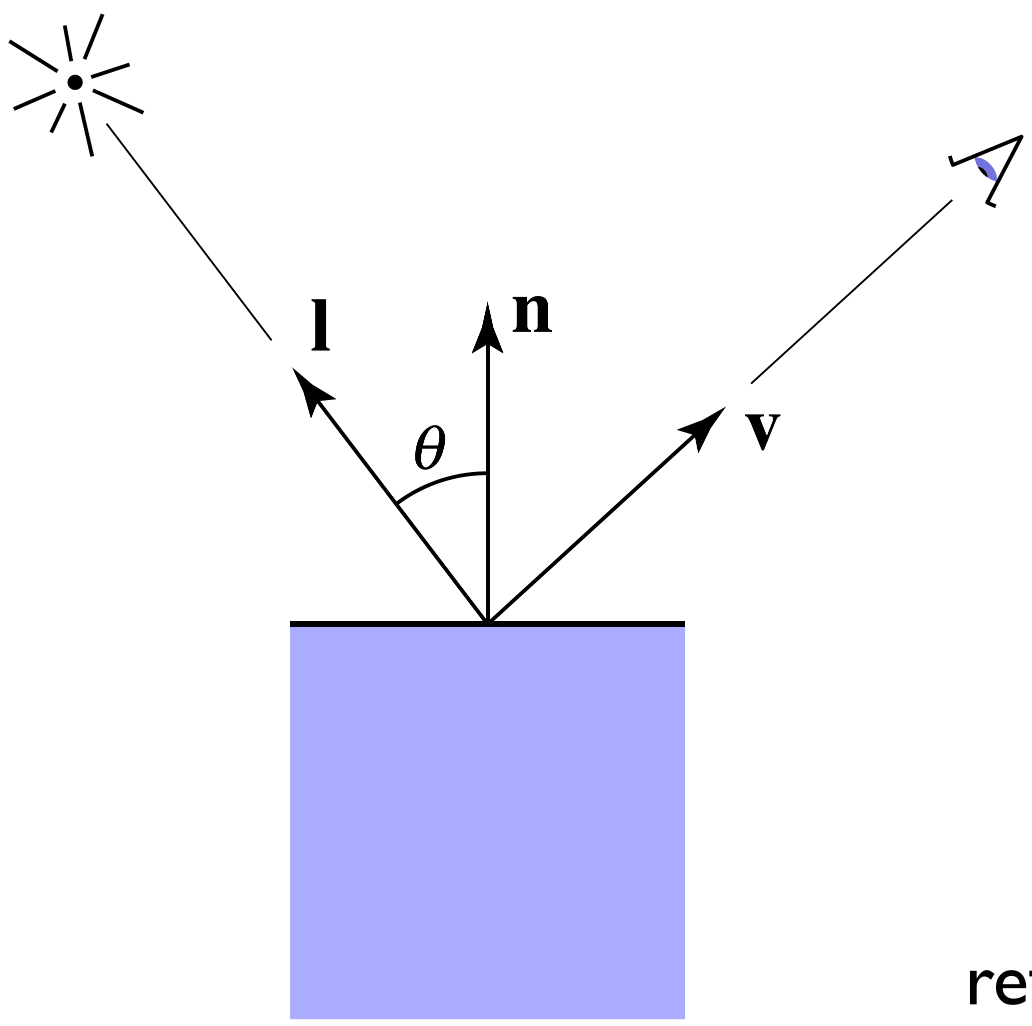
Light Falloff

距离平方反比



Lambertian (Diffuse) Shading

Shading independent of view direction



energy arrived at the shading point

$$L_d = k_d\,(I/r^2)\,\max(0, \mathbf{n} \cdot \mathbf{l})$$

diffusely reflected light

diffuse coefficient (color)

吸收能量系数

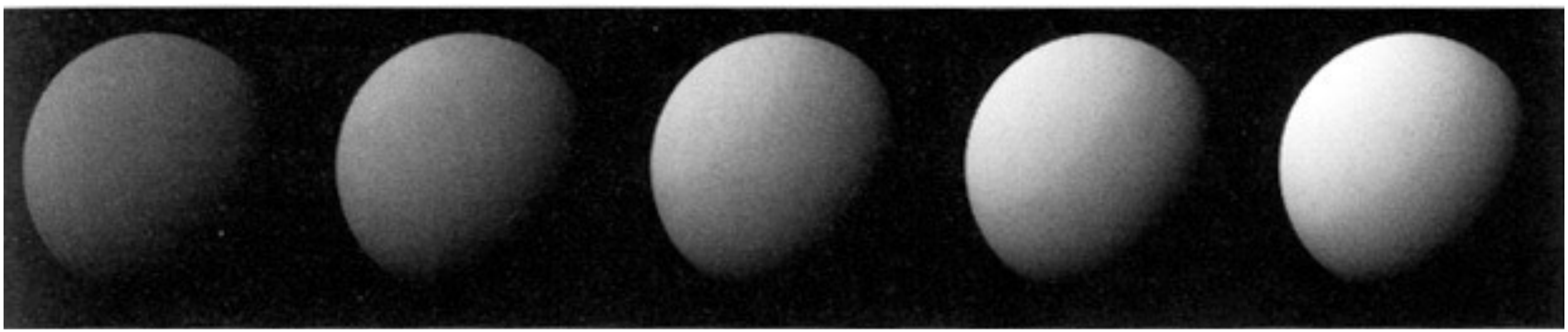
energy received by the shading point

与观察方向v无关

从每一个角度看都一样

Lambertian (Diffuse) Shading

Produces diffuse appearance



$k_d \longrightarrow$

[Foley et al.]

Thank you!

(And thank Prof. Ravi Ramamoorthi and Prof. Ren Ng for many of the slides!)