CS 348B - Computer Graphics: Image Synthesis Techniques
Stanford University

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Handout #25

Written assignment #2 - texture and local illumination

Due Tuesday, May 20, in class

(1) Paul Heckbert's chapter on texture resampling (course reader, paper #7) discusses prefiltering using 3D and 4D image pyramids. Neither perfectly matches the quadrilaterals that result from perspective projections of square texture areas. How many dimensions are needed for a perfect match? Ignore errors introduced by discretization of the pyramid. Defend your answer.

(2) Problem 16.1 in Foley, van Dam, Feiner, Hughes. An equivalent restatement follows:

(a) Describe the difference in appearance you would expect between a Phong illumination model that uses $(\mathbf{N}\cdot\mathbf{H})^n$ and one that uses $(\mathbf{R}\cdot\mathbf{V})^n$.

(b) Show that $arccos(\mathbf{R}\cdot\mathbf{V}) = 2\,arccos(\mathbf{N}\cdot\mathbf{H})$ when all vectors are coplanar.

(c) Show that this relationship is *not* true in general.

(3) Bill just started an internship at Specific Electric, and he is trying to evaluate light bulbs for efficiency. He has two light bulbs, A and B, which both consume 40 watts of power. Using a calorimeter, he observes that bulb A generates 39 watts of heat, while bulb B generates only 38 watts.

(a) He concludes that bulb B must emit twice as much light, and therefore is the better light bulb. Do you agree? Defend your answer.

(b) Assume a simplified version of the spectral luminous efficiency curve to be:

$$V(\lambda) \;=\; \max\;(\;0,\;684 * \left[1 - \left(\frac{550-\lambda}{150}\right)^2\right]\;)$$

Assume that bulb A is monochromatic; all of its energy is emitted at 600nm. How many lumens does bulb A emit?

(c) Assume that bulb B emits a uniform power at every wavelength between 200 and 600 nanometers (and is zero everywhere else in the spectrum). How many lumens does bulb B emit?

(4) Suppose that the Pioneer 10 space probe, launched in 1972, had a digital camera which it kept pointed toward the moon as it streaked away from earth and, in 1989, passed beyond the orbit of Pluto. Assume that the camera measures 201 x 201 pixels, has a 20-degree field of view, has a gamma of 1, and each CCD pixel is equivalent to a box (area-weighted) filter. Draw a carefully labeled plot of the intensity in the center pixel of this camera as a function of time from 1972 until today. You may assume that the moon is a uniform Lambertian surface (it isn't), and that the spacecraft's path allowed it to see a full moon at all times (it couldn't). Note: the moon is 2200 miles in diameter, is 240,000 miles from the earth, and is roughly 4 billion miles from Pluto. You may ignore any distance changes due to the motion of the moon and the earth through their orbits.

(Turn over for more problems.)

(5) Consider a hemispherical sky above a surface patch.

(a) Suppose the surface patch is tilted and its normal makes an angle of $\alpha < \pi/2$ with respect to the zenith. Because of the tilt, only part of the sky is visible to the surface. Assume the radiance of the sky is uniform and equal to L. Show that the irradiance on the tilted surface due to a uniform sky is $E = L\pi\cos^2(\alpha/2)$.

(b) In class, we approximated the radiance of a cloudy sky as uniform. That may be true in San Francisco where cloudy means foggy, but the radiance of an overcast sky in dry weather is non-uniform and may be approximated by a Cardioid distribution, that is, $L(\theta) = L\cos\theta$. Here θ is zero in the direction of the zenith. Thus, this radiance distribution is maximal straight up and zero at the horizon. Compute the irradiance from the cloudy sky (of an untilted patch).

(6) **For extra credit:** Perspective views of textured surfaces often require filtering of highly elongated areas. As discussed in class, the use of a mipmap to filter such textures often results in substantial aliasing or blurring. What is the corresponding problem when using a 4D hyperpyramid to filter solid (3D) textures being used to texture the surfaces of opaque objects. Under what conditions will it occur? How severe is this problem likely to be compared to the corresponding problem with simple (2D) textures?

(7) **For more extra credit:** Suppose the moon is rising over a pond where all the waves are moving from left to right (i.e. think of the surface as being made of cylinders whose axis is in the direction from you to the moon). What does the reflection of the moon on the surface look like? How is it different if the waves are moving from you toward the moon?