Computer Graphics - Exercise 02

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1 Color

a) Vector-based graphics support near arbitrary resolutions and are especially useful for displaying line-based imagery, e.g. schematics. Image buildup is computationally intensive and does not lend itself well to vectorization. Drawing complex images on vector-based displays becomes difficult and is one of the reasons vector-based displays have mostly fallen out of use in the present day.

   Raster-based graphics, on the other hand, lend themselves very well to vectorization, the specialty of GPUs, and repeated image buildup is independent of scene complexity. The resulting images map very well to the modern pixel-based displays. The major draw-back is the finite nature of pixel graphics, which leads to aliasing and Moiré effects while also resulting in the fixed resolution of raster-based graphics

b) A spectral color is a color that is evoked by monochromatic light. Either a single wavelength of light in the visible spectrum, or by a relatively narrow band of wavelengths (e.g. lasers). Every wavelength of visible light is perceived as a spectral color. When viewed as a continuous spectrum, these colors are seen as the familiar rainbow.

c) In low light conditions, the rods are more sensitive and work better than the cones. Therefore, rods are crucial for our scotopic vision. Cones, on the other hand, are responsible for our photopic vision and allow us to perceive color.

d) When looking at Mach bands (e.g. aligned shades of grey) one recognizes each transition zone between two shades as an edge by increasing the luminance gradient. Therefore the sensed brightness exceeds the actual brightness and increases the visual contrast between the two shades. This contrast enhancement can be explained with receptive fields (s. Lecture 2 Slide 52).

e) Explain three operations that can be carried out geometrically in the chromaticity diagram.

   - The colors along a line between two boundary points can be reproduced by mixing the colors of the endpoints. If the line goes through the "whitepoint" its endpoints colors are complementary.
   - Gamut mapping sets a "normalized color space" in form of a triangle to reduce/avoid color shifts between devices. The corner points of such a triangle represent the primary colors. To produce colors outside this gamut additional primary colors would be needed.
   - The MacAdams ellipses in the chromaticity diagram describe the intuitive hues humans would expect near the colors marked by the center points of the ellipses.

f) Additive color mixing does build up the desired color by combining red, green and blue colors, while subtractive color mixing produces the desired color by filtering colors through the use of cyan, magenta and yellow. Modern displays produce color via additive color mixing, while the primary colors in art class produce color via subtractive color mixing.

g) (i) Conversion from RGB to CMYK (cyan, magenta, yellow, black key color):

$$R' = \frac{R}{255}, \quad G' = \frac{G}{255}, \quad B' = \frac{R}{255} \tag{1}$$

$$K = 1 - \max(R', G', B') \tag{2}$$
$$C = (1 - R' - K)/(1 - K) \tag{3}$$
$$M = (1 - G' - K)/(1 - K) \tag{4}$$
$$Y = (1 - B' - K)/(1 - K) \tag{5}$$

At last when writing the CMYK tuple, we write the values in percent (e.g. instead of 1 we write 100).
So in the Case of RGB = (1, 0, 0) it's CMYK = (0, 100, 100, 0).

(ii) Conversion from RGB to HSV (hue, saturation, value):

$$R' = \frac{R}{255}, \quad G' = \frac{G}{255}, \quad B' = \frac{R}{255} \tag{6}$$

$$C_{max} = \max(R', G', B'), \quad C_{min} = \min(R', G', B'), \quad \Delta = C_{max} - C_{min} \tag{7}$$

$$H = \begin{cases} 0°, & \Delta = 0 \\ 60°(\frac{G'-B'}{\Delta} \bmod 6), & C_{max} = R' \\ 60°(\frac{B'-R'}{\Delta} + 2), & C_{max} = G' \\ 60°(\frac{R'-G'}{\Delta} + 4), & C_{max} = B' \end{cases} \tag{8}$$

$$S = \begin{cases} 0, & C_{max} = 0 \\ \frac{\Delta}{C_{max}}, & C_{max} \neq 0 \end{cases} \tag{9}$$

$$V = C_{max} \tag{10}$$

So in the Case of RGB = (1, 0, 0) it's HSV = (0 °, 100 %, 100 %)

(iii) Conversion of RGB to HSL:

$$R' = \frac{R}{255}, \quad G' = \frac{G}{255}, \quad B' = \frac{R}{255} \tag{11}$$

$$C_{max} = \max(R', G', B'), \quad C_{min} = \min(R', G', B'), \quad \Delta = C_{max} - C_{min} \tag{12}$$

$$H = \begin{cases} 0°, & \Delta = 0 \\ 60°(\frac{G'-B'}{\Delta} \bmod 6), & C_{max} = R' \\ 60°(\frac{B'-R'}{\Delta} + 2), & C_{max} = G' \\ 60°(\frac{R'-G'}{\Delta} + 4), & C_{max} = B' \end{cases} \tag{13}$$

$$S = \begin{cases} 0, & C_{max} = 0 \\ \frac{\Delta}{C_{max}}, & C_{max} \neq 0 \end{cases} \tag{14}$$

$$L = (C_{max} + C_{min})/2 \tag{15}$$

So in the case of RGB = (1, 0, 0) it's HSL = (0 °, 100 % , 50 %)

h) It's way cheaper to use black color for printing than to use all three colors to mix it. Since black is probably also the most used color for printing one should definitely not need to expensively mix it for printing. Many printer's also lack the precision to produce "good" black by using color, since this does require three ink dots, reasonably close to each other, instead of a single black one.

i) The YIQ system is intended to take advantage of the human color-response characteristics. The eye is more sensitive to changes in the orange-blue (I) range than in the purple-green range (Q). This means less bandwidth is required for Q than for I. This was most importantly used in TV

j) The direct center of the human view (seen through light hitting the fovea) is more sensitive to contrast such that our perception is not gravely influenced by changes in illumination over the day while the area outside the fovea (except, of course, the blind spot at the optical nerve) is more sensible to differences in brightness.

k) Participants of the color matching experiment are asked to reproduce a given color by adjusting the intensity of the three primary colors red, green and blue until the resulting color matches the given one. Surprisingly not all colors can be realized by combining the 3 primaries.

l) See Python Code