Colorimetry: Aiman RAZA & Mathieu HEBERT

1st Practical Session – Colorimetry & MATLAB

The goal of this lab session is to implement basic calculations of colorimetry in MATLAB to retrieve the CIE XYZ color coordinates, xy tristimulus values, and CIE L*a*b* coordinates.

Tip: To obtain help or examples for any MATLAB command, you can type the command name in the "Search Documentation" dialog box (in the top right corner). Otherwise, one can type the command, select it, and click F11 (or select help with the right-click mouse button).

Instructions:

1. Load the spectral_data.mat file in the workspace.

2. Plot the spectral reflectance data of three unknown objects against the wavelength information provided in the .MAT file. Add appropriate axis limits, figure title and axis labels.
   (Helpful MATLAB functions: figure, plot, xlim-ylim, xlabel-ylabel, title).

   Try to identify the approximate color of each object from their reflectance curve and comment your observations.

3. Plot (on a new figure) the spectral reflectance data of the now known objects (from the task 1) against the wavelength information provided in the .MAT file. The plots should have a similar color to that identified in task 2.

   Add appropriate axis limits, figure title, legend, and axis labels.
   (Additional MATLAB functions: legend, help plot (LineSpec)).

4. Load the CMFs.mat file in the workspace.

5. Plot the spectrum locus of the CIE 1931 xy and CIE 1964 xy_{10} chromaticity diagrams by using the provided color matching functions, both on the same figure. Add labels for each axis and legend for each spectrum locus.

   Hint 1: The spectrum locus is made of monochromatic lights in the wavelengths from 380nm to 780nm.
   Hint 2: The three columns of the CMFs can be used to calculate chromaticity coordinates for the CMF value per wavelength:
   ($xCMF_\lambda = cmfX_\lambda/(cmfX_\lambda + cmfY_\lambda + cmfZ_\lambda)$) ; ($yCMF_\lambda = cmfX_\lambda/(cmfX_\lambda + cmfY_\lambda + cmfZ_\lambda)$).
   Then these chromaticity coordinates (xCMF vs yCMF) can be plotted against each other to form the spectrum locus. Another line plot can connect the two ends of the above plot to close the horse-shoe shape chromaticity plot.

   Hint 3: While adding legend information, MATLAB assumes that each plot has a distinct name. In cases where multiple plots are used to make a single figure (like in this case), a blank space in the legend information can be a good workaround.

   (Helpful MATLAB function: hold)

6. Load the illuminants.mat file in the workspace.

Plot the chromaticity coordinates for each illuminant (A, D50, D65, and F12) using the MATLAB inbuilt CIE 1931 chromaticity diagram, on the same figure.

Identify each illuminant by a different marker and add the corresponding legend. Comment your observations.

Hint 1: Calculate the CIE XYZ coordinates followed by the CIE xy chromaticity coordinates for each illuminant.
Hint 2:

$$X = k \int_{\lambda} \phi(\lambda)\bar{x}(\lambda)d\lambda \text{ ...(1)}$$

$$Y = k \int_{\lambda} \phi(\lambda)\bar{y}(\lambda)d\lambda \text{ ...(2)}$$

$$Z = k \int_{\lambda} \phi(\lambda)\bar{z}(\lambda)d\lambda \text{ ...(3)}$$

Where, $\bar{x}, \bar{y}$ and $\bar{z}$ are the CIE color matching functions, $\phi(\lambda)$ is the product of the spectral radiance of the light source and the reflectance of the target stimuli, k is the normalizing constant set to 683 lumens/watt for standard colorimetry and λ is the wavelength information.

(Helpful MATLAB functions: scatter, scatter: 'mkr' (Marker symbol) and plotChromaticity)

7. Load the planckian_locus.mat file in the workspace.

8. Plot surfaces samples from task 1 in the CIE 1931 chromaticity diagram under each illuminant (A, D50, D65 and F12). Add the Planckian locus in the same CIE 1931 chromaticity diagram.
   Identify each illuminant's objects by a different marker, add the corresponding legend for every illuminant group and the Planckian locus. Comment the effect of the illuminants.

   Hint 1: Combine the spectral reflectance of the objects with the spectral distribution of the illuminants.

9. Obtain the CIE 1976 L*u*v* (CIELUV) and the CIE 1976 L*a*b* (CIELAB) values of the colors obtained in task 8. Draw the CIELUV chromaticity diagram and plot the u'v' chromaticity coordinates on it. Label the axis: u'/v' (and not u/v). Repeat the same by using the inbuilt MATLAB function.

   Hint 1 : u'=4x/(-2x+12y+3) ; v'=9y/(-2x+12y+3)
   Hint 2 : The xy chromaticity coordinates of the CIE 1931 CMFs can be converted into u'v' coordinates using the above formula.
   Hint 3: The u'v' chromaticity plot can be drawn using the exact same technique as used for drawing the horse-shoe shaped xy chromaticity plot.
   Hint 4: L* = CIE Lightness value, u*=13L*(u'-u_n'), v*=13L*(v'-v_n'); where the u_n' and v_n' describe a specified white object color stimulus (pure illuminant).

   (Helpful MATLAB function: xyz2lab, plotChromaticity: 'ColorSpace','uv')