DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

IMAGE ENCHANCEMENT WITH RESPECT TO VIEWING DISTANCE AND IMAGE CONTENTS

by

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November, 2009

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IMAGE ENCHANCEMENT WITH RESPECT TO VIEWING DISTANCE AND IMAGE CONTENTS

A Thesis Submitted to the
Graduate School of Engineering and Sciences of Dokuz Eylül University
In Partial Fulfillment of the Requirements for the Degree of Master of Science
in Electrical and Electronics Engineering

by

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November, 2009
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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **“IMAGE ENHACEMENT WITH RESPECT TO VIEWING DISTANCE AND IMAGE CONTENT”** completed by **YUSUF EMRE ÜĞE** under supervision of **ASST. PROF. DR. GÜLDEN KÖKTÜRK** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ACKNOWLEDGMENTS

At the first place, I would like to thank my advisor Asst. Prof. Dr. Gülden Köktürk for her supervision, advice, and guidance from the very early stage of this research work. Above all and when most needed, she provided me encouragement and support in various ways. Lastly, I thank my family for their never ending support and motivation.

Yusuf Emre ÜĞE

IMAGE ENHANCEMENT WITH RESPECT TO VIEWING DISTANCE AND IMAGE CONTENTS

ABSTRACT

Algorithms usually used for image enhancement are contrast, histogram equalization (HE) and sharpness. Generally, these algorithms are controlled with fixed parameters. If parameters used for these algorithms are not defined well, problems like detail loss in bright/dark areas of image and artificial sharpness will occur in image. For this purpose, image enhancement algorithms contrast, HE and sharpness have been changed with respect to both image content and viewing distance in order to get better results than traditional techniques. In this thesis, effects of contrast, HE and sharpness algorithms have been explained separately and compared with traditional techniques. At last part; images, which is applied image enhancement with respect to image content and viewing distance, has been compared with original images.

Keywords: Image enhancement, histogram equalization, contrast, sharpness, viewing distance, image content.

İZLEME MESAFESİ VE RESMİN İÇERİĞİNE GÖRE GÖRÜNTÜ İYİLEŞTİRME

ÖZ

Görüntü iyileştirmede yaygın olarak karşıtlık, histogram eşitleme ve keskinlik gibi algoritmalar kullanılır. Genelde bu algoritmalar sabit parametreler ile kontrol edilir. Eğer kullanılan bu parametreler iyi belirlenmezse resmin aydınlık karanlık bölgelerinde detay kaybı, yapay bir keskinlik gibi problemlere neden olabilir. Bu amaçla, görüntü iyileştirme kullanılan karşıtlık, histogram eşitleme ve keskinlik algoritmalarını hem resmin içeriğine göre hem de izleme mesafesine göre değiştirerek geleneksel görüntü iyileştirme yöntemlerinden daha iyi sonuç alınabilinir. Bu çalışmada karşıtlık, histogram eşitleme ve keskinlik algoritmalarının ayrı ayrı resme etkisi anlatılmış ve geleneksel yöntemler ile karşılaştırmıştır. Çalışmanın son bölümünde resmin içeriğine ve izleme mesafesine göre görüntü iyileştirmesi yapılmış resimler ile resimlerin orjinal halleri karşılaştırılmalı olarak gösterilmiştir.

Anahtar sözcükler: Görüntü iyileştirme, karşıtlık, histogram eşitleme, keskinlik, izleme mesafesi, görüntü içeriği.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

The purpose of image enhancement is to improve the perception of information in images for humans. Different techniques and algorithms can be used for image HE equalization, color management, gamma correction are most popular techniques to enhance image. Generally, they use fixed parameters. In example, de–gamma is used to make image brighter. If the image is too bright, it will cause detail loss in bright areas. So than, using de-gamma function in darker images it will cause better results. On the other hand, image enhancement must improve perception of image for human's eyes which also depends on viewing distance. In this case, different settings for different viewing distance may cause better results in image enhancement. Strong settings may cause artifacts in image enhancement; however artifacts seem less as viewing distance increases. As a result of these, using different algorithm techniques with respect to image content and viewing distance will enhance image.

In this thesis; contrast, HE and sharpness algorithms have been used with respect to image content and viewing distance for image enhancement. The contents of this are as follows:

In chapter 2, there is overview of general contrast algorithm in image enhancement. Existing methods for image contrast enhancement focus mainly on the properties of the image to be processed while excluding any consideration of the observer characteristics. Adaptive algorithm always produces adequate contrast in the output image, and results in almost no ringing artifacts even around sharp transition regions, which is often seen in images processed by conventional contrast enhancement techniques (Ji, Sundareshan &. Roehrig, 1994). Instead of standard contrast algorithms, changing the response of contrast algorithm with respect to image distance and histogram enhances contrast level of image without saturation artifacts. Also, adaptive contrast algorithm compared with typical contrast algorithm in this chapter.

In chapter 3, definition of HE is written. Purpose of HE in image enhancement is explained with examples. Adaptive histogram equalization (AHE) is applied to image with respect to image histogram width to prevent artifacts of standard HE. AHE technique takes control over the effect of traditional HE so that it performs the enhancement of an image without making any loss of details in it. AHE partitions the image histogram based on local minima and assigns specific gray level ranges for each partition before equalizing them separately. (Al-Wadud, Kabir & Chae, 2007).

