Computer Graphics
CSE 557, Winter 1997

Week 7 study sheet: Ray Tracing and Radiosity

Problem 1 In the Phong illumination model, specular reflections from each light source are approximated by taking the dot product between the direction of the viewer $\mathbf{V}$ and the direction of the reflected light $\mathbf{R}$, and raising the result to some power n_s.

a) Derive an expression for the direction of the reflected light $\mathbf{R}$ in terms of the directions of the light source $\mathbf{L}$ and surface normal $\mathbf{N}$.

b) Often, in shading computations, the viewer direction $\mathbf{V}$ and light source direction $\mathbf{L}$ are assumed to be constants. Under what circumstances might such an assumption be justified?

Problem 1 (continued)

Blinn and Newell have suggested that, when $\mathbf{V}$ and $\mathbf{L}$ are assumed to be constants, the computation of $\mathbf{V} \cdot \mathbf{R}$ can be simplified by associating with each light source a fictitious light source that will generate specular reflections. This second light source is located in a direction $\mathbf{H}$ halfway between $\mathbf{L}$ and $\mathbf{V}$. The specular component is then computed from $(\mathbf{N} \cdot \mathbf{H})^{n_s}$ instead of from $(\mathbf{V} \cdot \mathbf{R})^{n_s}$.

c) How does this new equation simplify the shading computation?

d) In what way might the new equation change the appearance of the specular highlights?

Problem 1 (continued)

The ambient term in the Phong model is one way to guarantee that all visible surfaces receive some light. Another possibility is to use the "headlamp" method in which a point light source is positioned at the eye, but no ambient term is used.

e) Are these two methods equivalent? If so, explain why. If not, describe a situation in which the results would be clearly different.

Problem 2 What is the asymptotic time complexity of ray tracing a scene consisting of m light sources and n objects, assuming that an image of p pixels is to be created and that rays are only traced to a recursive depth of at most 5?

Problem 3

Given:

- A ray $\vec{P}(s)$ through initial position $\vec{P}_0$ in direction $\mathbf{u}$ (a unit vector):

$$\vec{P}(s) \;=\; \vec{P}_0 \;+\; s\,\mathbf{u}$$

- A sphere S centered at $\vec{P}_c$ with radius r

Find: The intersection of $\vec{P}(s)$ with S.

Problem 4 What is the upper bound on the value of the BRDF of a Lambertian surface? Show how this upper bound is derived.

Problem 5 To simulate the physics of light, we need to be able to quantify it in its many forms. We therefore turn to *radiometry*, the science of the physical measurement of electromagnetic radiation, and *photometry*, the science of the *psycho*-physical measurement of visible light.

The photometric quantities tell us about the perceptual response of the visual system to radiant energy. It is always possible to convert from radiometric to photometric quantities using the integral

$$\Phi_v \;=\; \int \Phi_e(\lambda)\, V(\lambda)\, d\lambda \;\times\; [680 \text{ lumens/watt}],$$

where $V(\lambda)$ is the *relative spectral luminous efficiency curve*.

The *luminous efficiency* of a light source is defined as the ratio of total luminous flux (measured in lumens) to the total input power (measured in watts).

a) What is the luminous efficiency of a light source that emits light at a single 555nm wavelength, assuming no energy is lost to heat?

b) What is the luminous efficiency of an "ideal" white light source, whose power is constant over the spectrum, again assuming that no energy is lost to heat? (An estimate will do, but you should show how your estimate is derived.)

c) The label on the packaging for the 40-watt light bulb in my desk lamp says that the bulb is rated at 490 lumens. Assuming the bulb is an "ideal" white light source, about how much energy is actually being lost to heat every second I use it?