Image formation

Due on April 7, 2014 at 12:00

Digital Photography - Spring 2014

Exercise 2

You have an *exe2.mat* file containing the following:

- $D65$: spectral power distribution of daylight (31×1).
- A: spectral power distribution of an incandescent light source (31×1).
- $F2$: spectral power distribution of a fluorescent light source (31×1).
- T: Transformation matrix from camera sensitivities to sRGB (3×3).
- S: surface reflectances [$31 \times 512 \times 512$ = reflectance samples $\times$ y-dimension (vertical) $\times$ x-dimension (horizontal)] at each pixel position of an image as a function of the wavelength (31 samples between 400 and 700 nm).
- $I1$, $I2$: color images.
- $f1$, $f2$: 2-D filters.

1 Calculating sensor responses

1.1 Plot the three illuminants $D65$, A and $F2$ on the same plot. Normalize them so that the maximum value for each illuminant is 1. Can you already determine the effect of the different illuminants on the final image?

1.2 Plot the respective reflectance spectra corresponding to the image coordinates $(x = 130, y = 160)$ and $(x = 290, y = 320)$ on the same plot. Normalize them such that the maximum reflectance value for each point is 1. What colors do these reflectances represent?

1.3 In your code, there is a built-in function called *computeCameraSensitivity*, which computes camera sensitivities for different color channel correlations. Plot camera sensitivities for $\sigma = 10$ and $\sigma = 100$ on the same plot. What effects will the different sensitivity functions have on the final image?

Note : Make a legend for each plot (axis labels, titles, etc.).

2 Generating RGB images from the reflectances

Generate and display the RGB image

2.1 under illuminant $D65$ and using the camera sensitivities with $\sigma = 10$,

2.2 under illuminant $D65$ and using the camera sensitivities with $\sigma = 100$,

2.3 under illuminant A and using the camera sensitivities with $\sigma = 10$, 2.4 under illuminant A and using the camera sensitivities with $\sigma = 100$,

2.5 under illuminant $F2$ and using the camera sensitivities with $\sigma = 10$,

2.6 under illuminant $F2$ and using the camera sensitivities with $\sigma = 100$.

Normalize all images so that the pixel values are in the interval $[0, 1]$. How do the RGB images change between different illuminants and different σ?
Note : make a legend for each plot (axis labels, titles, etc.).

3 Color space conversion

3.1 Convert the image 2.1 to sRGB by applying the T matrix to the camera sensitivity image to obtain C_{linear}. Normalize the image so that the pixel values are in the interval $[0, 1]$. Then apply the following non-linearity:

$$C_{sRGB} = \begin{cases} 12.92 C_{linear} & \text{if } C_{linear} \leq 0.0031308, \\ (1+\alpha) C_{linear}^{1/2.4} - \alpha & \text{if } C_{linear} > 0.0031308 \end{cases} \tag{1}$$

where $\alpha = 0.055$ and $C \in \{R, G, B\}$. .

Discuss the effect of this conversion on the perceived image quality. Compare to the image in 2.2.

Hint: The function *find* can be useful.

4 Luminance-Chrominance Representation

For some applications a luminance chrominance representation of an image is helpful.

4.1 Use the following linear transformation to convert the image from Section 3 from sRGB to the following luminance chrominance representation:

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.2990 & 0.5870 & 0.1140 \\ -0.1687 & -0.3313 & 0.5000 \\ 0.5000 & -0.4187 & -0.0813 \end{bmatrix} \begin{bmatrix} R_{sRGB} \\ G_{sRGB} \\ B_{sRGB} \end{bmatrix}$$

Normalize the final image so that the pixel values are in the interval $[0, 1]$.

4.2 Display each of the channels, i.e. Y, Cr, Cb, separately. Compare them to a plot of the separate R, G, B channels. What is the difference?