In chapter 4, usage of adaptive sharpness algorithm with respect to viewing distance and advantages of adaptive sharpness algorithm depending viewing distance is explained. The effect of different sharpness filter types in digital image enhancement is searched with Hentschel & La Hei, (1999). The multiple filter system has advantageous over the single filter systemsince it allows adaptive peaking based on the video contents (Ling P. L., Znamenskiy S., 2009). Using different sharpness filter types and coefficients depending to viewing distance cause better sharpness in image enhancement.

In chapter 5, results of image enhancement with respect to image content and viewing distance algorithm are shown with comments.

Finally, conclusions are given in Chapter 6. Brief comments on applied methods and results are summarized.

CHAPTER TWO

CONTRAST ALGORITHM

2.1 Overview of Contrast Algorithm

Image enhancement aims improving the visual appearance of digital images. Most image enhancement techniques, often as defined by narrowly defined criteria, are designed for improving the visual appearance of an image. So, it is necessary to remember that enhancement is often an arbitrary exercise what is successful for one purpose may be suitable for another image for another purpose.

Contrast is ratio of maximum and minimum brightness values present on an image. Contrast enhancement is needed because digital data usually have brightness ranges that do not match capabilities of human visual system, or those of photographic films. It is usually necessary to rescale image brightness to ranges that can be accommodated by human vision, photographic films, and computer displays, because for analysts to view the full range of information conveyed by digital images.

For example, maximum possible range of pixel values is 0 to 255 (8 bits), but the display can show only the range of values 0 to 63 (6 bits), then the image will have poor contrast, and important detail may be lost in the values that can not be shown on the display as shown at Figure 2.1. (Campbell, Taylor & Francis, London, 2002).

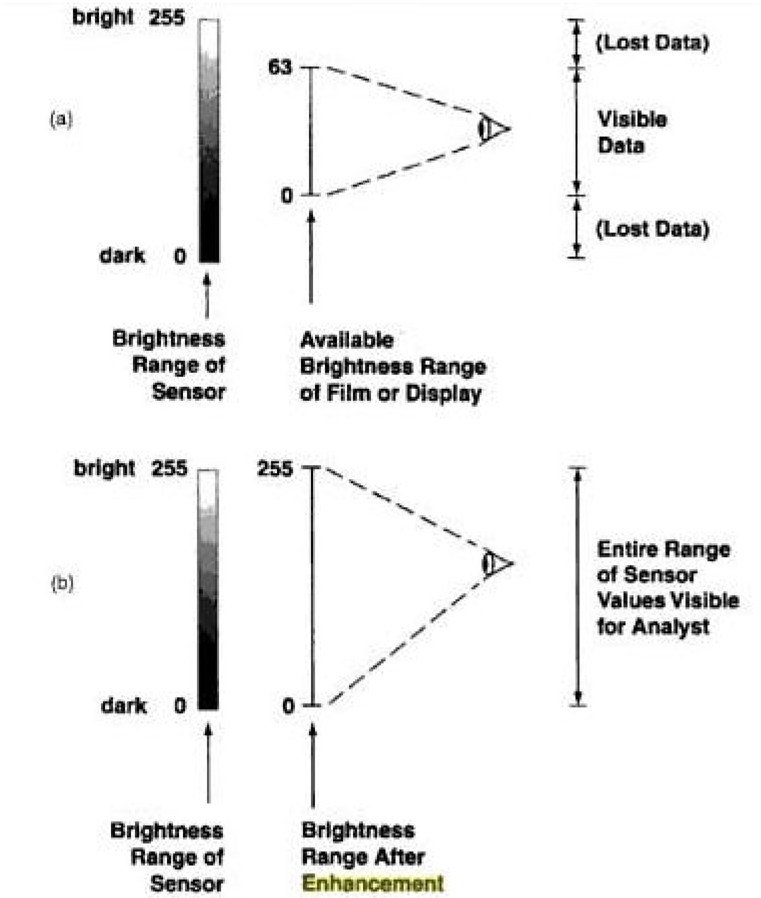


Figure 2.1 Loss of visual data in display of digital image

This lookup table or LUT is used for a display brightness value for each stored value and thus does not require actually modifying any of the values stored in memory for the image. Linearly expanding the contrast range by assigning the darkest pixel value to black, the brightest value to white, and each of the others to linearly interpolated shades of grey makes the best use of the display and enhances the visibility of features in the image.

A typical display can show 256 different levels of grey, and many of them can produce colors with the same 256 brightness values for each of the red, green, and blue components to produce a total of 16 million different colors.16 million different colors that such a system is capable of displaying, and even the 256 levels of grey, are far more than the human eye can detect. Under good viewing conditions, human eye can typically see only a few tens of different grey levels and hundreds of distinguishable colors.

Generally, it can be described the manipulation terms of a transfer function relating the stored brightness value for each pixel to a displayed value. If this relationship is one-to-one, there will be a unique displayed value for each stored value. Sometimes it is good to use transfer functions which are not one-to-one: several stored values are displayed with the same brightness value, so that other stored values can be spread further apart to increase their visual difference. (Russ, 1998)

Contrast enhancement algorithm manipulates each pixel value in original image to generate new set of values in the full range of 256/1024 (8 bits/10 bits). Linear stretch is typical contrast enhancement algorithm, which converts the original digital values into a new distribution, uses defined new minimum and maximum values. Linear stretch then matches the old minimum to the new minimum and the old maximum to the new maximum values.

