Computer Graphics	Profs. Brian Curless and Steve Seitz
CSE 591	Spring 2001

Homework #1

Visual Perception, Color, Image Processing, Affine Transformations

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Assigned: Monday, April 9th
Due: Monday, April 23th

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 classmates, but please *answer the questions on your own*.

Name:____

1. **True or False –** ***Justify Your Answer (no credit given for just "T" or "F")***
   24 points (2 each)

   a. An advantage of perfect pinhole cameras over cameras with lenses is that everything is in focus.

   b. Suppose that you view this page inside under candle light, and outdoors in the bright sun where the light is many times more intense. The text will be perceived as being many times brighter outside than it was inside because it reflects more light towards your eyes.

   c. Suppose two lights with spectra $f(\lambda)$ and $g(\lambda)$ are metamers. If you change the spectra to $2f(\lambda)$ and $2g(\lambda)$, the lights may no longer be metamers.

   d. To keep an object in focus as it moves closer the ciliary muscles will contract.

   e. Under certain light conditions, we have greater sensitivity in our periphery than in our fovea.

   f. Two colors with identical RGB values will always have the same spectra.

   g. Two colors that produce identical cone responses will always have the same spectra.

   h. The colors produced on a CRT display can be reproduced on a color printer, and vice versa.

   i. If a computer's video card is set to "Truecolor" mode, i.e. 24 bits per pixel, its monitor can produce every color perceptible by the human eye.

   j. The electrons coming out of the red, green, and blue electron guns of a color monitor have different energy spectra.

   k. A median filter is a convolution filter.

l. A Gaussian filter is a convolution filter.

2. Image Processing
29 points

a. (5 points) In class, we discussed salt and pepper, impulse, and Gaussian noise and some filters you could use to help remove this noise. Which filters work best to eliminate each kind? Why?

b. (12 points) Describe the effect of each of the following convolution filters, and specify what type of blur or sharpening operation is being performed (if at all). In addition, indicate which filter will will produce the brightest image when applied to a solid gray image. Justify your answers. Assume the filters are applied "as is" with the specified weights (do not normalize them).

0.1	0.1	0.1
0.1	0.1	0.1
0.1	0.1	0.1

0	-1	0
-1	5	-1
0	-1	0

0	0.2	0
0.2	0.4	0.2
0	0.2	0

0	0	0
-1	3	-1
0	0	0

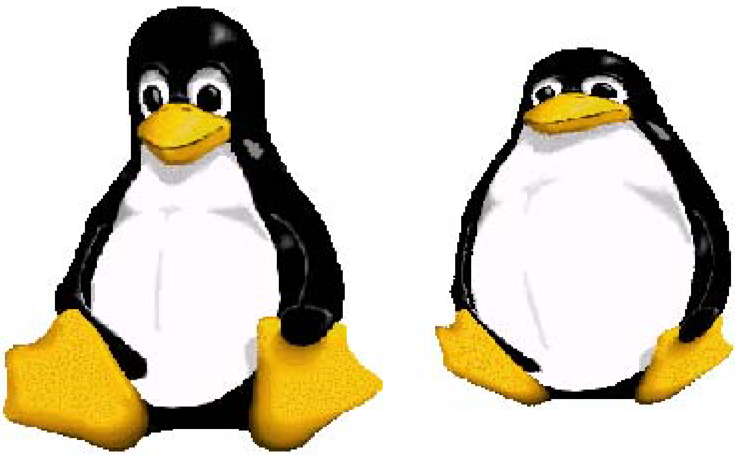
Problem 2 (cont'd.)

c. (12 points) Match the following image processing functions to their respective image pairs, where each pair is of the form f(x,y) → f(X(x,y), Y(x,y)) or f(r, theta) → f(R, THETA) where (r, theta) is polar coordinates:

1. R = r*r / 100.0 THETA = theta
2. R = r THETA = theta + r/60.0
3. R = r + 200.0*theta/(PI*2.0) THETA = theta
4. R = r THETA = (double)((int)(13.0 * theta)) / 13.0
5. X = 2.0*x Y = 2.0* (y + x/2.0)
6. X = 50.0 * cos(x/40.0) Y = 50.0 * sin(y/40.0)

The untransformed image is at left. Assume the origin is in the center of the image. The right image gets created from the left image by stepping through (x,y) coordinates of the right image, and then figuring out which pixels (X,Y) need to be plucked from the input image.

I.

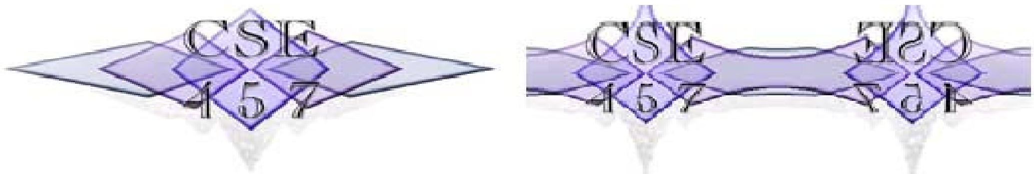


II.

Problem 2 (cont'd.)

III.

IV.

