CS 435 - Computational Photography

Assignment 1 - Pixel Operations

Introduction

In this first assignment we want to get you comfortable with importing and exporting images as well applying basic point-processing algorithms.

Subsequent assignments will likely be far more involved, but we want to you getting your "hands dirty" as soon as possible!

In this assignment you will demonstrate your ability to:

- Obtain images and import them into Matlab
- Demonstrate the application of several pixel-processing algorithms.
- Render histograms and images

Grading

Theory Questions	15pts
RGB $\rightarrow$ Grayscale	15pts
RGB $\rightarrow$ Binary	15pts
Gamma Correction	20pts
Changing Hue	15pts
Histograms	20pts
TOTAL	100pts

Table 1: Grading Rubric

1 (15pts) Theory Questions

1. (2pts) Given a point in 3D space, (3,5,20) and an effective focal length of 10, where will this point appear on the 2D image plane?

   $z' = 10; (x, y, z) = (3, 5, 20)$

   $(x', y') = \frac{z'}{z}(x, y) = \frac{10}{20}(3, 5) = (\frac{3}{2}, \frac{5}{2})$

2. (2pts) If we have a focal length of 10 and a lens effective diameter of 5, what is the field of view of this camera system (in degrees)?

   $D = 5, f = 10$

   $\tan(\frac{\theta}{2}) = \frac{D}{2f} \implies \theta = 2\tan^{-1}(\frac{1}{4}) = 2(14.036°) = 28.072°$

3. (3pts) Given a pixel in RGB color space with the values $R = 100, B = 10, G = 200$, what is the value of this pixel in HSV color space?

   $(R, G, B) = (100, 200, 10)$

   $(R', G', B') = (\frac{100}{255}, \frac{200}{255}, \frac{10}{255})$

   $\max(R', G', B') = \frac{200}{255}; \min(R', G', B') = \frac{10}{255}$

   $G > R > B \implies H = 120° + 60° \frac{B' - R'}{\max(R', G', B') - \min(R', G', B')} = 120° - 60° \frac{90}{190}$

   $\implies H = 91.578°$

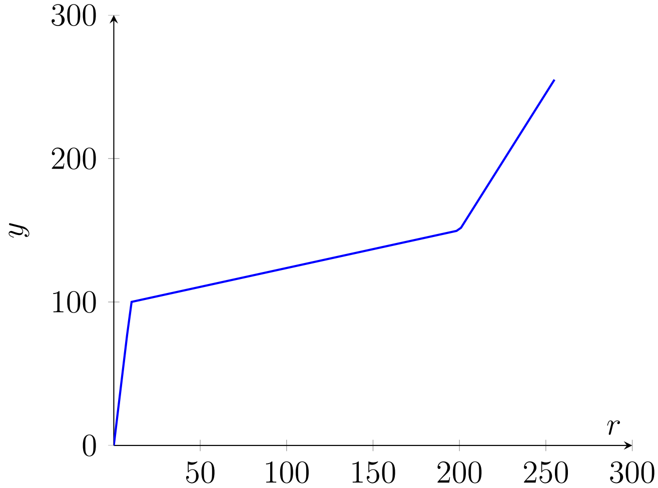
   $S = \frac{\max(R', G', B') - \min(R', G', B')}{\max(R', G', B')} = \frac{190}{200} = .95$

   $V = \max(R', G', B') = \frac{200}{255} = 0.784$

4. Based on observing a histogram perhaps we decided to create the following pixel intensity mappings in order to stretch the values of a particularly compressed area (you may assume the full range is [0,255]):

   [0,10]→[0,100]
   (10,200]→(100,150]
   (200,255]→(150,255]

   (a) (2pts) Draw a 2D graph showing these mappings. The x-axis will be the input values and the y-axis will be the output values.



(b) (3pts) What are the equations for these mappings?

$$\alpha = \frac{s_1}{r_1} = \frac{100}{10} = 10$$

$$\beta = \frac{s_2 - s_1}{r_2 - r_1} = \frac{150 - 100}{200 - 10} = \frac{50}{190} = 0.263$$

$$\gamma = \frac{C_{max} - s_2}{C_{max} - r_2} = \frac{255 - 150}{255 - 200} = \frac{105}{55} = 1.909$$

$$y = \begin{cases} \alpha r & r \in [0, r_1] \\ \beta(r - r_1) + s_1 & r \in [r_1, r_2] \\ \gamma(r - r_2) + s_2 & r \in [r_2, C_{max}] \end{cases} = \begin{cases} 10r & r \in [0, 10] \\ 0.263(r - 10) + 100 & r \in [10, 200] \\ 1.909(r - 200) + 150 & r \in [200, 255] \end{cases}$$

(c) (1pt) Given a value of 50, what will this value be mapped to?

$y(50) = 0.263(50 - 10) + 100 = 110.5$

(d) (2pts) In your own words, describe the effect of this mapping.

Intensely dark areas become somewhat lighter, as we see a stretch from $[0, 10] \to [0, 100]$. Lighter areas become darker, as we see a squish from $(10, 200] \to (100, 150]$. Intensely light areas become somewhat darker, as there is a stretch from $(200, 255] \to (150, 255]$.

