Computer Graphics 1

8 Shading and Shadowing

Summer Semester 2021

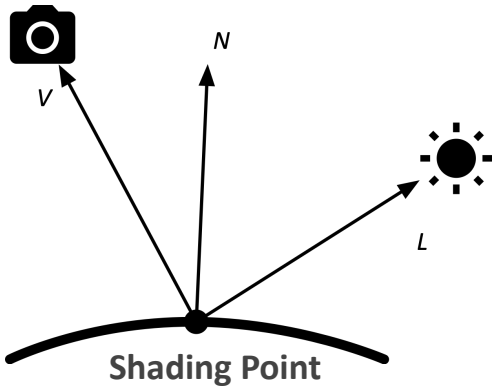
Ludwig-Maximilians-Universität München

Tutorial 8: Shading and Shadowing

- Shading
  - The Phong and Blinn-Phong Reflection Model
  - Shading Frequency
- Shadowing
  - Shadow Map

Shading

- Shading is *local* by definition
- The purpose of shading is to compute the color of a shading point
- Computation take many factors into consideration:
  - Camera (view) direction, V
  - Surface normal, N
  - Light direction, L
  - Material parameters: color, schininess, …
  - ...



The Phong Reflectance Model

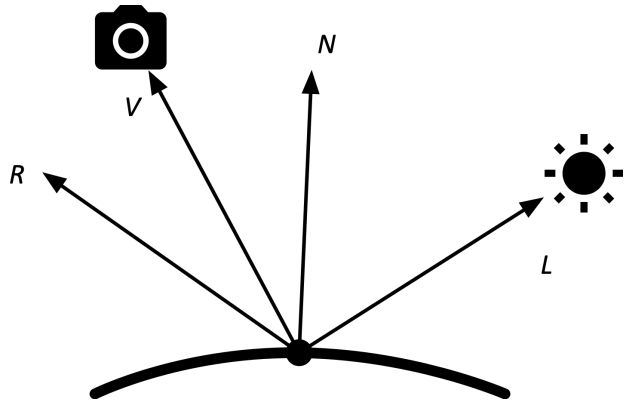
$$L_{\text{Phong}} = L_a + L_d + L_s = k_a + k_d \max(0, \mathbf{N} \cdot \mathbf{L}) + k_s \max(0, \mathbf{R} \cdot \mathbf{V})^p$$

Ambient Term — Diffuse/*Lambertian* Term — Specular/*Phong* Term

The Phong Reflectance Model takes these into account:

- Ambient: a constant intensity
- Diffuse: surface normal and light direction
- Specular: reflected beam direction and camera direction

The specular term is defined as Phong's Term



The Blinn-Phong Reflectance Model

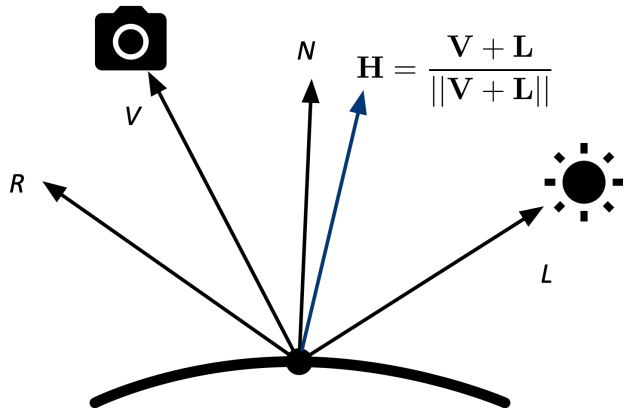
$$L_{\text{Blinn-Phong}} = L_a + L_d + L_s = k_a + k_d \max(0, \mathbf{N} \cdot \mathbf{L}) + k_s \max(0, \mathbf{N} \cdot \mathbf{H})^p$$

Ambient Term — Diffuse/*Lambertian* Term — Specular/*Phong* Term

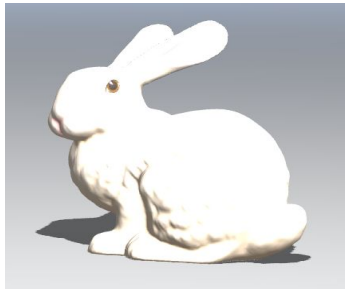
The Blinn-Phong reflectance model is an improved version of Phong's reflectance model:

