INTERNATIONAL COLOUR VISION SOCIETY

Gamma Correction

Here we introduce the concept of gamma correction and go through how to perform a gamma correction on your display.

1. Prerequisites

MATLAB (tested on 2022b) (software)

PsychToolbox-3 (tested on version 3.0.19) (software)

ColorCAL (hardware)

2. Theory

In producing light output from a computer display, or other light emitting device, it is not guaranteed that the light energy that is emitted is directly proportional to the value requested from the computer. So, typically we must go through a calibration process in which we measure the light output as a function of the requested value. For computer displays, the relationship is typically a power-law ($L = I^{\gamma}$, where L is output intensity, I is requested signal and γ (gamma) must be determined for each display), and the calibration process is called gamma correction. This terminology is generally used even when the relationship for a particular device takes a form other than a power law.

One useful approach is to characterize the relationship between light output and the signal from the computer. The inverse of this function can be used to linearize the relationship so that, once the signal has undergone correction, the output is directly proportional to the input. The principle is summarized in Figure 1, which describes the gamma correction for a cathode ray tube (CRT) display, which is a type of monitor often used in psychophysical experiments. The principle is the same for any device that you need to linearize/check linearity for. Typically, the relationship between light output and the signal from the computer are measured independently for the red, green and blue channels separately, as the gamma applied to each of these channels may differ.

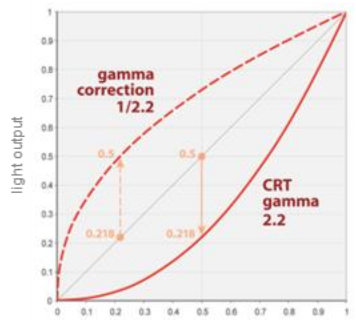

Figure 1: The solid red line shows the measured relationship between the signal requested by the computer and the light output of a CRT display (which follows a typical power-law with gamma = 2.2). Specifying 50% of the available computer signal produces only 21.8% of the available output. To linearize the output, the low input signals must be boosted, according to the dashed gamma-correction curve. Using these values the 21.8% output is boosted to 50%.

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3. Gamma correction in practice

3.1. Gamma Measurement via the ColorCal

measureGamma.m allows you to measure a display's gamma using the ColorCal (see Worksheet XX). Simply, this code loops through many luminance recordings, increasing the input to the display between each recording. Using the **'tri'** mode, we will loop through the red, green and blue channels. Once all recordings for one channel are made, a power curve is fitted to the recorded data, as this reflects the kind of non-linearity of displays. This means that the data need to be normalized such that the maximum output, found at the maximum input, is (1,1). This is because, no matter the gamma, the maximum value should not be transformed, and 1 to any exponent is still 1. MATLAB's **fit** function is used to fit a power law function in the format:

$$L = b * I^c + d$$

Where **L** is the output luminance, **I** is the input value, and **b**, **c** and **d** are values found by the **fit** function.

The figure generated by the curve shows the relationship between the output luminance and the input value. The script will save the *gamma* values for each channel into a **.mat** file. What does this look like for the display you measured? Discuss amongst your group. *What is the gamma value for your display device and how does it compare to the typical gamma of c=2.2? What do the other fitted variables tell us?*

3.2. Gamma Correction

Once a gamma has been measured, a display's output can be 'linearized'. Simply, input values are mapped to a power curve of **reciprocal exponent** to the recorded gamma. Expressed mathematically: $I = L^{1/\gamma}$, where L is output intensity, and I is signal you should request. **exampleGammaCorrection.m** shows a short example of how input values are corrected using measured gamma values.

If the "gamma" function is not well characterized by a power law, other parametric functions can be fit and inverted. Or, the measurements can be interpolated and a table that enables inversion via table lookup can be generated. Typically, this table is sample much more finely than the digital quantization of the device being characterized.

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