CS 559: Computer Graphics

Homework 2

This homework must be done individually. Submission date is Tuesday, February 17, 2004, in class.

Question 1:

The LUV space (defined below) is approximately perceptually uniform. Hence, one way to decide whether two pairs of colors in RGB space, say a, b and c, d, are separated by the same perceptual distance is to first convert all the colors into LUV space then compute their relative distances there using a standard distance metric. To get to LUV, you first need to get from RGB to XYZ, using the matrix given in class.

LUV coordinates, (L^*, u^*, v^*) are computed in several steps. First compute (X_n, Y_n, Z_n) which are the XYZ coordinates of white. Then compute the following four values:

$$\begin{aligned} u' &= \frac{4X}{X + 15Y + 3Z} \\ v' &= \frac{9Y}{X + 15Y + 3Z} \\ u'_n &= \frac{4X_n}{X_n + 15Y_n + 3Z_n} \\ v'_n &= \frac{9Y_n}{X_n + 15Y_n + 3Z_n} \end{aligned}$$

Finally, compute:

$$\begin{aligned} L^* &= 116\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16 \\ u^* &= 13L^*(u' - u'_n) \\ v^* &= 13L^*(v' - v'_n) \end{aligned}$$

When $Y/Y_n < 0.01$, $L^* = 903.3Y/Y_n$, rather than the equation above. Note that when $r = g = b$, $u' = u'_n$ and $v' = v'_n$ and hence $u^* = v^* = 0$. In other words, the L^* component of $L^*u^*v^*$ encodes intensity. You might like to write a program to do the color conversions, and test it before trying to answer the questions (testing on white, black and grey is a good start.) This question explores linear interpolation of colors, a frequent operation in 3D graphics (as we will see).

a. Convert the following 3 RGB colors to (L^*, u^*, v^*):

   (i) (0.4,0,0)

   (ii) (0.5,0,0)

   (iii) (0.6,0,0)

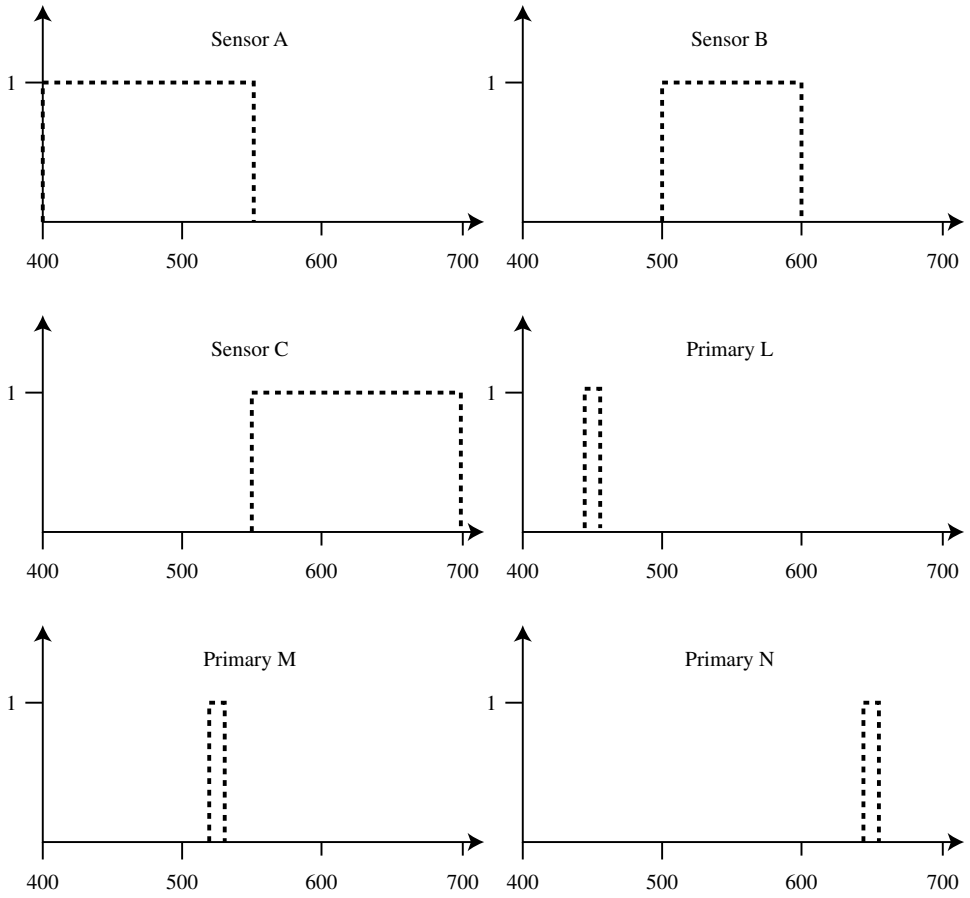
b. What is the midpoint, in LUV space, between the colors (i) and (iii) above?

c. Is the midpoint in LUV space the same as the midpoint in RGB space converted into LUV (i.e. the answer to (a)(ii) above)?

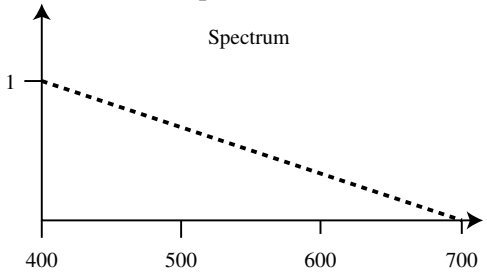
d. Does interpolation in RGB space the same results as interpolation in LUV space?

Question 2:

Consider the three sensors, A, B and C, shown below, and the three primaries, L, M, and N. Sensor A has a response of 1 between 400nm and 550nm, Sensor B responds between 500nm and 600nm, and Sensor C responds between 550nm and 700nm. Primary L emits energy between 445nm and 455nm. Primary M emits between 520nm and 530nm. Primary N emits between 645nm and 655nm.



a. What is the response of each sensor to the spectrum shown below?



b. How much of each primary would be required to simulataneously generate a response from each sensor that is the same as their response to the spectrum above? (In other words, how much of each primary is required to match the spectrum response?)

Question 3:

Show the results of running Floyd-Steinberg, as presented in class, on the 5x2 image (5 columns, 2 rows) with a constant 0.3 gray intensity. Use the horizontal zig-zag pattern, and if there is no pixel to receive a part of the error, just ignore that term.