**Project Title:  Image Processing Fundamentals**

**Project Number**: Project 2

**Course Number**: CEG 7850-01

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**Declaration Statement:**

I hereby declare that this Report and the Matlab codes were written/prepared entirely by me based on my own work, and I have not used any material from another Project at another department/ university/college anywhere else, including Wright State. I also declare that I did not seek or receive assistance from any other person and I did not help any other person to prepare their reports or code.  The report mentions explicitly all sources of information in the reference list. I am aware of the fact that violation of these clauses is regarded as cheating and can result in invalidation of the paper with zero grade. Cheating or attempted cheating or assistance in cheating is reportable to the appropriate authority and may result in the expulsion of the student, in accordance with the University and College Policies.

**Abstract:**

Image enhancement techniques were observed. The nonlinear transformation effects are shown at various values of the free parameter *c* for the logarithmic transform, and the additional free parameter γin the power-law transform. The results show that for Figure 3.8a from the text, a logarithmic transform with a value of c=100 sufficiently improved the image quality. However, this image enhancement technique did not improve the quality of Figure 3.9a from the text in any meaningful way. The use of power-law processing was more effective in enhancing Figure 3.9a. The most obvious improvement is observed with values of c=0.05 and gamma=1.5 applied to the lower-law processing technique. The greatest quality enhancement of Figure 3.8a results from the use of c=5.00 and gamma=0.75 but are less significant than the improvements observed after the logarithmic transform.

Histogram Equalization is employed to recreate the image enhancements demonstrated in Figure 3.20 from the textbook. There is an apparently direct correlation between image quality and uniformity seen in the histogram of an image. A local histogram equalization function was developed to process Figure 3.32a and reduce the noise within the very different local regions.

Additionally, it is shown that the solution to textbook problem 3.14 is a probability density function (PDF) of pz(z) = 1/(L-1) for 0<=r<=(L-1). The histogram processing procedure for finding a PDF is described and followed.

**Technical Discussion:**

The intensity logarithmic transformation applied to the images from Figure 1 (Figure 3.8a in the text) and Figure 2 (Figure 3.9a in the text) is equation 3-4 from the text and as follows:

S = c\*log( 1+r ) (eq. 1)

where s is the resulting pixel value, r is the original pixel value, and c is a constant that took the following values:

c = [1, 10, 50, 75, 100, 150]

The function developed in MatLab required that the pixel values be cast from unsigned 8-bit integers to floating point doubles, and back again. A loss is pixel value precission is likely, however it is negligable due to the desired unsigned 8-bit integer representation.

A close-up of a foot

Description automatically generated with low confidence

Figure 1: Original image taken from Figure 3.8a in text.

Diagram, engineering drawing

Description automatically generated

Figure 2: Original image taken from Figure 3.9a in text

The power-law transformation applied to the images from Figure 1 and Figure 2 is taken from equation 3-5 from the text and as follows:

S = c\*r^(gamma) (eq. 2)

where s is the resulting pixel value, r is the original pixel value, and c and gamma are constants that took the following values:

c =[0.05, 0.50, 1.0, 5.00, 10.0, 20.0, 0.05, 0.50, 1.00, 5.0, 10.0, 20.0]

gamma =[1.50, 1.25, 1.0, 0.75, 0.25, 0.67, 0.67, 0.25, 0.75, 1.0, 1.25, 1.50]

Again, the function developed in MatLab required that the pixel values be cast from unsigned 8-bit integers to floating point doubles, and back again. A loss is pixel value precission is likely, however it is negligable due to the desired unsigned 8-bit integer representation.

Histogram equalization is utalized to recreate the textbook image Figure 3.20 from Fig. 3(a-d). An equalized histogram (or color map) was aplied to the original image. Both the histogram and [R,G,B] color map are observed as well.

A close-up of several rolls of toilet paper

Description automatically generated with low confidenceA picture containing several

Description automatically generated

1. (b)

A close-up of several rolls of toilet paper

Description automatically generated with medium confidenceA close-up of several rolls of yarn

Description automatically generated with low confidence

1. (d)

Figure 3: Original Images used in the Histogram Equalization process. These images are taken from the text and are originally 8-bit unsigned integer images, the casting of which may result in precision errors through rounding or concatenation.

A local histogram equalization function was developed to apply the same histogram equalization algorithm mentioned previously to a smaller subset of elements. This allows for the acceptance of high contrast regions that may have hidden subtleties within a small area of the image, as in Figure 4.

A picture containing text, scene, room, gallery

Description automatically generated

Figure 4: This image is taken from Figure 3.32a of the text and contains an embedded image within the dark region and has noise applied to the pixel values.