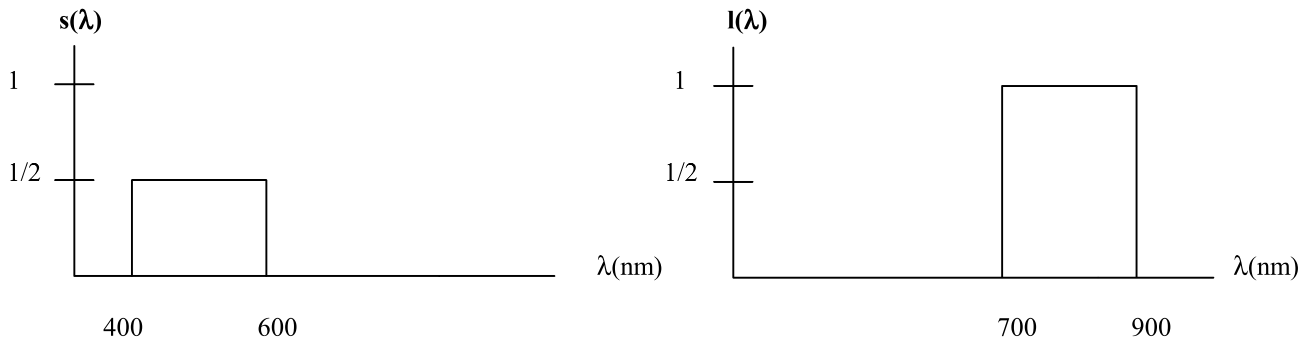


V.

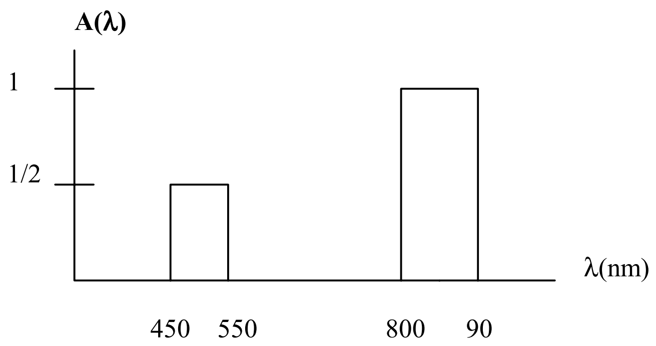
VI.

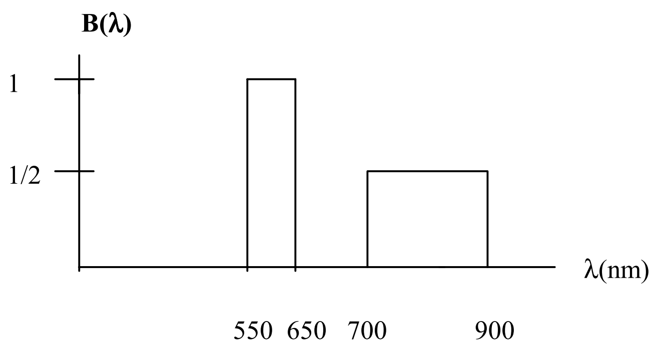
3. Color Perception
20 Points

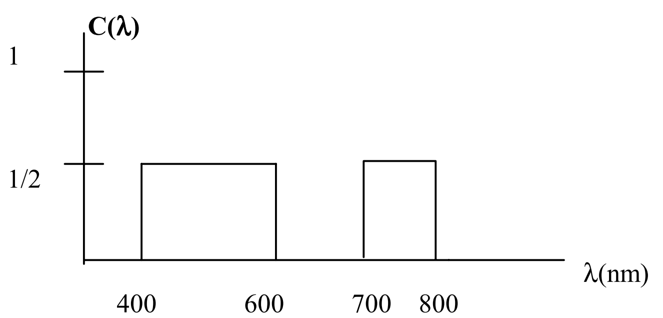
A recently discovered breed of pot-bellied pig has two types of cones, labeled s(λ) and l(λ), with spectral sensitivities as shown below.



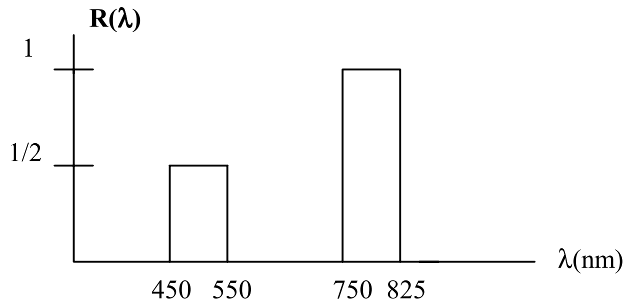
a. (10 points) We perform the color matching experiment with this rather intelligent pig using the three lights shown below. Determine which, if any of these lights, are metamers for the pig. Show your work in the column next to the spectral plots.







b. (10 points) We now repeat the experiment by shining the lights from (a) onto a piece of paper with surface reflectance R(λ) shown below. Determine under which, if any, of the lights the surface will yield subtractive metamers for the pig. Show your work.



4. Affine Transformations
27 Points

a. (2 points each) As discussed in class, any two-dimensional affine transformation can be represented as a 3x3 matrix. Here are some useful matrices:

$$A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad B(a,b) = \begin{pmatrix} 1 & 0 & a \\ 0 & 1 & b \\ 0 & 0 & 1 \end{pmatrix} \quad C(a,b) = \begin{pmatrix} \cos a & \sin a & 0 \\ -\sin a & \cos a & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$D(a,b) = \begin{pmatrix} a & 0 & 0 \\ 0 & b & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad E = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad F(a) = \begin{pmatrix} 1 & a & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Which of the matrices above implements each of the following transformations?

Translation

Reflection through the line y=x

Differential (Non-Uniform) Scaling

Reflection through the x-axis

Shearing

Rotation about the origin

Problem 4 (cont'd.)

b. (15 points) Consider a line that passes through a point **p** = (p_x, p_y, p_z) in the direction **v** = (0, cos α, sin α). Write out the product of matrices that would perform a rotation by θ about this line. You should **not** multiply these matrices out, but you do need to list all of the elements in these matrices.