Homework Set Two
ECE 161
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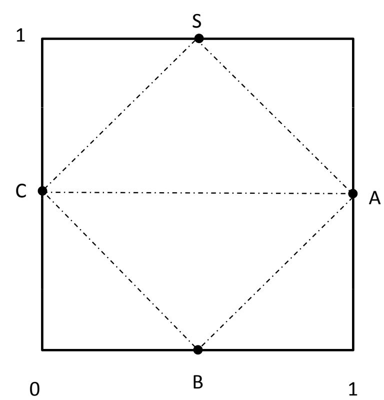
1.

The figure below shows a 2D room illuminated by a single source S at point $(0.5, 1)$ which is not a point source at infinity. We consider three paths for the light that leaves S and arrives at the point $C = (0, 0.5)$ on the left wall. The first path is straight, i.e. $\overline{SC}$. The second path has an intermediate bounce on the right wall, at point $A = (1, 0.5)$, i.e. it is $\overline{SAC}$. Finally, the third path also bounces on the floor, at point $B = (0.5, 0)$, i.e. is $\overline{SABC}$.



The walls are bright and have uniform albedo $\rho_w = 0.6$. The floor is covered by a dark carpet of uniform albedo $\rho_f = 0.2$. The source emits power E in all directions. For each of the three paths, what percentage of this power actually reaches C?

2. Consider the surface

$$Z = X^2 + Y^2$$

and assume that it is illuminated by a point source at infinity, with direction of light $\mathbf{s} = 1/\sqrt{6}(1,1,2)^T$. Assume that the focal length is $f = 1$, the light emits the same amount of power at all wavelengths $E(\lambda) = 1, \forall\lambda$, and the surface has constant albedo (as a function of the spatial coordinates X, Y, Z)

$$\rho(\lambda) = \begin{cases} 0 & \lambda \leq 500 \\ \frac{1}{100}\lambda - 5 & 500 \leq \lambda \leq 600 \\ 1 & \lambda > 600 \end{cases}$$

a) Find the 3D coordinates (X, Y, Z) of the surface point P_0, whose projection on the image plane is $p_0 = (1,2)^T$.

b) What is the power $P(p_0, \lambda)$ that reaches the image plane at p_0?

c) Consider the color space with matching functions

$$\begin{aligned} f_0(\lambda) &= \begin{cases} 1 & 400 < \lambda < 500 \\ 0 & \text{otherwise} \end{cases} \\ f_1(\lambda) &= \begin{cases} 1 & 500 < \lambda < 600 \\ 0 & \text{otherwise} \end{cases} \\ f_2(\lambda) &= \begin{cases} 1 & 600 < \lambda < 700 \\ 0 & \text{otherwise} \end{cases} \end{aligned}$$

What are the values of the image colors at the image pixel corresponding to image plane point p_0?

3. (from Forsyth and Ponce) Derive the equations for transforming from RGB to CIE XYZ and back. This is a linear transformation. It is sufficient to write out the expressions for the elements of the linear transformation. You do not have to look up the actual numerical values of the color matching functions.

Hint: let (a, b, c) be the coordinates of a color on the RGB space, and $p_r(\lambda)$, $p_g(\lambda)$, $p_b(\lambda)$ the RGB primaries. Denote the coordinates in XYZ space by (d, e, f) and the XYZ matching functions by $x(\lambda)$, $y(\lambda)$, and $z(\lambda)$. Derive the equations that relate (d, e, f) to (a, b, c) as a function of the RGB primaries and XYZ matching functions. The answer involves a matrix of dot-products.

4. In class we have seen that a light of spectral radiance $L(\lambda)$ can be written as a function of the primaries $p_i(\lambda), i = 1, 2, 3$, of a color space with matching functions $f_i(\lambda), i = 1, 2, 3$, as

$$L(\lambda) = \sum_{i=1}^{3} \left[\int L(\xi) f_i(\xi) d\xi \right] p_i(\lambda)$$

Use the equation above to verify Grassman's laws.

5. (MATLAB) In this problem we verify that color can be a very important cue for image understanding. We start from the observation that human skin usually falls within a limited range of colors, which tends to be very distinct from that of most other objects in the world. Hence, it is possible to find the skin locations in an image by *color thresholding* . This consists of selecting all pixels whose colors fall within a region of color-space delimited by six thresholds (one upper and one lower bound for each color channel). The file `family.jpg` contains a photograph of several people. Identify the skin regions in this image as follows.

a) in the RGB color space, start with an upper and lower bound for each color channel (I would suggest 0 and 1) and identify the pixels whose colors fall within those bounds. Manually change your thresholds until the identified regions contain as much skin (and as little non-skin) pixels as possible. Hand in the segmented image (image containing the detected skin pixels only, all other pixels set to zero) and write down your thresholds. Also, write down how many iterations of threshold adjustment you needed to get to your final result.

b) convert the image to the HSV color space (using `rgb2hsv`) and repeat the process. Try to explore the perceptual nature of the HSV space. For example, start by looking up a color wheel (such as `http://r0k.us/graphics/SIHwheel.html`) and identifying the values of HSV space associated with skin. Then, perform your search in a way that explores the properties of the space (I would suggest a search for hue thresholds first, followed by an adjustment of saturation and value thresholds). Write down the thresholds and number of iterations, and hand in the segmented image.

c) comment on the relative difficulty of performing the task in the two spaces. Which led to an easier search for the thresholds?

d) do the two segmented images look equally good? In which space is the segmentation better? Can you give an explanation for this?

Note: Sample code for performing the bulk of the programming required by the problem is available from the course webpage.