However, this linear stretch may different effect at different gray levels. It can be called piece-wise linear stretch which means that the original brightness range was divided into segments before each segment was stretched individually. (Campbell, Taylor & Francis, 2002)

As shown in Figure 2.2, contrast algorithm effects on 3 different segments. 0 used for pure black and 65535 defined for pure white. Meanings of segments shown in Figure 2.2 are like this: Red line is for dark part, blue line for average part, yellow line for bright part of image. Green line is used to show response of original image without contrast algorithm. It means that original pixel value is not altered by contrast algorithm.

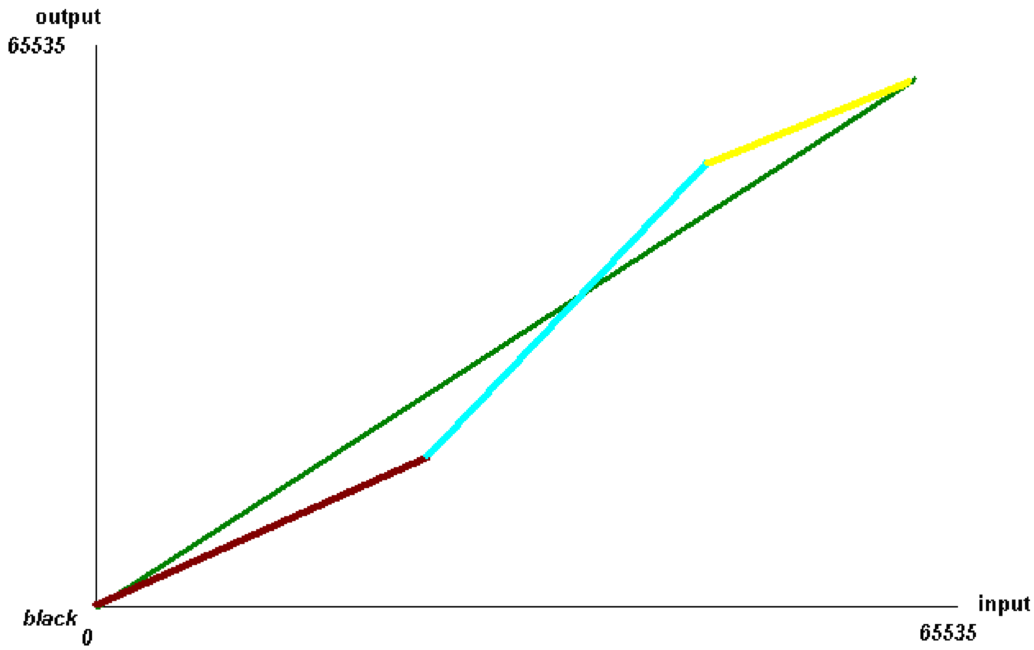


Figure 2.2 Typical contrast algorithm with 3 segments

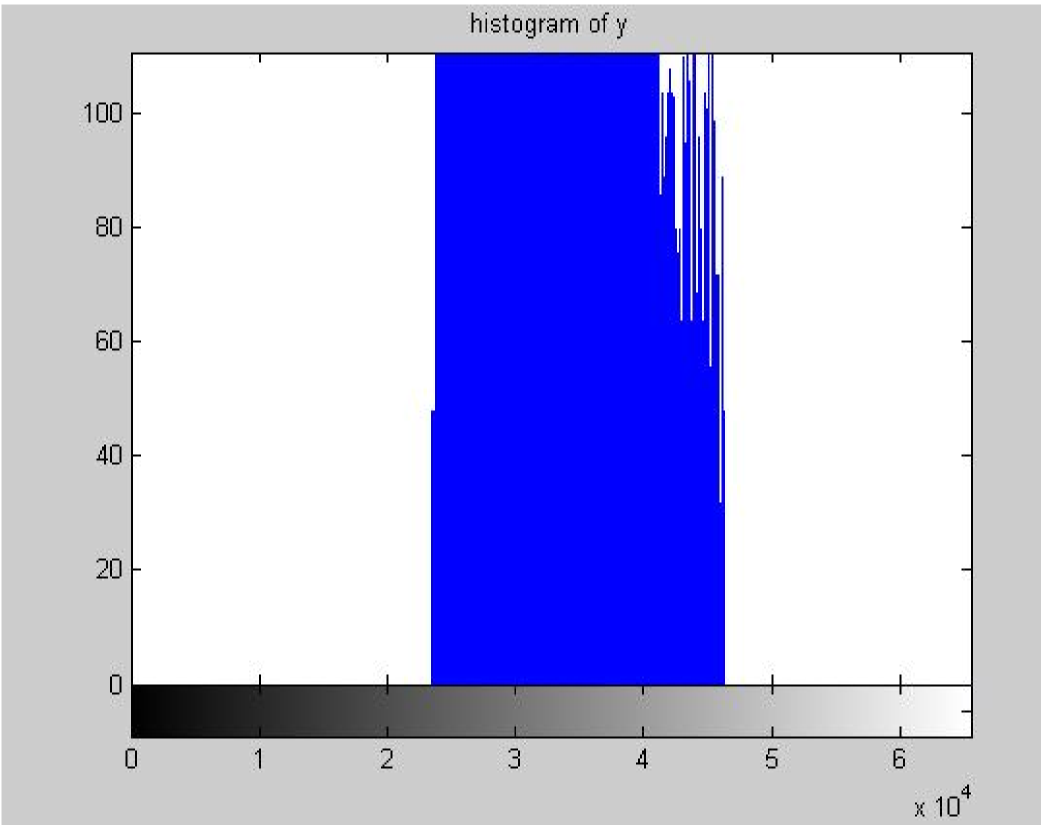
2.2 Adaptive Contrast Algorithm with respect to Image Content and Viewing Distance

