Assignment 1: Point Operations and Contrast Adjustment

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Section 4

November 18, 2019

Introduction

The purpose of this lab was to learn the properties and methodology behind point operations and contrast adjustments. Grey-scale image, which are the type of images primarily used in this lab project, I(x, y) is nothing more than a stored Height x Width array of numbers somewhere in memory[1]. The amplitude at each index of the array correspond to an image intensity value (how dark or bright the pixel is at that point).

The lab was mainly conducted using Matlab and the C programming language. The combination of these two programming languages was achieved by using MEX functions which provide an interface between Matlab and C. Matlab was used as the scripting language for the project while the actual functions were implemented in C.

Theory

Point operations consist of operations that are the direct manipulation of image intensity values[1]. These operations take the general form

$$I_p(x, y) = A \cdot I(x, y) + B$$

where I(x,y) is the input image, I_p(x,y) is Point transformed output image, and A and B are point operation variables applied to the input image intensity value at that specified index.

The vast majority of images used in this lab are 8 bit meaning that there are 256 values of image intensity, with 0 being black (dark) and 255 being white (light). The range of image intensity is 0 - 255, if the operations exceeds this limits it will cause an underflow/overflow. This must be addressed by either using a 32 bit integer value and saturating the result and then casting the value back to an 8 bit integer or simply having a conditional statement setup in such a way as to ensure that any value exceeding this range remains as the minimum or maximum range value. In this lab, for simplicity sake the second method was used.

Contrast adjustment/stretching is the a method used to enhance or suppress certain image intensity values depending on certain conditions or requirements of the processing[1]. These operations take the general form

$$I_{cs}(x, y) = T \cdot I(x, y)$$

Where I(x,y) is the input image, I_{cs}(x,y) is the contrast stretched output image and T is the Transfer function applied to the input image intensity value.

Results

2.1.1

Q. 1

(a) Original Image (b) Transformed Image

Figure 1: Point Transform

Q. 2

(a) Fish Input Image (b) Bridge Input Image (c) Applied Mask Image

Figure 2: Mask Applied to Two input Images

Q. 3

(a) 1st Sample Input Image (b) Averaged Image

Figure 3: Averaging of 4 images, Reduced Noise

2.2.1

Q. 1

(a) Original Image

(b) Transformed Image

Figure 4: Contrast Stretching

Q. 2

(a) Original Image

(b) Transformed Image

Figure 5: Contrast Piece wise

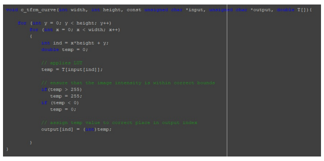
Q. 3

(a) Original Image

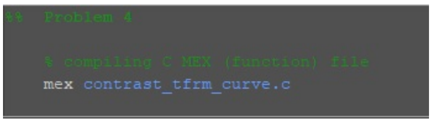
(b) Transformed Image

Figure 6: Contrast Highlight

Q. 4



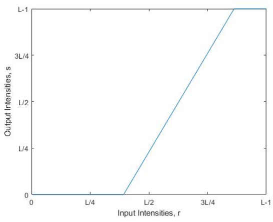
(a) Updated LUT Code



(b) LUT Compilation

Figure 7: LUT Integration for Contrast Stretching

Q. 5

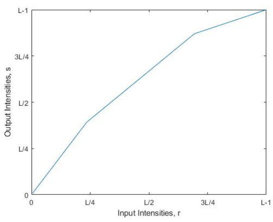


(a) LUT for Contrast Stretching

(b) Transformed Image

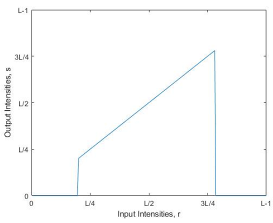
Figure 8: Contrast Stretching LUT

Q. 6



(a) LUT for Contrast Piece wise

(b) Transformed Image



(c) LUT for Contrast Highlight

(d) Transformed Image

Figure 9: Contrast Stretching and Contrast Highlight LUTs

Analysis

Q. 1

For alpha blending, we can use the equation

$$I_{cs}(x, y) = \alpha \cdot I_1(x, y) + (1 - \alpha) \cdot I_2(x, y)$$

where $\alpha = 1$ denotes a opaque object, $\alpha = 0$ denotes a transparent object and $0 < \alpha < 1$ denotes a semi transparent object. Since the mask for this example is a binary image only $\alpha = 1$ and $\alpha = 0$ are relevant.

Q. 2

Image intensity values that are under the specified rmin value will get reduced to zero. On the other hand image intensity values that are over rmax will be set to 255 the highest image intensity for an 8 bit image. For the image intensity range in between the two rmin and rmax values there will be a linear mapping of these values. This can be observed in figure 8(a) in the Results section.

Q. 3

One potential benefit of Look up tables is that they are less intensive to compute. intensity level transforms require you to calculate the function M x N times where M is the height of the image in pixels and N is the width of the image in pixels. With LUT tables the mapping function only needs to be carried out L times where L is the range of image intensities. Another benefit of LUT is once the table is calculated once it can be reused multiple times on images with the same image intensity range. One potential downside of this method would be if the image has a very large image intensity range and small resolution it may take longer to compute with LUT.

Q. 4

We can using contrast stretching to map from the higher 12 bit image to a lower 8 bit image using this equation

$$I_{cs}(x, y) = \frac{2^8}{2^{12}} \cdot I(x, y)$$

For most applications there should not be a problem because the human eye is not capable of discerning between a 12 bit and 8 bit image. For medical imaging, the case is different because it is possible that a machine learning algorithm might detect something with 12 bits of precision that it is not able to detect in an 8 bit mapping as some information is lost in the process. It should also be noted that these Image intensities be cast to double data type before implementing the equation and then cast back to an integer type afterwards.

Q. 5

Contrast stretching can only resolve detail that was originally there in the first place. if most of the image intensity values of the image are at 0 (the case for very dark images) then contrast stretching will not be able resolve any more detail to provide high contrast detailed image. Sensor noise would also produce a very grainy image and perhaps if the camera is able to take many photos in quick succession, it can create an averaged image like in section 2.1.1 which would be capable of reducing noise.

Conclusion

In this lab, the objective and subjective benefits of point operations and contrast adjustments were observed. One such example of a objective improvement would be how the averaging of multiple images produced a clearer image with less noise compared to the image quality of the input images. Similarly, an example of subjective improvement would be many of the contrast adjustments such as the piece-wise operation that would linearly adjust certain ranges of image intensity values based on the particular users preferences. While simple, Point operations and Contrast adjustments provide an opportunity tweak images such that information that is not readily apparent can become more easily recognized.

References

1. “Assignment 1 – Point Operations and Contrast Adjustment.” Assignment 1 – Point Operations and Contrast Adjustment, 2016.

2. Gonzalez, Rafael C., and Richard E. Woods. Digital Image Processing. 4th ed. New York, NY: Pearson, 2008.