Mehrdad Baradaran - 99222020

Assignment 01

professor : Dr. Mahmoudi Aznaveh

Q1 Answer :

Luminance is a numerical value that measures the intensity of light reflected by a surface. Actually it determines how bright or dark an object is from human eyes. it is not subjective and does not differ from person to person. But Brightness is a subjective metric derived from Luminance, which tells how the light is perceived by the human eye. Although Brightness is derived from Luminance, it is a human and personal perspective of the amount of light, and it can vary person to person because of conditions like viewing angle or environment and even human visual system.

In image processing, we use luminance for technical analysis and operations on the image but Brightness is related to how the image is perceived by a human. For instance, Luminance is determined by analyzing pixel values or color space in the image. We can use luminance in algorithms like Contrast Enhancement. In contrast, we use brightness adjustment in image processing to determine and modify the darkness and brightness of an image.

It is essential to understand the differences between Luminance and Brightness in image processing since two objects with the same Luminance can have different Brightness from the perspective of different people. This variation can be attributed to factors such as the visual system, contrast, and the environment. Likewise, two objects with different Luminance can appear to have the same Brightness under certain conditions. Therefore, the Brightness concept is relevant when the output of an algorithm or operation is intended to be viewed by a human, and it may not be necessary for more technical operations.

In contrast, Perceived Intensity is the human perception of light. So it is related to the concept of Brightness. In the plots, the second graph clearly examines the human perception of 6 different light intensities. As we can see at the initial value of 0 there is a decay and the value goes below 0. Then it starts to increase with a slope close to infinity. It is noteworthy that the growth slope from one light to the next is infinite in actual Intensity. For example it grows at a 90-degree angle. But in the second graph, which represents human perception, the growth is at an angle less than 90 degrees. We see the subjective nature of this metric here which changes based on the conditions.

Furthermore, we see that when the second graph reaches the next light value, for example 1, it has a slight immediate increase and then returns to the value of 1. All these immediate changes at the boundaries and the growth slope from one light to the next are due to environmental factors like the visual system or contrast and other factors. We know these factors make Brightness a subjective metric and Luminance an objective and physical quantity.

Q2 Answer :

To calculate the CMYK values, we'll use the following equations based on RGB:

$$K = 1 - (R', G', B')$$

$$C = \frac{1 - R' - K}{1 - K}$$

$$M = \frac{1 - G' - K}{1 - K}$$

$$Y = \frac{1 - B' - K}{1 - K}$$

Where R',G',B' are normalized values of RGB (between 0 and 1). We'll first normalize the RGB values by dividing each by 255:

$$R' = \frac{251}{255} \approx 0.984$$

$$G' = \frac{151}{255} \approx 0.592$$

$$B' = \frac{51}{255} \approx 0.200$$

Then, we'll calculate K and then C,M,Y:

$$K = 1 - MAX(0.984, 0.592, 0.200) = 1 - 0.984 = 0.016$$

$$C = \frac{1 - 0.984 - 0.016}{1 - 0.016} = 0$$

$$M = \frac{1 - 0.592 - 0.016}{1 - 0.016} \approx \frac{0.392}{0.984} \approx 0.398$$

$$Y = \frac{1 - 0.200 - 0.016}{1 - 0.016} \approx \frac{0.784}{0.984} \approx 0.796$$

To convert the color to YIQ, we'll use the following transformation matrix:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

We'll plug in the RGB values:

$$Y = ((0.299 \times 251) + (0.587 \times 151) + (0.114 \times 51))/255 \approx 0.6647$$

$$I = ((0.596 \times 251) + (-0.275 \times 151) + (-0.321 \times 51))/255 \approx 0.359$$

$$Q = \frac{(0.212 \times 251) + (-0.523 \times 151) + (0.311 \times 51)}{255} \approx -0.038$$

For the conversion to YCbCr:

$$Y \approx 161$$

$$Cb \approx 69$$

$$Cr \approx 179$$

We see above an overview of three distinct color representation models, namely RGB (Red, Green, Blue), YIQ, and YCbCr. We commonly use RGB for displaying images on electronic devices such as televisions and our computer monitors due to its ease of use and high level of understandability. However it also has limitations like a limited color gamut and suboptimal performance for wide-gamut images. YIQ is a color space that is used in NTSC color television systems. We see it has three components: luminance, I, and Q. These represent chrominance differences. YIQ is compatible with NTSC color TV standards but it is not generally applicable beyond this specific domain.