Typical contrast algorithm had been altered original pixel luminance level with specific response. This response can be different with respect to luminance of pixel. The response of contrast algorithm can be linear or summation of different line segments as shown in Figure 2.2. Contrast of image is the ratio of maximum brightness of image to minimum brightness of image. So, decreasing minimum brightness level of image and increasing maximum brightness level of image will increase image contrast. As shown Figure 2.2, typical contrast algorithm decrease the brightness in dark area of image (red line in Figure2.2) and increase the brightness in bright area of image (yellow line in Figure2.2).

Unlike typical contrast algorithm, adaptive settings with respect to image content and viewing distance had been improved image contrast enhancement. Instead of using fixed regions in contrast algorithm, adaptive dark, mid and bright regions had been decided for contrast algorithm. Histogram of image was used to define these three regions. 65536 histogram levels were decided to get better resolution and clear information about pixel luminance values. However; these regions are selected with respect to image histogram. As shown at Figure 2.3, typical average image histogram starts at 23491 and stops at 46292. This histogram information shows that image has no too dark and too bright pixels which are nearby 0 and 65535. If typical contrast algorithm was used in this image, there would not be good enhancement for this image. Because, image has not too dark and bright pixels and typical contrast algorithm enhance image in dark and bright regions. On the other hand; dark, mid and bright regions had been selected adaptively with respect to image histogram to get better contrast enhancement.

In this thesis, histogram start and stop points are determined with trade off pixel value. There could be some noise and artificial pixels due to compression of image that could cause too dark and bright pixels in image. So, pixels numbers up to five pixels were ignored to determine histogram start/stop points.

(a)



(b)

Figure 2.3 An average image (a) and its y histogram (b)

After determination of histogram start/stop points, determined histogram region was divided by three to get dark, mid and bright regions for that image. The division of determined histogram was done 30% for dark region, 40% for mid region and 30% for bright region as shown Figure 2.4. Red and yellow lines show separation between these three regions. Similar division method can be applied without determining histogram start/stop points. In this case, there would not be any dark and bright regions for this average image. We could get dark and bright regions for every image by determining histogram start/stop points. Dark, mid and bright regions were shown as brighter areas in Figure 2.5.

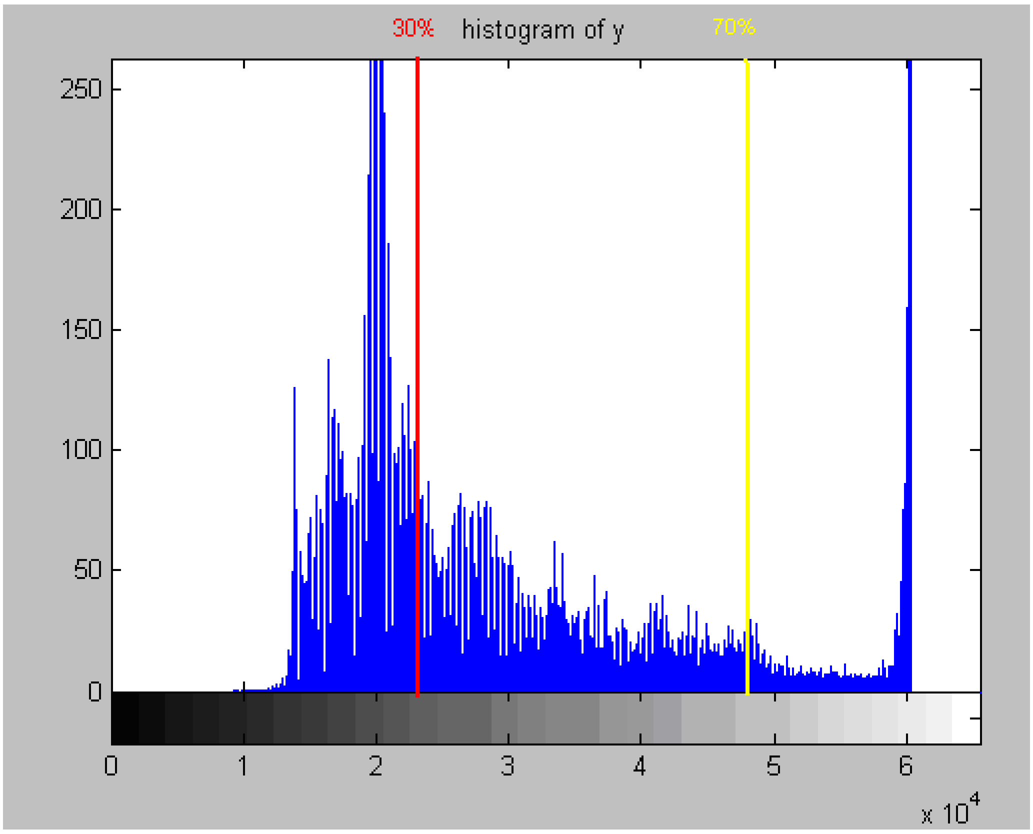
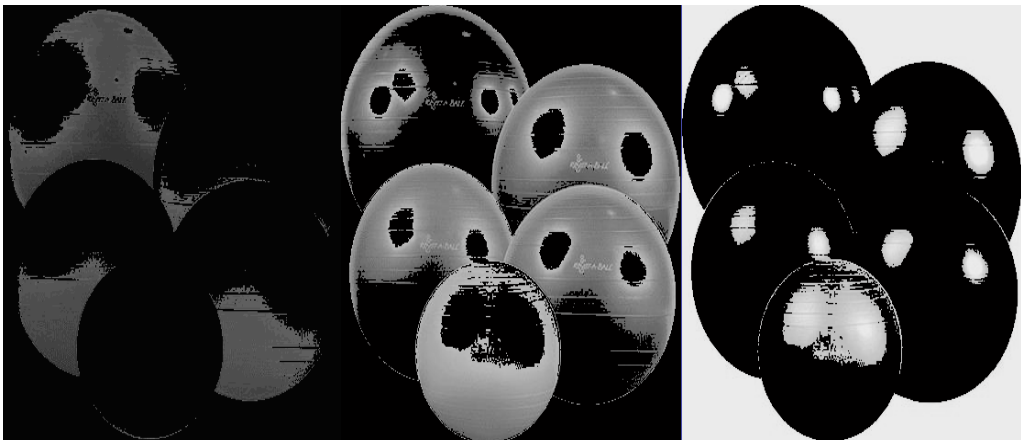