A mask size of 3x3 was applied to the image. While there was no documented overlap parameter for the blockproc() function, a virtual function of histeq() was successfully passed into the aforementioned blockproc() function along with the specified mask size and lamda function name. This process was considerably more computationally intensive than the previous processing methods attempted. However, the processing time is still reasonable for the desired outcome.

There is no pertinent technical discussion to be had on the theoretical problem (3.15 from the text).

**Results Discussion:**

The logarithmic transformation applied to Fig. 1 are shown in Fig. 5 and the corresponding results to Fig. 2 are shown is Fig. 6, below.

A picture containing text

Description automatically generated

(a)

Figure 5: These images are the application of (eq. 1) to Fig. 1 with the values of (a) c = 1 , (b) c = 10,

1. c = 50, (d) c= 75, (e) c = 100, (f) c = 150 .

A picture containing qr code

Description automatically generated

Figure 6: These images are the application of (eq. 1) to Fig. 2 with the values of (a) c = 1 , (b) c = 10,

1. c = 50, (d) c= 75, (e) c = 100, (f) c = 150 .

To my judgement, the best image quality resulting from the transformations applied in Fig. 5 and Fig. 6 are for c = 100, as seen in Fig. 7. However, it is quite apparent that this method of image enhancement is not effective for Fig. 2. This is most likely because the values of the image are saturated, and therefore have a much more uniform distribution that a logarithmic function would not be able to differentiate as well as if the image initially had high contrast, as in Fig. 1.

A picture containing text, invertebrate

Description automatically generated

Figure 7: Logarithmic Transformation applied to Fig. 1 with a value of c = 100

The power-law transformation was also applied to both Fig. 1 and Fig. 2 and results in the images in Fig. 8 and Fig. 9, respectively.

A picture containing text, music, piano

Description automatically generated

Figure 8: Power-law transformation applied to Fig. 1 with the corresponding values of

c = [0.05, 0.50, 1.0, 5.00, 10.0, 20.0, 0.05, 0.50, 1.00, 5.0, 10.0, 20.0]

and gamma = [1.50, 1.25, 1.0, 0.75, 0.25, 0.67, 0.67, 0.25, 0.75, 1.0, 1.25, 1.50]Qr code

Description automatically generated

Figure 9: Power-law transformation applied to Fig. 2 with the corresponding values of

c = [0.05, 0.50, 1.0, 5.00, 10.0, 20.0, 0.05, 0.50, 1.00, 5.0, 10.0, 20.0]

and gamma = [1.50, 1.25, 1.0, 0.75, 0.25, 0.67, 0.67, 0.25, 0.75, 1.0, 1.25, 1.50]

The power-law transformation was more successful than the logarithmic transformation at enhancing the image in Fig.2 as shown in Fig. 12, below. There was also successful image enhancement of Fig. 1 using the power-law, as seen in Fig 11. It is noteworthy that Fig. 12 is much more improved than Fig. 11 in reference to the logarithmic transformation (Fig. 5 and Fig. 6 respectively).

A close-up of a blob

Description automatically generated with low confidence

Figure 10: Power-law Transformation applied to Fig. 1 with a value of c = 5.0 and gamma = 0.75

Diagram, engineering drawing

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Figure 11: Power-law Transformation applied to Fig.2 with a value of c = 0.05 and gamma = 1.50

Figure 3.20 from the text was recreated in Fig. 12, below.

A picture containing text, screenshot

Description automatically generated

Figure 12: Recreation of Figure 3.20 from the text using images from Figure 3(a-d)

I have also added an addition plot, the RGB plot to Fig 12., this can be seen in Fig. 13. The RGB is a probability distribution of pixel values equal to or less than the given value. This shows this contrast of the image. From experimentation and Fig 13, it is clear to see that the closer an image’s RGB distribution is the a linear function of slope 1, the better the image quality.

Diagram

Description automatically generated

Figure 13: Recreation of Figure 3.20 from the text using images from Figure 3(a-d) with an appended RGB plot to represent the probability of a pixel of equal or lesser value being selected, if randomly drawn.

A local Histogram Equalization function was developed an applied to Fig. 14. This function had a 3x3 mask and resulted in revealing the embedded patterns that were initially hidden in the image. These results are seen in Fig. 15.

A picture containing text, scene, room, gallery

Description automatically generated

Figure 14: The original image Figure 3.15 from the text

A picture containing text, electronics

Description automatically generated

Figure 15: The post-processing Image resulting from a local histogram equalization function applied to Fig. 14.

The following is the derived solution from Problem 3.14 from the text.

Diagram

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Where the solution steps, 1-4 are referring to the procedure describe on page 143 of the text.

**Conclusion:**

This project has revealed some subtleties of effective use-cases for differing image processing techniques.