HOMEWORK 4: Due Thursday Feb 21 by noon

1. **Chromaticity diagrams**

   On the web site you will find a text file called `cie` which contains color matching functions in the XYZ coordinate system. The format of the file is `wavelength X Y Z` from 380 nanometers to 780 nanometers. To read it in, type: load cie -ascii

   (a) For this problem we ask you to produce hardcopy of your plots as well as of your matlab commands. On one graph, plot the color matching functions, $X(\lambda)$, $Y(\lambda)$, $Z(\lambda)$. On another graph, plot the xy chromaticity diagram. Connect the "line of purples" on your diagram.

   (b) The conversion from the CIE XYZ space to the NTSC receiver primary system R_N, G_N, B_N is given by the following linear transformation:

$$\begin{bmatrix} R_N \\ G_N \\ B_N \end{bmatrix} = \begin{bmatrix} 1.910 & -0.533 & -0.288 \\ -0.985 & 2.000 & -0.028 \\ 0.058 & -0.118 & 0.896 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

   The Society of Motion Picture and Television Engineers (SMPTE) made its own receiver primary color coordinate system. The conversion from the CIE XYZ space to the SMPTE receiver primary system R_S, G_S, B_S is given by the following linear transformation:

$$\begin{bmatrix} R_S \\ G_S \\ B_S \end{bmatrix} = \begin{bmatrix} 3.508 & -1.741 & -0.544 \\ -1.069 & 1.977 & 0.035 \\ 0.056 & -0.197 & 1.051 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

   Suppose there existed two sets of phosphors which exactly corresponded to the NTSC and SMPTE primaries. Inside the xy chromaticity diagram, plot the two triangles that correspond to the color gamuts of these two sets of phosphors. Does it appear that the NTSC or SMPTE primaries provide a larger gamut?

2. **Adding colors (Paper and pencil problem):**

   (a) Color C has tristimulus values T_1, T_2, and T_3. W denotes the reference white for the system. We form an additive mixture of colors: $A = \frac{1}{2}(C+W)$. What are the tristimulus values for A? What are the chromaticity coordinates for A?

   (b) The numerical values for the chromaticity coordinates for color C are $r = 0.1$ and $g = 0.1$. Where on the chromaticity diagram would color A be represented? Prove your result. (Include numerical values for the chromaticity coordinates for color A if that's possible from the information given).

3. **Amplitude thresholding in RGB or HSV:**

Read the image threepeppers.jpg into Matlab and display it with imshow. If we read it into an array "a" then we can break it into three separate color planes and look at them as follows:

```
>> r = a(:,:,1);
>> imshow(r)
>> g = a(:,:,2);
>> imshow(g)
>> b = a(:,:,3);
>> imshow(b)
```

Each of these color planes is of size 335 by 493. Note that these 3 separate color planes can be stuck back together into a single color image array using Matlab's command reshape:

```
newim = reshape([r g b], 335, 493, 3);
```

Convert from the RGB system to the HSV system using Matlab's command rgb2hsv. In this problem the goal is to segment out the yellow bellpepper. On the web site there is a file called labels.mat which has the ground truth segmentation for the bellpeppers image. You can read it into matlab using "load labels" There are 5 values in the label image, corresponding to the 5 segments. You can look at the label image for example by saying "imshow(uint8(labels)*50)" where the multiplication by 50 is because the max value in the label image is 5, which is quite dark (low contrast) for an 8-bit grayscale expected to go from 0 to 255, so we are just remapping the values to go from 50 to 250 rather than from 1 to 5.

(a) Look at the 3 color planes R,G,B. Which one do you think would be the best for segmenting the yellow pepper, if we were to do the segmentation simply by thresholding $T_1 \leq x \leq T_2$ on that color plane? Explain. Likewise look at the 3 color planes H,S,V and answer the same question.

(b) Choose whichever of the R,G,B color planes you think would be best. Choose a threshold T_1 and plot an ROC curve as you vary T_2 and compare the yellow pepper segment against yellow pepper ground truth (TPR and FPR). Draw ROC curves for a few different values of T_1. Do the same thing for whichever of the H,S,V color planes you think would be best. Take the best of the your ROC plots from the RGB system and the best from the HSV system, and show them on the same plot. What can you conclude about this amplitude thresholding approach in RGB or HSV space?

(c) Now try to improve your ROC curves by considering the yellow pepper segment to be not merely the pixels whose amplitudes lie between T_1 and T_2, but where you use some morphological operators to clean up the segmentation. Show the new plots and comment on the results.