Figure 2.4 Division of determined histogram



(a) (b) (c)

Figure 2.5 Dark (a), mid (b) and bright (c) regions in image

Contrast algorithm had been used viewing distance and image histogram as parameter. Three separate gains were applied to dark, mid and bright regions. Contrast gains applied to these regions are called left gain, mid gain and right gain in this thesis. As shown in histogram Figure 2.4 dark regions are left, bright regions are right hand side. These gains can be also assumed that transfer functions for dark, mid and bright regions. As viewing distance increases, left gain and right gain parameters increases. It means that dark region become darker and bright region becomes brighter as viewing distance increases. General contrast feeling will be increased with respect to the viewing distance. However, image brightness information had also been used as feedback of contrast algorithm to enhance contrast better. After determining histogram start/stop points, image histogram is divided by three fixed regions. These regions are used for how many pixels are located in dark, mid and bright area. The difference is these three regions are fixed and adaptively changed with respect to image. The pixels which have brightness value between 0%-30% are locating at dark area. The pixels with brightness value between 30%-70% are in the mid area and pixels with brightness value between 70%-100% are in bright area. For example, image in Figure 2.3 has almost no pixels at dark and bright area. Pixels are locating in mid area for this image.

The ratio of numbers of pixels at dark region to total number of pixels in image is called dark ratio in this thesis. Left gain also depends on dark ratio of image. As image becomes darker, dark ratio increases and left gain decreases. If the image is too dark, left gain will decreases too much and dark pixels becomes brighter instead of making dark pixels darker. At the first sight, it could be assumed that it would reduce contrast, however details in the dark region would be more visible. The results of algorithm are shown and explained in Section 2.3. Equation of the left gain is given in Equation 2.1.

$$\text{Leftgain} = 1 - (0.007)*\text{distance} + (0.1)*\text{ dark ratio} \qquad (2.1)$$

Typical contrast algorithm has another trade off problem as losing detail at dark areas. For example, there is detail in very low brightness levels like around 5% white. If strong left gain applied to dark pixels of image, detail would not be seen in image. Because dark pixels becomes darker and black level will be saturated in example around 5% of white and then detail at 5% white can not be seen in image. Another fixed region is used to overcome this black saturation problem. This region checkes histogram of image between 0%-10% of white in very dark area. If there is some pixels in 0%-10% of white, contrast algorithm detects these pixels and halfen left gain applied to these pixels to overcome more saturation as shown in below equation as leftgain10.

$$\text{leftgain10} = 1 - (0.0035)*\text{distance} + (0.05)*\text{ dark ratio} \tag{2.2}$$

Behavior in dark area is exactly same as bright area. Right gain also depends on dark ratio of image. Ratio of numbers of pixels at bright region to total number of pixels in image is called bright ratio in this thesis. As image becomes brighter, bright ratio increases and right gain decreases. Also there is a fixed region check pixels between 90%-100% white to prevent saturation in bright area. Half amount of right gain will be applied pixels between 90%-100% white levels. Equations for bright area are given below:

$$\text{Right gain} = 1 + (0.007)*\text{distance} - (0.1)*\text{ bright ratio} \tag{2.3}$$

$$\text{rightgain90} = 1 + (0.0035)*\text{distance} - (0.05)*\text{ white ratio} \tag{2.4}$$