During the early days of color television, black-and-white sets were still expected to display what were originally color images. YIQ model separated chrominance from luminance. Luminance information is contained on the Y-channel, whereas color information is carried on I and Q channels (in-phase and in-quadrature) , in-short YIQ(Luminance, In-phase, Quadrature). In addition to providing a signal that could be displayed directly on black-and-white TVs, the system provided easy coding and decoding of RGB signals which was not directly possible. Due to the fact that the Y-channel carries a lot of luminance information, it has a bandwidth assigned to it of 4Mhz, I-channel has a bandwidth assigned to it of 1.5Mhz, and Q-channel has a bandwidth of 0.6Mhz.

We select each of these models on the specific application. For instance, YCbCr is commonly used for image and video display due to its high compression capability and compatibility with compression standards. RGB is preferable for graphics work and image editing due to its wider color gamut, and YIQ is utilized when compatibility with NTSC color TV standards is required.

Q3 Answer :

First we utilize the probability integral transformation to transform the probability distribution *pr*(*r*) to the desired probability distribution *pz*(*z*). As the transformation of a probability distribution to a normal distribution is integral we can find a transformation function that converts the given probability distribution to the desired one.

Compute the cumulative distribution function *Fr*(*r*) for *pr*(*r*).

Compute the cumulative distribution function *Fz*(*z*) for *pz*(*z*).

Find the transformation function *z*=*T*(*r*) using the inverse of the cumulative distribution function.

Compute the cumulative distribution function *Fr*(*r*) for *pr*(*r*). This function is the integral of the probability distribution function from negative infinity to the variable *r*: $F_r(r) = \int_{-\infty}^{r} \quad p_r(r')dr'$

Similarly, for the probability distribution *pz*(*z*), compute its cumulative distribution function *Fz*(*z*): $F_z(z) = \int_{-\infty}^{z} \quad p_{rz}(z')dz'$

Then, using the inverse of the cumulative distribution function *Fz*(*z*), find the transformation function z = T(r) : $z = T(r) = \ F_z^{-1}(F_r(r))$

$$z = T(r) = (r^2 - 2r)^{0.5}$$

Q4 Answer :

a) we show each step in the algorithm using tables

step1: we count each color number and scaled all them.

num	count	scaled
1	8	0.14
2	8	0.28
3	2	0.42
5	7	0.71

step 2: We calculate PMF and next CDF with previous numbers.

PMF	CDF
8.25	8.25
8.25	16.25
2.25	18.25
7.25	1

step3: Finally we have s therefore we will see Equalized for each color.

s	Equalized
2.24	2
4.48	4
5.04	5

7	7

so the final image would be:

2 4 2 2 2

4 7 5 7 4

4 7 7 7 4

4 7 5 7 4

2 2 2 4 2

b) first we need to convert numbers into binary form:

1	0 0 0 0 0 0 0 1
2	0 0 0 0 0 0 1 0
3	0 0 0 0 0 0 1 1
5	0 0 0 0 0 1 0 1

so bit-planes would be:

Bit 0	Bit 1	Bit 2
1 0 1 1 1	0 1 0 0 0	0 0 0 0 0

0 1 1 1 0	1 0 1 0 1	0 1 0 1 0
0 1 1 1 0	1 0 0 0 1	0 1 1 1 0
0 1 1 1 0	1 0 1 0 1	0 1 0 1 0
1 1 1 0 1	0 0 0 1 0	0 0 0 0 0

and we see other bits would be 0.

c) we apply linear histogram sketching:

We know the range is [0,7] so we should find max and min number to then calculate scale value number:

min_num = 1

max_num = 5

scale_value = (7 - 0) / (5 - 1) = 7 / 4 = 1.7

so we just need to apply this scale value to colors:

new_num = (color - min_num) * scale_value

so the colors become:

1 → 0 2 → 2 3 → 4 5 → 7

And final image become:

0 2 0 0 0

2 7 4 7 2

2 7 7 7 2

2 7 4 7 2

0 0 0 2 0

Sources :

[Brightness - Wikipedia]

[Luminance vs. Illuminance: What’s the Difference? (hunterlab.com)]

[RGB color model - Wikipedia]

[YIQ Color Model in Computer Graphics - GeeksforGeeks]

https://la.mathworks.com/help/images/understanding-color-spaces-and-color-space-conversion.html#:~:text=Independent%20Color%20Spaces.-,YCbCr,components%20(Cb%20and%20Cr).