2 Dataset

For the programming component of this assignment, you may use a *color* image of your choosing. Make sure that you include your image with your submission so that we can recreate your results. In each of the following sections you'll be asked to output images. The images will also be included in your report.

Placing RGB picture here to avoid repetition:

Figure 1: Original RGB Image

3 (15pts) RGB $\rightarrow$ Grayscale

The first point-processing thing we want to be able to do is to convert an image from color to grayscale.

Read in your color image and use the following formula to convert it to a grayscale image. You **may not** use a built-in function to do this (i.e rgb2gray).

$$Gray = 0.2989R + 0.5870 * G + 0.1140B \tag{1}$$

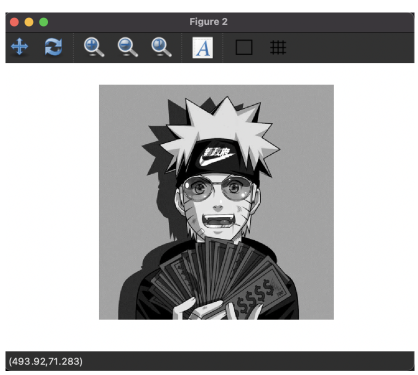


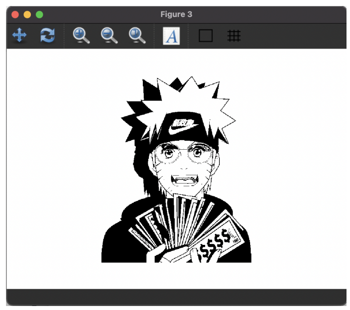
Figure 2: Grayscale Image

4 (15pts) RGB → Binary

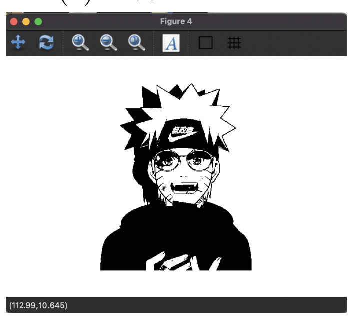
In this part, we want to be able to convert your color image (or grayscale image) into a binary image, where each pixel is either black or white.

Produce three binary images, one for each of the following thresholds (as percentages of maximum possible intensity value):

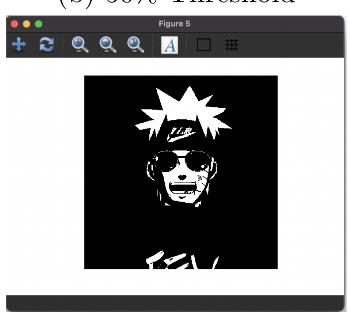
- t=25%
- t=50%
- t=75%



(a) 25% Threshold



(b) 50% Threshold



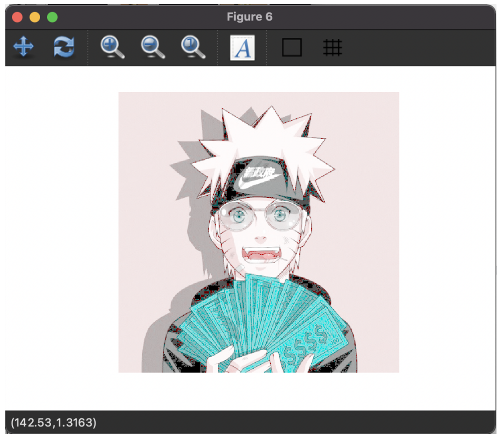
(c) 75% Threshold

5 (20pts) Gamma Correction

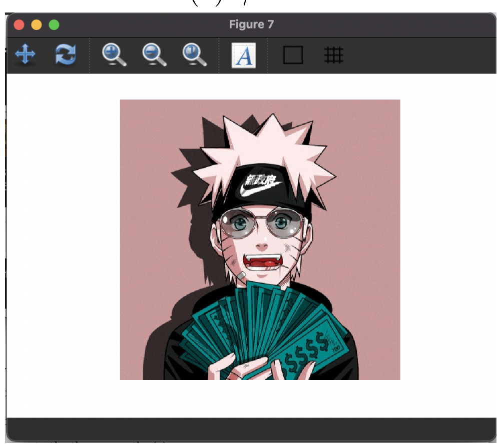
In this part, we want to apply some gamma correction to your image. First convert your RGB image so that its channels are in the range $[0, 1)$. Next apply gamma correction to each channel via the formula $s = cr^\gamma$. Finally display your gamma corrected image.

Produce three gamma corrected images, each with parameter $c = 1$ and values of gamma as:

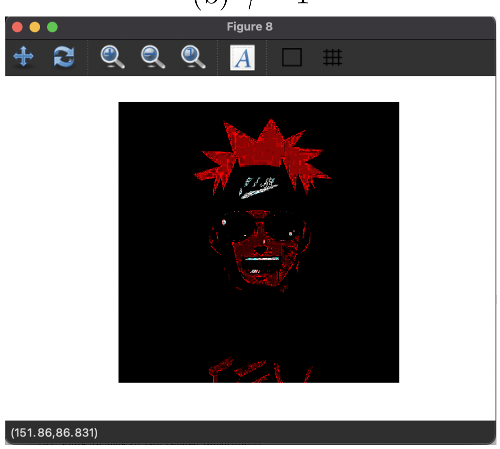
- $\gamma = 0.2$
- $\gamma = 1$
- $\gamma = 50$



(a) $\gamma = .2$



(b) $\gamma = 1$



(c) $\gamma = 50$

6 (15pts) Changing Hue

In this part we'll go from RGB space to HSV space, change the hue, then return to RGB space.

Create a new RGB image that has the hue value of pixels increased by a value of 50 deg. Do this by first converting your image from RGB to HSV, increasing the hue, then returning to RGB space. Keep in mind that when you increase the hue values, you might end up with values out of the range $[0, 360]$. Think about how to deal with this in your implementation.

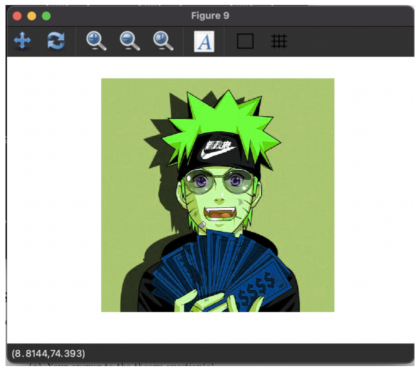
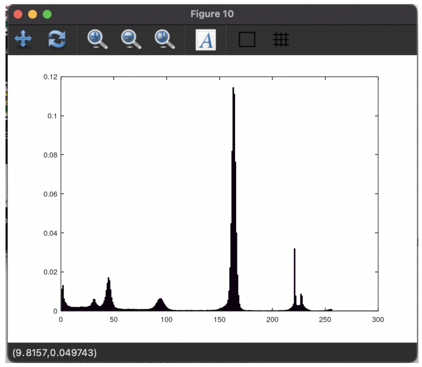


Figure 5: Hue-Shifted Image

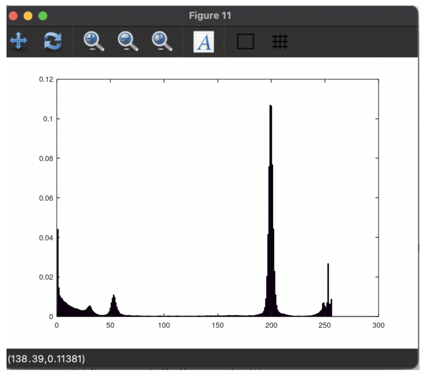
7 (20 points) Histograms

Histograms are a critical analysis tool use for many computer vision problems. Display four histograms for your image, each of which have 256 bins. **You may not use a built-in function to obtain the histogram**. To plot your histogram, use the *bar* function of Matlab.

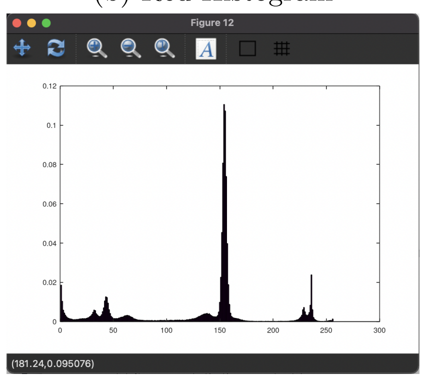
- Grayscale histogram
- Histogram of the red channel
- Histogram of the green channel
- Histogram of the blue channel.



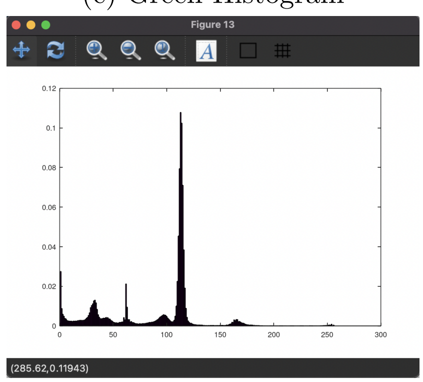
(a) Grayscale Histogram



(b) Red Histogram



(c) Green Histogram



(d) Blue Histogram

Submission

For your submission, upload to Blackboard a single zip file containing:

1. PDF writeup that includes:
   (a) Your answer to the theory question(s).
   (b) The RGB and Gray images for Part 3.
   (c) The RGB and Binary images for Part 4 (so 4 images total).
   (d) The RGB and Gamma Corrected images for Part 5 (so 4 images total).
   (e) The RGB and Hue adjusted images for Part 6.
   (f) The histograms for Part 7 (4 total)
   (g) A README text file (**not** Word or PDF) that explains:
      i. Features of your program
      ii. Name of your entry-point script
      iii. Any instructions on how to run your script
   (h) Your source files.
   (i) The chosen image(s) that you processed.