- Ambient: a constant intensity
- Diffuse: surface normal and light direction
- **Specular: surface normal and half vector** $\mathbf{H} = \dfrac{\mathbf{V} + \mathbf{L}}{||\mathbf{V} + \mathbf{L}||}$
  - **No reflected direction needed ⇒ Fast computation**

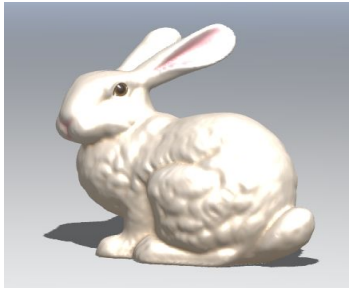
The specular term is defined as Blinn-Phong's Term



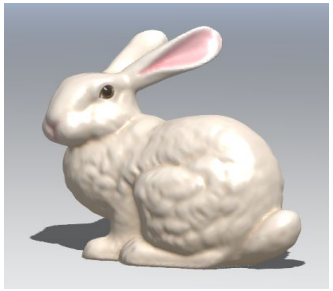
Shininess



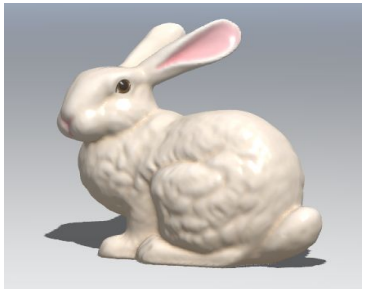
p = 1



p = 10



p = 50

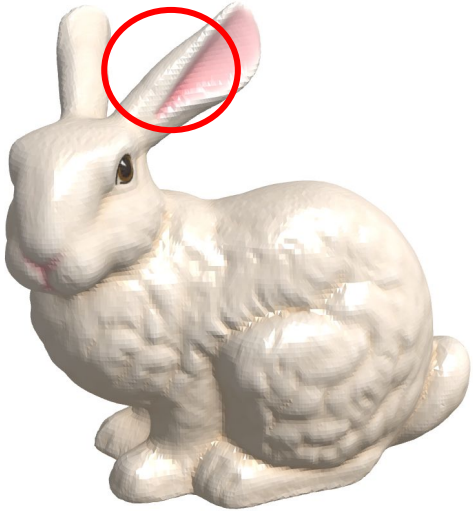


p = 200

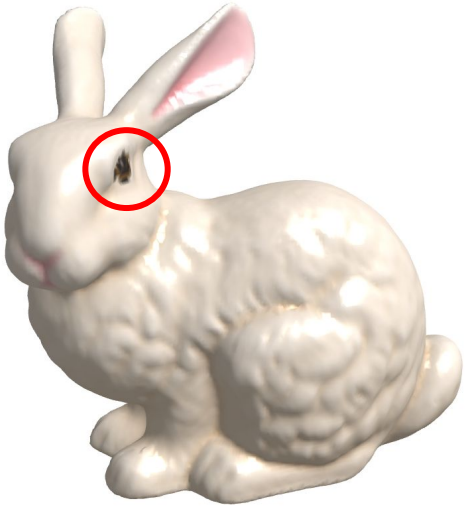
p = 1000

Reflection becomes more shiny when *p* increases, but we can't see it if it is too high

Shading Frequency



Flat Shading (per face)



Gouraud Shading (per vertex)

Phong Shading (per fragment)

Flat shading: shading triangles with a single color

Gouraud shading: shading of polygons by interpolating colors that are computed at vertices

