11a. More on refraction and shading

Reading

Recommended:

- Hearn & Baker, Section 14.5

Optional:

- Glassner. An Introduction to Ray Tracing, 2.4.

Addenda

These notes are addenda to the lectures on shading and ray tracing.

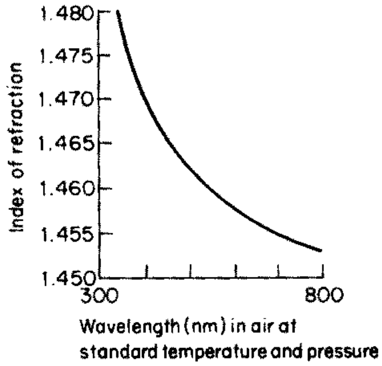
They cover:

- More on refraction
- Gouraud vs. Phong interpolated shading

Refraction and wavelength dependence

The index of refraction varies according to the properties of the material.

Medium	Index of refraction
Vaccum	1
Air	1.0003
Water	1.33
Fused quartz	1.46
Glass, crown	1.52
Glass, dense flint	1.66
Diamond	2.42



Index of refraction variation for fused quartz

In addition, the index of refraction varies with wavelength. As a result, different wavelengths are refracted a different amount.

Usually, this effect is ignored in computer graphics, in part because it requires sampling many wavelengths to get the correct result.

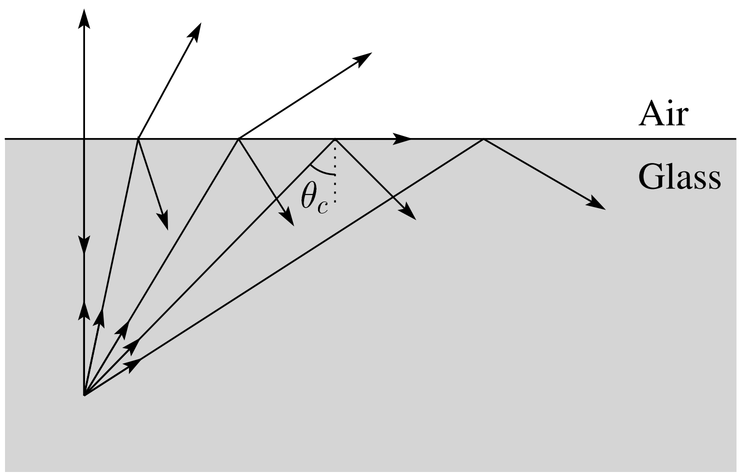
Total Internal Reflection

The equation for the angle of refraction can be computed from Snell's law:

What happens when $\eta_i > \eta_t$?

When θ_t is exactly 90^o, we say that θ_i has achieved the "critical angle," θ_c.

For $\theta_i > \theta_c$, no rays are transmitted. Only reflection occurs, a phenonenon known as "total internal reflection" or TIR.



Gouraud vs. Phong interpolation

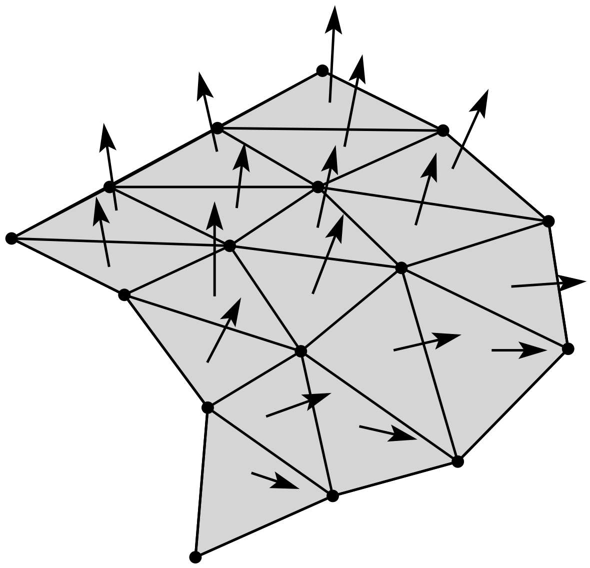
Smooth surfaces are often approximated by polygonal facets, because:

- graphics hardware generally wants polygons (esp. triangles)
- they can be easier for designing ray-surface intersection algorithms

How do we compute the shading for such a surface?

Facted shading

Assume each face has a constant normal.



For a distant viewer and a distant light source, how will the color of each triangle vary?

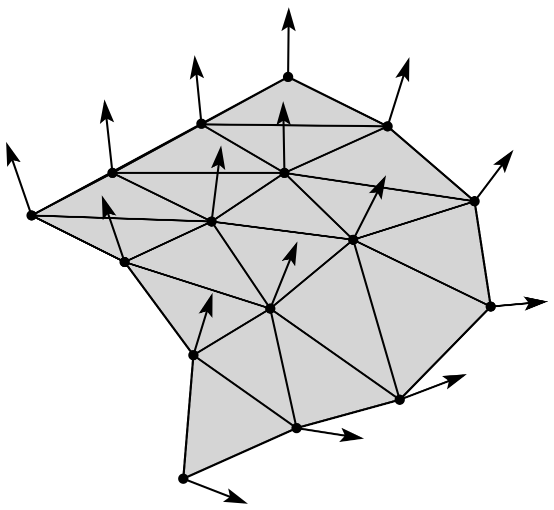
Result: facted, not smooth, appearance.

