ETH zürich

computer graphics laboratory

Prof. Dr. Markus Gross

Visual Computing

Exercise 07: Light & Colors

Hand-out Date: 10 November 2023

Goals

- Understand the theoretical basics of color spaces.
- Working with the CIE-Chart.

Resources

The lecture slides and exercise slides are accessible via the Visual Computing Course Web Page.

Tasks

1. Color Modes

- How do you transform a specification in RGB into CMY?
- Why were color spaces such as RGB, CMY, YIQ, and HSL specified, and where are they being applied?
- Provide the values for a medium gray in the following color modes: RGB, CMY, YIQ and HSV.

2. RGB Color Space and White Point Calibration

The RGB color space is a subspace of the XYZ color space. Assume the base vectors are directly related to the used phosphors often used in monitors, also known as ITU-R BT.709-standard. The color components x and y of the RGB base vectors are given in the table below.

	R	G	B
X	0.64	0.30	0.15
Y	0.33	0.60	0.06

The white point is identified as (0.9505, 1.0000, 1.0890).

- Name one advantage and one disadvantage of the RGB color space. Furthermore, list one color space each, which does not have this advantage or disadvantage.
- Evaluate the z-component of the RGB-base vectors.
- Provide the equation system for the white point calibration. Name the calibration parameters C_R, C_G and C_B.
- Suppose $C_R = 0.6445$, $C_G = 1.1919$ and $C_B = 1.2031$ are given as a solution. Evaluate the transformation matrix from the linear color space RGB into the color space XYZ.

3. Color Space Transformation

In this exercise we focus on the transformation from colors in the sRGB-color space into the broadly known color spaces used in television, namely PAL and NTSC.

- In order to be compatible with old black and white systems, the first channel of the PAL-color space (also known as YUV-color space) is the Y-coordinate of the XYZ-color space. Since the Y-coordinate

  $$Y = 0.2126 * R + 0.7152 * G + 0.0722 * B$$

  contains a major green component, Cb and Cr are chosen in a way such that they contain a major blue respectively red component:

  $$C_B = B – Y, C_R = R – Y.$$

  Finally norming the Cb- and the Cr-channels leads to the YUV- or PAL-color space:

  $$U = 0.49 C_B, V = 0.88 C_R$$

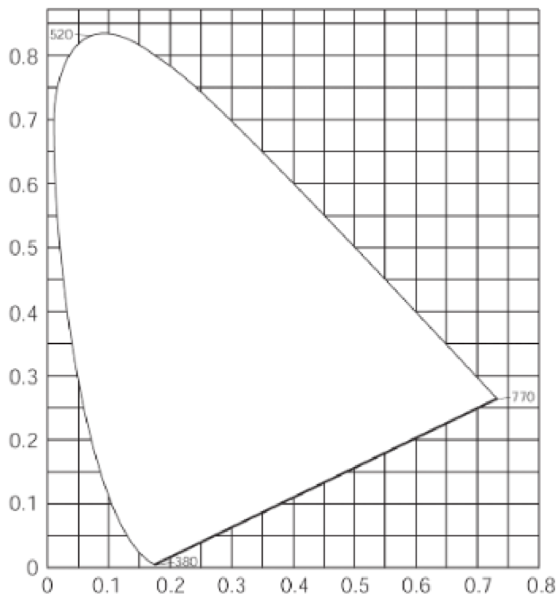
  Provide the transformation matrix from the sRGB-color space into the YUV-color space.

- The YIQ- or NTSC-color space is used as the US television standard. It is created from the PAL color space, by swapping the U- and V-coordinates followed by a rotation by 33 degrees around Y-axis. Evaluate the transformation matrix for the conversion from PAL to NTSC. You do not have to evalu¬ate trigonometric expressions.
- The YIQ-channels are splitting the bandwidth proportional to 8:5:2 during the transfer of NTSC color signals. Why is such an uneven bandwidth being used?

4. CIE-Chart

- Which properties does a mixed color in the CIE-Chart have to its primaries?
- Which meaning does the connection between 770nm and 380nm have in this chart?
- The figure below shows a CIE-Chart. Add following primaries into the chart.

	x	y	Y
C1	0.1	0.8	12
C2	0.6	0.3	26
C3	0.2	0.05	10



- Determine the dominant wavelengths λ_1, λ_2 and λ_3 of the 3 primaries.

- For each primary, draw the isoline of constant saturation passing through it into the chart.
- Determine the primary C_{123}, which is the sum (in the XYZ-space) of the 3 primaries C_1, C_2 and C_3. Add it to the chart.
- Can all spectral colors with full saturation be mixed from three linearly independent primaries?