4.3 Display the Cb, Cr channels in true color: each time create a three-channel image where the values of the luminance channel are set to 0.5 and the values of the other chrominance channel are set to 0.

Note: The MATLAB function *imshow* displays only images in the RGB color space!

4.4 Display the R, G, and B channels in true color: each time create a three-channel image where the values of the complementary channels are set to 0.

Note : make a legend for each plot (axis labels, titles, etc.).

5 Image Filtering

In this question you will experiment with an image filtering method.

5.1 Convert the image $I1$ to gray-scale and normalize the pixel values so that they are in the interval $[0, 1]$.

5.2 Filter the above gray-scale image with the filters $f1$ and $f2$ to create the filtered images D_1 and D_2. Normalize the images so that the pixel values are in the interval $[0, 1]$. Display them on the same figure. What do these filters compute?

5.3 Compute the magnitude of the filter response as $D = \sqrt{D_1^2 + D_2^2}$ and display it. What does this magnitude image represent?

Note : make a legend for each plot (axis labels, titles, etc.).

6 Image Saliency

A concept in computer vision is that of *visual saliency*: Visually salient objects in an image stand out from their surrounding regions and immediately grab our attention. In this exercise you will implement a simple visual saliency algorithm, where the saliency value of each pixel with respect to its neighborhood is based on its color and lightness properties. The goal is to produce saliency maps which contain well-defined boundaries of salient objects and disregard high frequencies arising from texture, noise, and blocking artifacts.

6.1 Which is the salient object in the image $I2$?

6.2 Convert the image $I2$ to the LAB color space and obtain $I2_{LAB}$.
Hint: Use the functions *makecform* and *applycform*.

6.3 Compute the average of each channel in the image $I2_{LAB}$ and put the averages in the vector $\mathbf{I}_\mu$.
Hint: You should get a $1 \times 1 \times 3$ vector.

6.4 Compute the saliency map $\mathbf{S}_\mu$ of the image at each pixel position (x, y) as

$$\mathbf{S}_\mu(x, y) = \|\mathbf{I}_\mu - I2_{LAB}(x, y)\|_2^2,$$

where $\|\cdot\|_2^2$ denotes the Euclidean distance.
Hint: You should not use any loops for this computation. The *repmat* command can be handy.

6.5 Display $\mathbf{S}_\mu$. What do you observe on the resulting saliency map? Do the pixels of the salient object have the same saliency value? Why?

6.6 Filter the image $I2_{LAB}$ with a Gaussian filter of standard deviation $\sigma = 8$ and size $w = 31$. Denote the blurred image by $\mathbf{I}_\sigma$.
Hint: The function *fspecial* can be handy.

6.7 Compute the saliency map $\mathbf{S}_\sigma$ of the image at each pixel position (x, y) as

$$\mathbf{S}_\sigma(x, y) = \|\mathbf{I}_\mu - \mathbf{I}_\sigma(x, y)\|_2^2,$$

6.8 Display $\mathbf{S}_\mu$ and $\mathbf{S}_\sigma$. Compare the two saliency maps in terms of uniformity in saliency and object boundary.

6.9 Why are the above saliency maps computed in the LAB color space and not in the original RGB?

Note : make a legend for each plot (axis labels, titles, e.t.c.).

7 HAND IN

Remarks :

- Be careful of the figures in MATLAB when dealing with images. You may want to close the figure before displaying a new one.
- Do NOT use loops or points will be deduced. To avoid them, the MATLAB functions *repmat* or *diag* might come in handy.

General hint: When in doubt, look it up in MATLAB help.

Exercises have to be done individually. You can upload one MATLAB /.m/ file, containing all your results and discussions on Moodle. The first line of the /.m/ file should contain your full name. The /.m/ file also needs to be structured such that each part of the exercise is easily identifiable, by following the numbering in this document. Use the following name for you /.m/ file: *ex2_firstname_lastname.m*.
Hand in your commented working code by April 7, 12:00.