CS52: Homework 1

Out: Sep 29. Due: Oct 8.

Problem 1: Image Storage

Your task is to write an image editing application for professional digital photographers. The application will have to manage a large number of images, which, for efficiency reasons, are all loaded in memory at the same time. Your target user have images whose average size is 4096×4096 (16M pixels) and is equipped with 768 MB ($1MB = 1024^2$ bytes) of memory dedicated to your application.

You have the choice of using one of the following image formats.

1. single precision, floating point HDR images (96bpp)
2. high-precision color images (48bpp)
3. standard color images (24bpp)
4. standard color images: encoded after gamma correction $\gamma = 2.2$ (24bpp)

(a) For the given formats, how many images can your program handle?

(b) Most of todays digital cameras have sensors whose dynamic range is about 12 bits for each color channel. Which of the previous formats will store your image without loss of information?

(c) For efficiency reasons, you are unable to store all the photographs at their highest quality. You can save memory in one of two ways: drop color precision or drop image resolution. For each of these simplifications, describe which kind of artifacts you will introduce. In the case of the color depth, describe the changes to image quality when changing between 96bpp, 48bpp, 24bpp-gamma, 24bpp-linear.

(d) Suppose your monitor has a non-linear transfer function of the form $f(x) \propto x^{\gamma}$, and, as such, expects 8bit values gamma corrected values as input. Write pseudocode for how to convert the value of a color channel of each format into the corresponding one that can be shipped to the display. You can assume that functions like *min*, *max*, *pow* are defined. Hint: make sure your computed values are not overflowing.

Problem 2: Image Compositing

Given two fragments overlapping a pixel, $A = (c'_A, \alpha_A)$ and $B = (c'_B, \alpha_B)$, we have shown in class that if A overlaps B, then

$$A \textbf{ over } B = \left(c'_{(A \textbf{ over } B)} = c'_A + (1 - \alpha_A)c'_B, \alpha_{(A \textbf{ over } B)} = \alpha_A + (1 - \alpha_A)\alpha_B\right)$$

where c' indicates pre-multiplied colors.

(a) Write the color and coverage results of A **over** B for the following cases (colors given in RGBA format, not pre-multiplied).

1. $A = (1.0, 1.0, 1.0, 1.0),\ B = (0.5, 0.5, 0.5, 0.5)$
2. $A = (0.5, 0.5, 0.5, 0.5),\ B = (0.5, 0.5, 0.5, 0.5)$
3. $A = (0.0, 0.0, 0.0, 0.0),\ B = (0.5, 0.5, 0.5, 0.5)$
4. $A = (0.0, 0.0, 0.0, 0.0),\ B = (0.5, 0.5, 0.5, 0.0)$

(b) Supposed that for each pixel, the area covered by A does not overlap with the one covered by B. Write the expression for the resulting color and coverage. Is there a restriction of the possible values of α_A and α_B in this case? In this case, does A **over** $B = B$ **over** A?

Problem 3: Ray-Sphere Intersection

Given the ray $\mathbf{r}(t) = (0, 0, 0) + t(1, 0, 0)$ and a set of spheres of unit radius and centered respectively at

1. $\mathbf{O} = (0, 0, 0)$
2. $\mathbf{O} = (3, 0, 0)$
3. $\mathbf{O} = (1, 1, 0)$
4. $\mathbf{O} = (-3, 0, 0)$
5. $\mathbf{O} = (0, 3, 0)$

(a) Which of the given sphere will be intersected by the ray?

(b) What is the difference between the intersection on each sphere?

Problem 4: Ray-Disk Intersection

Derive the formula for the intersection of a ray with a disk for radius r, center $\mathbf{O}$ and oriented along the normal $\mathbf{N}$.

Extra credit: Ray-Cylinder Intersection

Derive the formula for the intersection of a ray and the side surface of a cylinder of radius r and height h centered at the origin and orientated along the z axis. Hint: $\mathbf{P} = (P_x, P_y, P_z)$ is a point on the cylinder surface if $P_x^2 + P_y^2 = r^2$ and $-h/2 \leq P_z \leq h/2$.