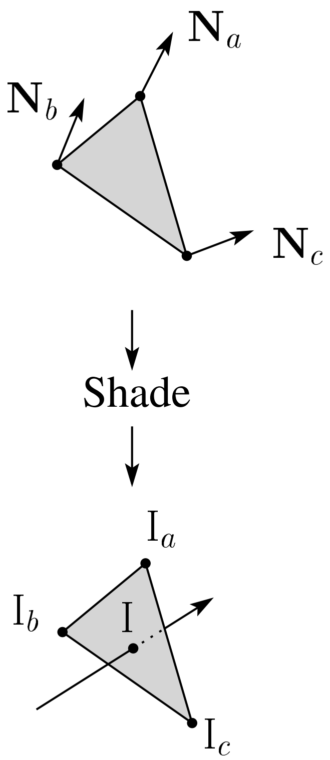
Gouraud interpolation

To get a smoother result that is easily performed in hardware, we can do “Gouraud interpolation.”

Here’s how it works:

1. Compute normals at the vertices.
2. Shade only the vertices.
3. Interpolate the resulting vertex colors.

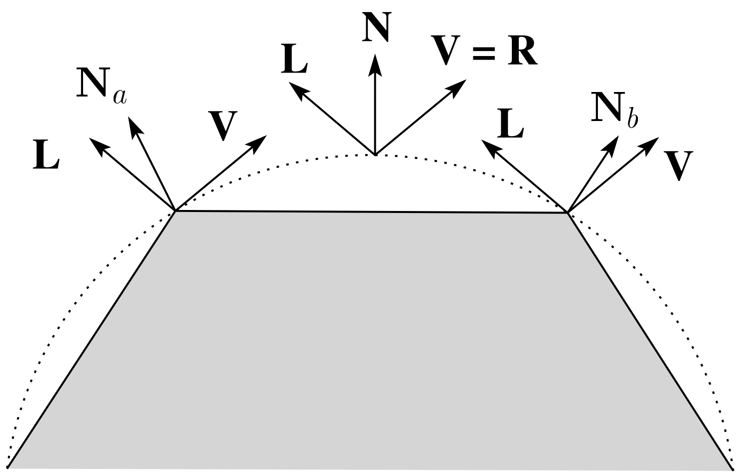




Gouraud interpolation, cont'd

Gouraud interpolation has significant limitations.

1. If the polygonal approximation is too coarse, we can miss specular highlights.



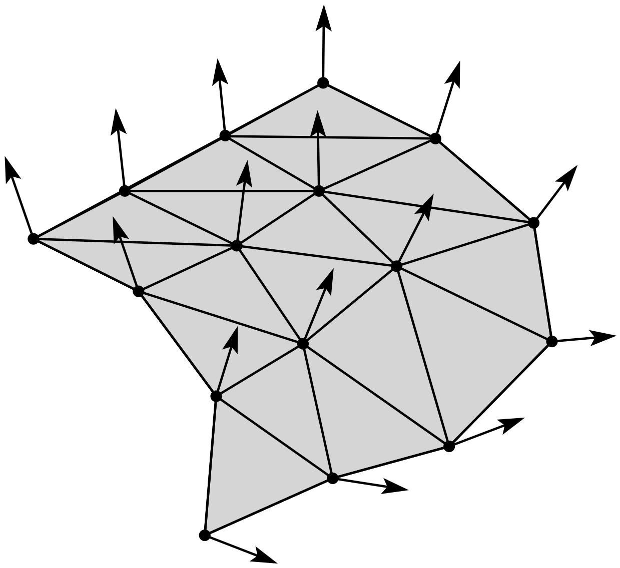
2. We will encounter Mach banding.

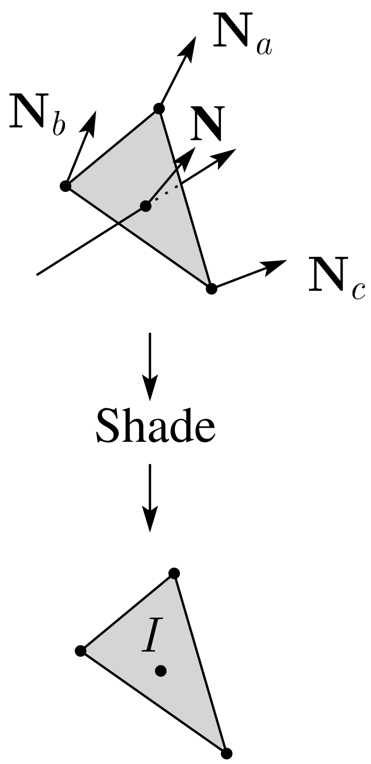
Phong interpolation

To get an even smoother result with fewer artifacts, we can perform "Phong interpolation."

Here's how it works:

1. Compute normals at the vertices.
2. Interpolate normals and normalize.
3. Shade using the interpolated normals.





Summary

What to take home from these notes:

1. What total internal reflection is and how to handle it in a ray tracer.
2. The difference between Gouraud and Phong interpolation.