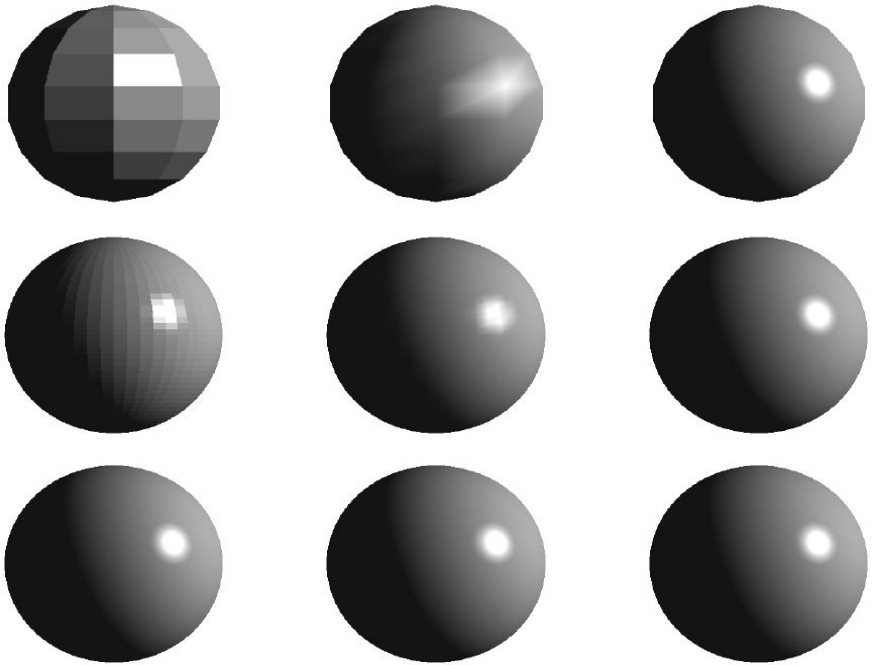
Phong shading: normals are interpolated between the vertices and lighting is evaluated per-pixel

Shading Frequency (cont.)

With more faces, vertices are closer to each other,

different shading frequencies are harder to distinguish:

- Flat shading
  - face becomes a pixel eventually
- Gouraud shading
  - interpolation between vertices is gone
- Phong shading
  - Works as before



Flat Shading **Gouraud Shading** **Phong Shading**

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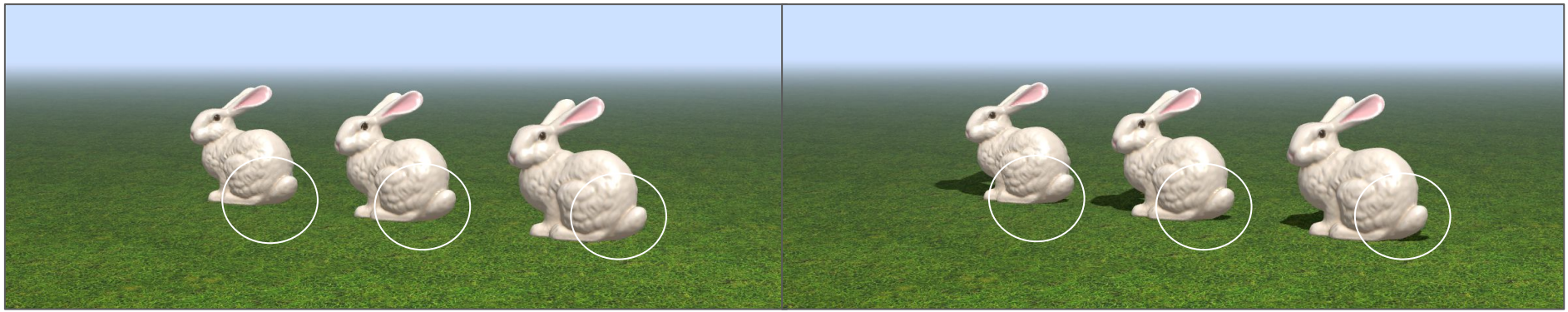
Shadow