Contrast algorithm uses difference between bright pixels (70%-100% white) and dark pixels (0%-30% white) in mid area. The ratio of difference amount of pixels between bright and dark area to total amount of pixel in image is called white to black difference ratio in this thesis. Mid gain altered image adaptively with respect to difference between bright and dark region ratio to overall pixel number. If number of pixels in bright area is more than number of pixels in dark area, Equation 2.5 is used to compensate image. If else, Equation 2.6 is used. The effect of mid gain is lower than left and right gain because it is just used to compensate image.

$$\text{Midgain} = 1 - \text{abs }(0.05 * \text{w2b\_dif\_ratio}) \tag{2.5}$$

$$\text{Midgain} = 1 + \text{abs }(0.05 * \text{w2b\_dif\_ratio}) \tag{2.6}$$

In adaptive contrast algorithm, viewing distance and histogram information are used as feedback of algorithm. There are four fixed regions to get information about dark and bright pixels in order to control contrast left, mid and right gain parameters.

0%-10% and 90%-100% white area pixels are used to prevent saturation in too dark and too bright area. 0%-30% and 70%-100% white area pixels are used to have knowledge about dark and bright pixels in image. On the other hand, regions; which are affected by left, mid and right gain; are adaptively selected with respect to image histogram start/stop points.

2.3 Comparison between Adaptive Contrast Algorithm and Typical Contrast Algorithm

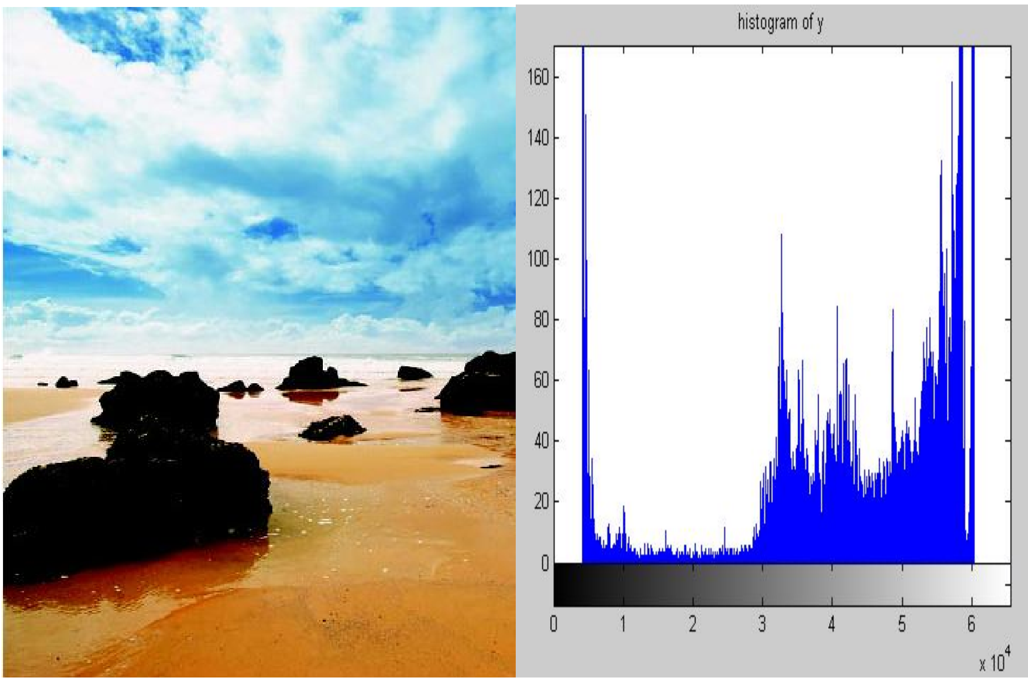
The most visible advantage of adaptive contrast algorithm is preventing saturation in image. Also deepness felling is improved with respect to typical contrast algorithm. In typical contrast, fixed left and right gain is applied to image for fixed dark and bright regions. As explained in Part 2.2, adaptive contrast algorithm has adaptive left/mid/right gain parameters with respect to image content and viewing distance. In this comparison, typical contrast left and right gain parameters are used like adaptive contrast algorithm viewing distance at 10 meters. Adaptive contrast algorithm has lots of advantages as:

- In adaptive contrast algorithm, dark, mid and bright regions are changing with respect to image histogram start/stop points. In typical contrast algorithm these regions are fixed. For example, there will not good enhancement in too dark and bright images with typical contrast algorithm.

- Left/right gain parameters changes with respect to image histogram and viewing distance. In typical contrast algorithm, these parameters are all fixed.

- Mid gain parameter changing with respect to image histogram for compensating image brightness level at mid region.

- In adaptive contrast algorithm, very dark/bright areas are checked and reduced contrast applied to that specific region to prevent saturation in black and white.



(a) (b)

Figure 2.6 Original image (a) and its histogram (b)

(a) (b)

Figure 2.7 Contrast enhanced images with typical (a) and adaptive contrast algorithms (b)

As shown in Figure 2.6, original image has pixels less than 10% and more than 90% white levels. For these too dark and bright regions, adaptive contrast algorithm reduces contrast gain to overcome saturation problem. There is not any feedback algorithm in typical contrast algorithm so saturation problem occurs in typical contrast algorithm. This artifact can be seen in Figure 2.7, saturation problem occurs on clouds. However, there is not saturation and brightness distribution smother in adaptive contrast algorithm.

