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Homework 3:
Shading, Raytracing, and Image Processing

Received: Friday May 7, 1999
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DIRECTIONS

Please provide short written answers to the questions in the space provided. If you require extra space, you may staple additional pages to the back of your assignment. Feel free to talk over the problems with your classmates, but please answer the questions on your own.

NAME: ______________________________________

Problem 1.

The Phong shading model can be summarized by the following equation:

$$I_{phong} = k_e + k_a I_a + \sum_i \left[I_{l_i} \left[k_d (\mathbf{N} \cdot \mathbf{L}_i)_+ + k_s (\mathbf{V} \cdot \mathbf{R}_i)_+^{n_s} \right] \min\left\{ 1, \frac{1}{a_0 + a_1 d_i + a_2 d_i^2} \right\} \right]$$

where the summation i is taken over all light sources.

The variables used in the Phong shading equation are summarized below:

I a_0 a_1 a_2 d_i k_e k_a k_d k_s n_s I_a I_{li} $\mathbf{L}_i$ $\mathbf{R}_i$ $\mathbf{N}$ $\mathbf{V}$

(a) Which of the quantities above are affected if...

…the viewing direction changes?

…the position of the i^{th} light changes?

…the orientation of the surface changes?

Problem 1 - continued.

(b) Blinn and Newell have suggested that, when **V** and **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 H halfway between **L** and **V**. The specular component is then computed from $(\mathbf{N}\cdot\mathbf{H})_+^{n_s}$ instead of from $(\mathbf{V}\cdot\mathbf{R})_+^{n_s}$.

Under what circumstances might L and V be assumed to be constant?

How does the new equation using H simplify shading equations?

(c) 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.

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

Problem 1 - continued.

(d) Respond TRUE or FALSE to each of these statements and ***explain your reasoning***.

_____ The Phong model is a physical simulation of the behavior of real-world light.

_____ For polished metal, the specular component n_s would be large.

_____ A rough surface with many tiny microfacets is likely to have a large diffuse reflection coefficient.

(e) Describe the relationships between **N**, $\mathbf{L}_i$, and $\mathbf{R}_i$ that would result in a point shaded with the Phong model appearing maximally bright.

(f) The equation above is not the only hallmark to Mister Phong's fame. We also talked in class about the difference between two polygon shading methods, one called Phong and one called Gouraud. Describe a scene where the difference between Phong and Gouraud shading would be noticeable.

Problem 2.

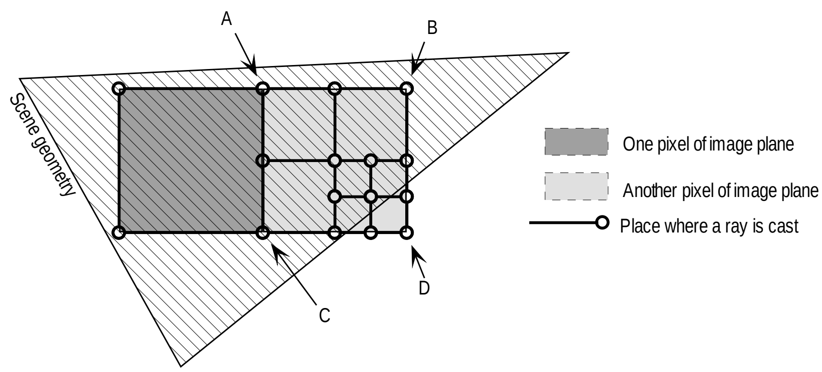
(a) The company you work for has just bought rights to a raytracing engine. Unfortunately, you don't have the source code, just a compiled library. You have been asked to determine how rays are terminated. So, you call the authors you find out even they don't remember for sure. All they can tell you is this: *The termination criteria for tracing rays is either (a) rays are traced to a maximum recursion depth of 5, or (b) rays are adaptively terminated based on their contribution to a pixel color.*

Describe a scene that can be used to determine which method is used. Be specific about all relevant aspects of the scene and what you would look for in the resulting image to determine which termination method is used.

Problem 2 - continued.

(b) One of the features included in the raytracing engine your company bought is a brand new algorithm for <u>antialiasing by adaptive supersampling</u>.