Without shadows, the bunnies look like they are floating above the ground

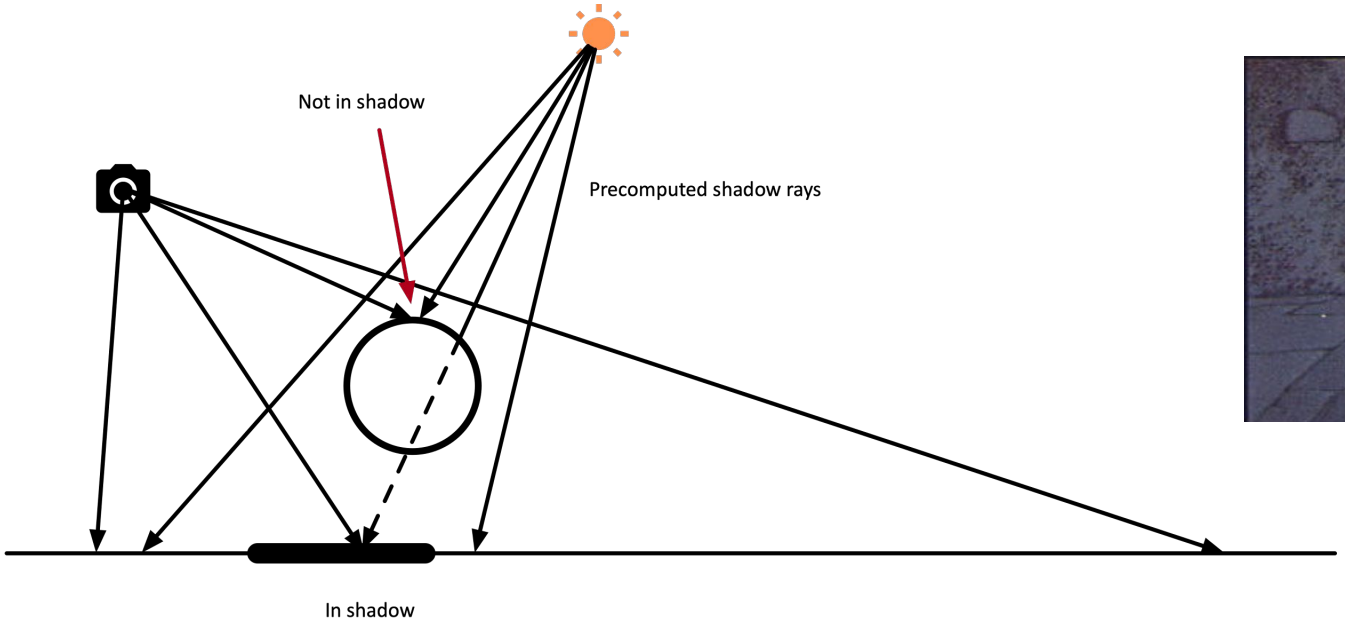
⇒ Shadow plays an important role for spatial vision (objects touch each other)

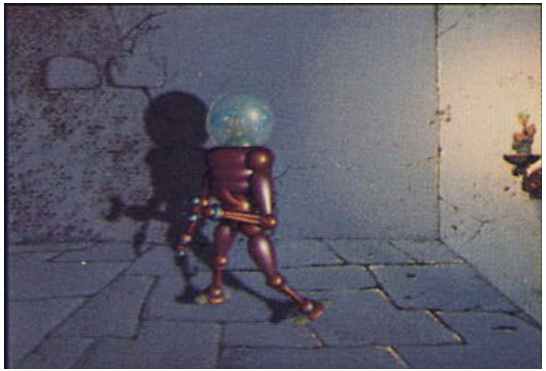


Shadow Map

Basic idea: A point ***not*** in shadow can be seen both by the light (camera) and view camera

The idea can be implemented by comparing depth buffer values (therefore requires two rendering passes).



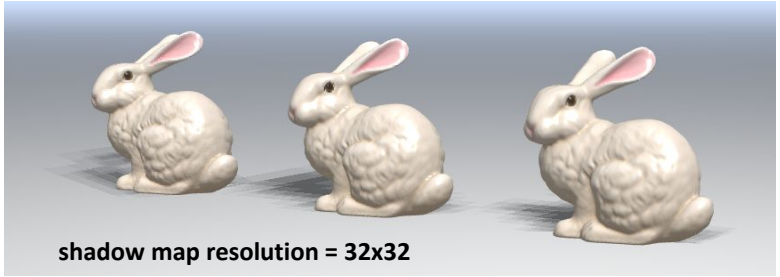


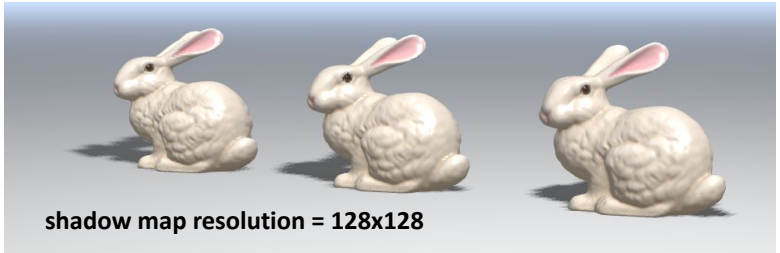
Lance Williams. 1978. Casting curved shadows on curved surfaces. In Proceedings of the 5th annual conference on Computer graphics and interactive techniques (SIGGRAPH '78). Association for Computing Machinery, New York, NY, USA, 270–274. DOI:https://doi.org/10.1145/800248.807402