Figure 2.8 Original image

Figure 2.9 Image after typical contrast algorithm

Figure 2.10 Image after adaptive contrast algorithm

Image at Figure 2.8 has too dark and bright pixels. When typical contrast algorithm applied to image, white saturation occurred in left side of image. White coffee cup and gray background saturated so detail loss in bright area. Right edge of coffee cup can not be seen because of saturation in Figure 2.9. On the other hand, no saturation occurs in adaptive contrast algorithm because of 90%-100% white pixel feedback functions as shown Figure 2.10

Image in Figure 2.11 is cut from gray scale ramp pattern in medium gray levels. As seen its histogram, image has narrow histogram which will be in middle region of typical contrast algorithm. Typical contrast algorithm affected in fixed two regions which are including histogram levels 0-19670 and 45875-65535. Typical contrast algorithm has no effect on this image. Because, histogram of image is not in these fixed regions, that is affected by typical contrast algorithm, as seen at Figure 2.12. On the other hand, these effected regions are chosen with respect to image histogram. Image histogram is divided by three with its histogram start/stop points. As seen at Figure 2.11, image histogram almost starts at 35000 and stops at 45000. Histogram width of this image is 10000. As mentioned before in Chapter 2.2, dark region is this image is first quarter of histogram width which is between 35000 and 37500. Mid region of this image is including second and third quarters of histogram width which are between 37500 and 42500. Lastly, bright region of this image is fourth quarter of histogram width which is between 42500 and 45000. As a result of these, adaptive contrast algorithm had worked on any images with adaptively selected regions with respect to image histogram. Image and its histogram after adaptive contrast algorithm are shown in Figure 2.13. Dark, mid and bright regions can be seen in image and its histogram. Dark pixels become darker and bright pixels become brighter as a result of this adaptive contrast algorithm with respect to image histogram.

