

# Written Assignment #2 Solution

15-462 Computer Graphics, Fall 2007

**DUE: Tuesday, December 4, just before class**  
**(4 problems, 100 points total)**

The work must be your own. Please use any resources available to you (the book, the web, etc.), but write up the answers in your own words. **Please show your work**, explaining all of the steps. Also please cite any external references you use (other than the textbook) to come up with your answers.

## 1. [30 points] Rendering and Light

Consider the following rendering algorithms studied in class:

1. OpenGL graphics pipeline
2. Ray Casting
- 3.. Ray Tracing
- 4.. Particle Tracing
5. Path Tracing
- 6.. Lightfields/Lumigraph

a) Which of the above cannot handle mirror surfaces? Why?

*OpenGL Graphics pipeline and Ray Casting*

*Handling mirrors requires figuring out what is being reflected by the mirrored surface. Neither OpenGL nor Ray Casting can handle surface-to-surface lighting computations.*

b) Which of the above have the largest memory requirements for a typical scene? Why?

*Lightfield methods are the most memory-hungry. All other approaches have storage requirements in the order of number of surfaces, whereas Lightfields are in the order of number of possible views.*

c) Given the following expressions for particular light paths (see Lecture 19), which of the above algorithms can handle them:

i. LDSE

3,4,5,6

ii. LSDE

4,5,6

iii. LD

4 (and 6 in limited sense)

iv. LDSSSE

3,4,5,6

v. LDSDSDE

4,5,6

d) What is the light path expression for “color bleeding”? Which of the algorithms can handle it?

*LDDE (or more general variants, like  $L(D/S)*DD(D/S)*E$ )*

4,5,6

## 2. [20 points] Direct vs. Global Illumination

Consider Nayar et al examples of separating direct illumination from global illumination [http://www1.cs.columbia.edu/CAVE/projects/separation/separation\\_gallery.php](http://www1.cs.columbia.edu/CAVE/projects/separation/separation_gallery.php) to answer the following questions:

- a) If the skin of a yellow pepper blocked all lighting at its surface, what color would the yellow pepper appear to us?

*If we assume that the pepper reflect all light, it will look dark-greenish, as shown on the Direct Illumination image on the above website.*

- b) If you pluck a petal from a red flower and examine it in isolation it would appear to be not as red as when observed as part of the flower. Why?

*Color bleeding between the petals of a flower makes the color of the flower much stronger, as shown by the flower image on the above website.*

- c) The differences in skin color are due to the albedo of the skin surface, or due to the subsurface scattering within the skin layer?

*As can be clearly seen from the images, skin color is totally the function of subsurface scattering as Direct Illumination images of skin all have the same color.*

## 3. [20 points] Hierarchical Data Structures

- a) Describe, in 1 sentence, the main difference between the following two approaches: (1) constructing a bounding volume hierarchy (e.g. bounding boxes or bounding spheres), (2) constructing a hierarchy of splitting planes (e.g. KD trees or BSP trees).

*Bounding volume hierarchy partitions the set of all geometric objects in the environment, whereas splitting planes hierarchy partitions the environment itself.*

- b) Propose a top-down technique for constructing a bounding box hierarchy:

*e.g. Compute distances between all objects. Pick two further objects. Split the other objects evenly between the two and put bounding boxes around them. Repeat for each box.*

- c) Propose a bottom-up technique for constructing a bounding box hierarchy:

*e.g. Compute distance between all  $N$  objects. Merge closest objects into  $N/2$  pairs, and put bounding boxes around each. Repeat for each box.*

#### 4. [30 points] Visual Perception

- a) Why is tone mapping possible? That is, why can we ever hope that a sunset and a picture of a sunset could be made to look the same to a human observer?

*Because human eye is not a photometer. The existence of brightness metameres suggests that humans cannot perceive absolute brightness.*

- b) What does the Campbell-Robson contrast sensitivity curve tell us about human vision?

*Humans are sensitive to mid-frequency than to high or low frequencies of a visual stimulus.*

- c) How is that being used for lossy image compression, e.g. JPEG?

*Instead of compressing all frequencies at the same rate, the low and high frequencies are compressed more.*

- d) Which step of the JPEG compression is lossy? That is, at which stage is information being lost when compressing an image.

*When encoding each 8x8 patch of frequency coefficients, the number of bits that are spent storing them is not enough for a faithful, lossless reconstruction. In particular, less bits are spent on high frequencies than on others. NOTE: it is not true that high frequencies are completely chopped off while low and mid frequencies are faithfully reproduced – all are compressed losslessly, but at a different rate.*