The normal implementation is to sample rays at the corner of every pixel, compare the colors of each sample, and if the difference between neighboring sample colors is too great, subdivide that region recursively and sample more times. (See the diagram below, or Foley, et al., 15.10.4)

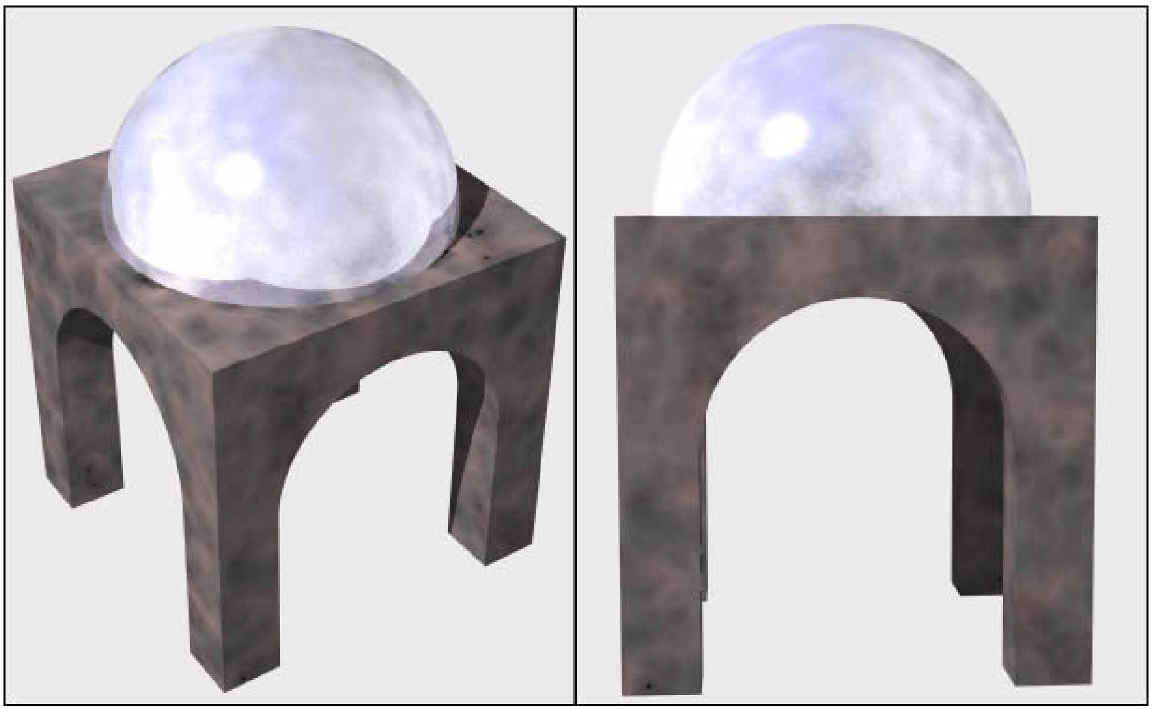


However, in this new algorithm, we subdivide and supersample if neighboring rays *intersect different objects*. In other words, note the light-grey pixel above. Three of the four corner samples (a, b, and c) intersect the scene geometry. The fourth corner (d), misses the geometry completely. So we choose to supersample this pixel without ever comparing colors.

In what ways is this better than the traditional way? In what ways is it worse?

Problem 2 - continued.

(c) Your next job at your company is to go through old images in the archives and decide how they were built. One such 3D model is shown below, rendered from two different viewpoints. Describe the Constructive Solid Geometry (CSG) operations that might have yielded this shape. Note that we looking for how CSG could have formed this shape, including the names of the primitives used and what CSG operations were used to combine them. We are **<u>not</u>** expecting you to generate the transformations (scale, rotate, translate) that were used to move each primitive into position.



Problem 3.

(a) Respond TRUE or FALSE to each of these statements and ***explain your reasoning***.

______ Mean filters can be used for smoothing an image as well as reducing noise.

______ When using a mean filter, increasing the size of the filter sharpens the image.

______ A median filter does a better job of throwing out impulse and salt and pepper noise than a mean filter.

______ A median filter is a type of convolution filter.

Problem 3 - continued.

(b) Convolution filtering can modify images in a variety of ways. Describe the expected effect of filtering an image using the following convolution kernel. Justify your answer.

$$\begin{bmatrix} -1 & -3 & -1 \\ -3 & 16 & -3 \\ -1 & -3 & -1 \end{bmatrix}$$

(c) Some image I(i,j) is given as an array of greyscale values, each between 0 and 1. If we filter this image with the convolution kernel in part (b), we get a new image I'(i,j). What are the maximum and minimum values the filtered image I'(i,j) can take on at a particular pixel?

Problem 3 - continued.

(d) Why might the following convolution kernel be a good choice for smoothing images taken from interlaced video?

$$\frac{1}{38}\begin{bmatrix} 1 & 1 & 1 \\ 8 & 16 & 8 \\ 1 & 1 & 1 \end{bmatrix}$$

(e) Suppose you had a digital photograph where the camera was moving downward at the exact instant the picture was taken. That is, everything in the image is blurred a little bit vertically, but not horizontally. Devise a convolution operator to sharpen this image. Note that a general "sharpen" filter would work, but for this special case, it can be done better.