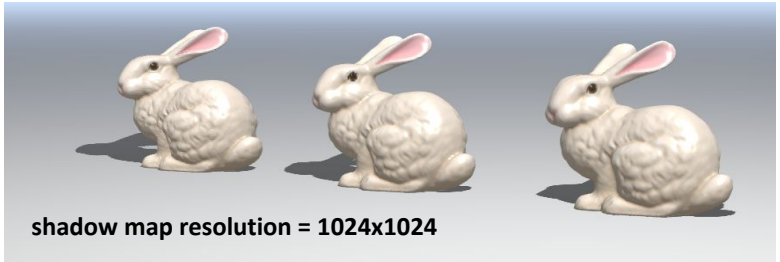
Problem with Shadow Maps

- Hard shadows
- Quality depends on shadow map resolution
- Involves equality comparison of floating point depth values

  => issue of scale, bias, tolerance

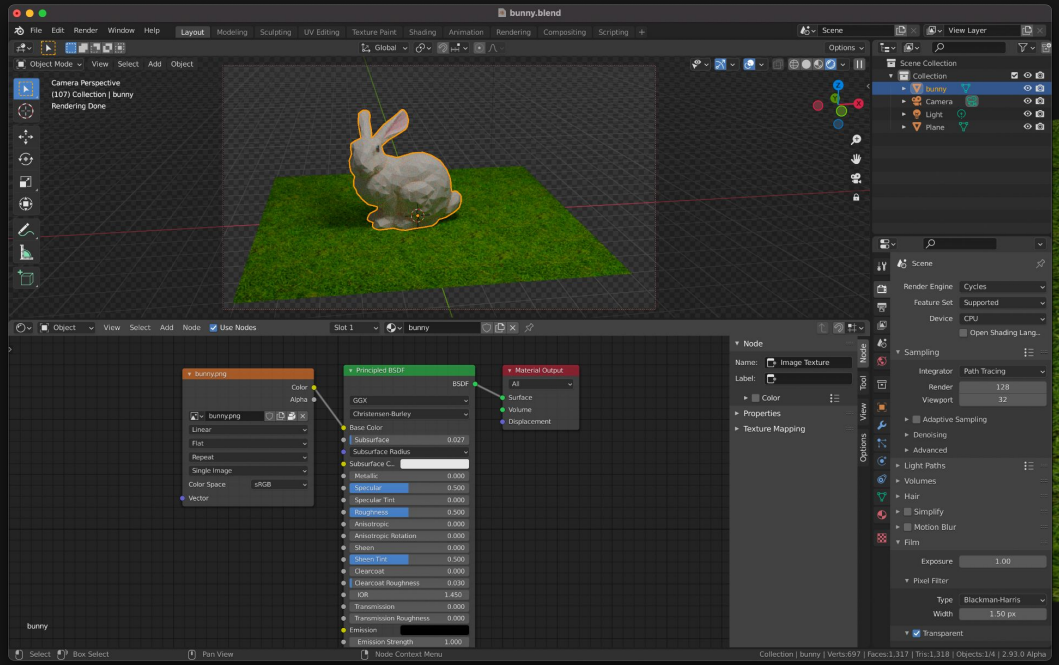






Breakout: A Lovely Bunny with Shadows

Open bunny.blend, press F12 key to render the bunny with soft shadows.



Summary

- We covered:
  - The classic Phong and Blinn-Phong reflectance models, and the meaning of the parameters in the model
  - The three shading frequencies and their differences
  - Shadow as an important visual effect, how shadow map can be used in creating shadows and its limitation
- Shadows are a first step towards modern computer graphics, we encourage to checkout the following book: