Assigment 2: Grey Level and Color

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I. Introduction

This document is the report of my Assignment 2 from my Fall 2023 class CAP-5400 Digital Image Processing, as a graduate student. The individuals who are overviewing this assignment are our professor Dr. Dmitry Goldgof and Mr. Anthony McCofie (Teaching Assistant). The purpose of this algorithm is to cover multiple color correcting algorithms for both color and gray-scale images (Histogram-Stretching, Histogram-Equalization, and Histogram-Equalization with thresholding).

II. Grey Scale Transormations

A. Histogram Stretching

Histogram stretching is a technique used to improve the overall contrast and visual quality of an image. It works by redistributing the pixel intensity values in an image to span a wider range. For my implementation the range must be provided by the user, but for an ideal performance select a range of the widest range (0, 255).

$$P' = \frac{(P - C) \cdot (B - A)}{(D - C)} + A$$

Figure 1: Histogram Equalization

In this case P is the pixel value of position *I(i,j)*, (C, D) is the current range of the image, and (A, B) is the input range for the function.

Figure 2: Left image - Original image,
Right image - Equalize Gray-level image (A=0, B=255)

B. Histogram Equalization (Gray-Scale)

Histogram equalization in grayscale also aims to improve the overall contrast and visual quality of an image. The difference is that instead of working by providing a range, it uses the histogram and the cumulative histogram to derive the new output range of pixel values. For this project, I used the **OpenCV** implementation.

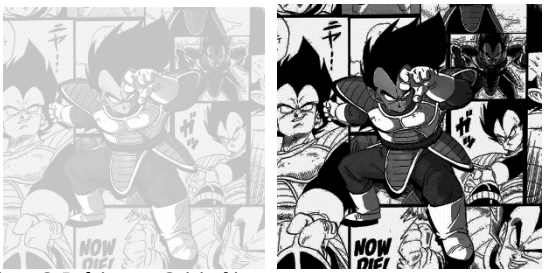

Figure 3: Left image - Original image,
Right image - Histogram Equalized image

Values given a gray-image with bad contrast both stretching, and equalization produce very similar results. Given that stretching identifies a good range for the image (which can be helped by multiplying the ranges by 5%) and giving an input range wide enough to properly stretch all values.

C. Histogram-Equalization with Thresholding

Given an image with 2 distinct contrast areas the idea is to perform the Equalization in pixels which are lower than a given **T value.**

Figure 4: Landscape with 2 distinct contrast areas

To achieve this, we need to construct a modified image based on the input image **I**. The new image **H** should be created as follows:

$$H(i,j) = \begin{cases} I(i,j), & T > I(i,j) \\ T, & else \end{cases}$$

Figure 5: Thresholded image equation

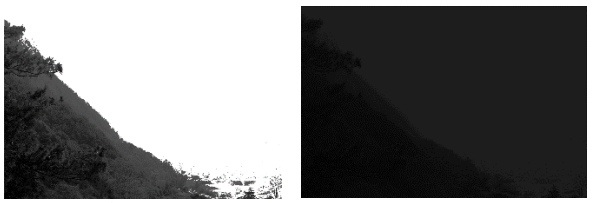

Figure 6: Left image – Pixels which are less than T,
Right image – Image used for Equalization → H

Now equalize the image **H** and use both images (**I & H**) to reconstruct the output image (**I'**) as following.

$$I'(i,j) = \begin{cases} H(i,j), & T > I(i,j) \\ I(i,j), & else \end{cases}$$

Figure 7: Histogram-Equalization with Thresholding equation

Figure 8: Histogram-Equalization with Thresholding

III. Color Transormations

A. Histogram Equalization on RGB channels

Equalization of the RGB levels can lead to some issues and not produce the desired results. Mainly the loss of color balance will result in an image with unnatural colors, due to some channels overcompensating for others.

Figure 9: Low Contrast Portrait and combined RGB equalized channels

Figure 10: Image Equalized in RGB independently

B. Histogram Equalization on HSI

Equalization in the HSI color space is often preferred over RGB due to the chromatic information being held in one channel instead of 3 (which is the case in RGB). Since hue and saturation are separated this allows to increase the contrast of an image without affecting the balance of the colors.

Figure 11: Low contrast Baboon and combined HSI equalized channels

Figure 12: Image Equalized in HSV independently

C. Best Performing Histogram Equalization

When increasing the overall contrast of a color image is preferred to equalize an image over the Intensity channel on the HIS color space.

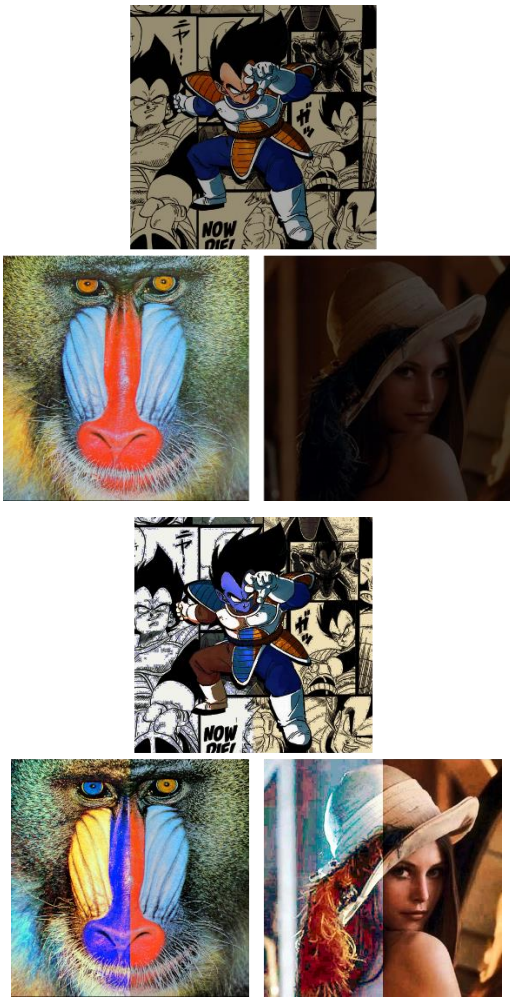

Figure 12: Upper half are low contrast iamges, lower half are the same images split into RGB equalization and Intensity equalization (from HSI)

IV. Conclusion

In conclusion, histogram stretching is a valuable image enhancement technique used to improve the contrast and visibility of image details. However, when it comes to preserving natural color balance and achieving better control over contrast enhancement, histogram equalization in the HSI (Hue, Saturation, Intensity) color space often outperforms its counterpart in RGB (Red, Green, Blue). By separating the luminance (intensity) from the color information, HSI-based equalization allows for precise control, preventing unnatural color shifts and maintaining the image's overall visual appeal. This makes HSI-based histogram equalization a preferred choice for various image processing tasks where color fidelity and natural appearance are essential.