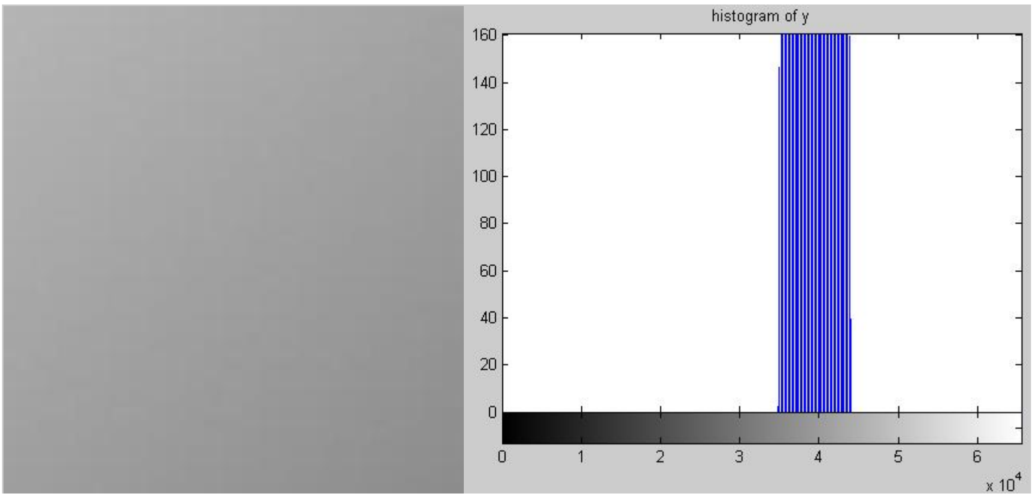


Figure 2.11 Original image with its histogram

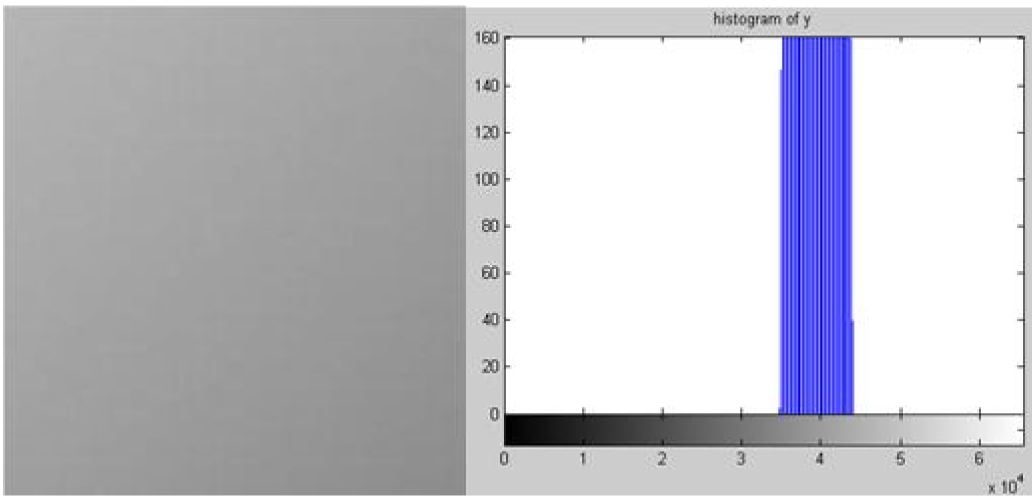


Figure 2.12 Image and its histogram after typical contrast algorithm

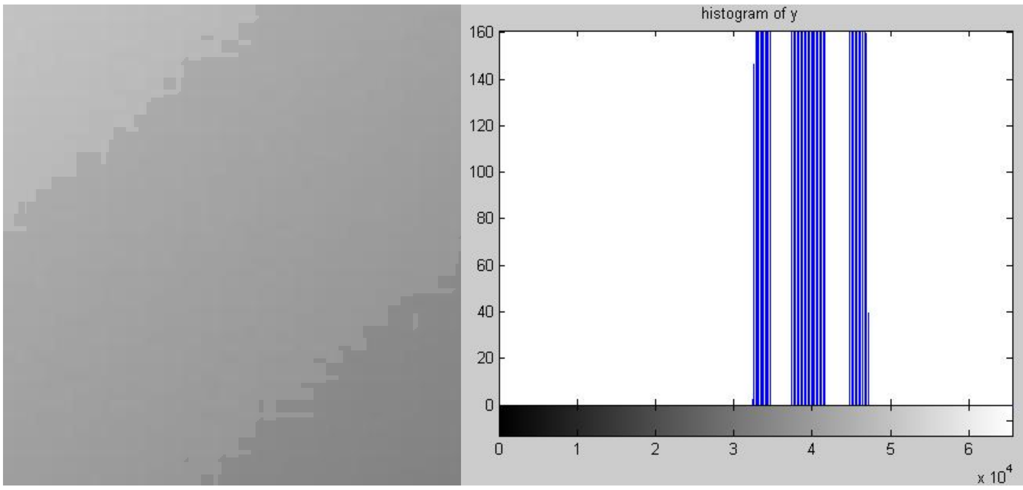


Figure 2.13 Image and its histogram after adaptive contrast algorithm

By determining start/stop points of the histogram, adaptive contrast algorithm will affect any image. As seen in Figure 2.13, adaptive contrast algorithm affects on gray scale image which has very limited histogram. As result of contrast algorithm, discontinuous transition may occur in histogram. Adaptive histogram equalization algorithm is also applied to compensate discontinuous transition in image histogram.

CHAPTER THREE

HISTOGRAM EQUALIZATION

3.1 HE in Image Processing

HE is an image processing technique which is used for adjusting the gray scale of the image so that gray level histogram of the input image is mapped onto a uniform histogram. The aim of HE is to obtain a uniform histogram for output image. (Russ, 1998)

For a monochromic image, the intensity histogram *h (i)* is defined to be number of pixels in the image with intensity equal to *i*.

$$h(i) = \begin{cases} 1 & \text{if } f(x,y) = i \\ 0 & \text{otherwise} \end{cases} \tag{3.1}$$

Consider an image containing several large objects with nearly uniform intensities; the corresponding histogram would have several peaks near the mean intensities of these objects. We must apply a mapping function which increases the separation of intensities near peaks in the histogram to enhance contrast within these objects. This will widen and lower the peaks in the histogram and make small intensity variations within these objects more visible. The histogram of output image will be flattened, if this contrast stretching process is applied to all peaks in the initial histogram. Hence, this contrast enhancement approach is called histogram equalization.

A mapping function is defined as *m (i)* which yields a flat histogram to implement HE. The first step is calculating the cumulative histogram *H (i),* which is defined to be number of pixels in the image with intensity less than or equal to *i.* As shown Equation 3.2 H *(i)* can be easily obtained by numerically integrating *h (i)*:

$$H(i) - \sum_{j=0}^{i} h(j) \tag{3.2}$$

When a particular *h (i)* is flat the corresponding *H (i)* will be linear. Thus, to perform HE, we need to make the cumulative histogram linear. This can be accomplished using the following mapping function:

$$m(i) = D_{min} + D_{max}\frac{H(i)}{H(I_{max})} \tag{3.3}$$

When the objects of interest in an image all lie in known range of intensities [*I min* ... *I max*]. There is little need to display image pixels which lies outside of this range. Pixels whose intensities are greater than *I max* can be mapped to maximum display value *D max.* Similarly, Pixels whose intensities are below *I min* can be mapped to minimum display value *D min.* When output pixels are computed using *g(x, y) = m (f (x, y)),* where *g (x)* is equalized version of *f (x)* via transfer function *m*. The range of display intensities used more effectively, making small image variations easier to see.

To amplify contrast even further, local properties of an image must be considered. One way to do this is to divide the image into small regions and calculate the *h (i), H (i),* and *m (i)* for each region separately. Enhancement can be then be done in each region separately or by interpolating region histograms to obtain a mapping function *m (i)* for each point in the image. The amount of enhancement performed at each point is determined by size of the regions used to calculate *h (i)* and *H (i)*. Smaller regions yield greater enhancement. This contrast enhancement approach is called AHE.

When HE is applied to each of color channels in an image is often distorted. Therefore, it is preferable to convert the image to YUV space and to apply enhancement only to image intensity Y. The image can then be transformed back to RGB space for display. (Sangwine & Home, 1998)

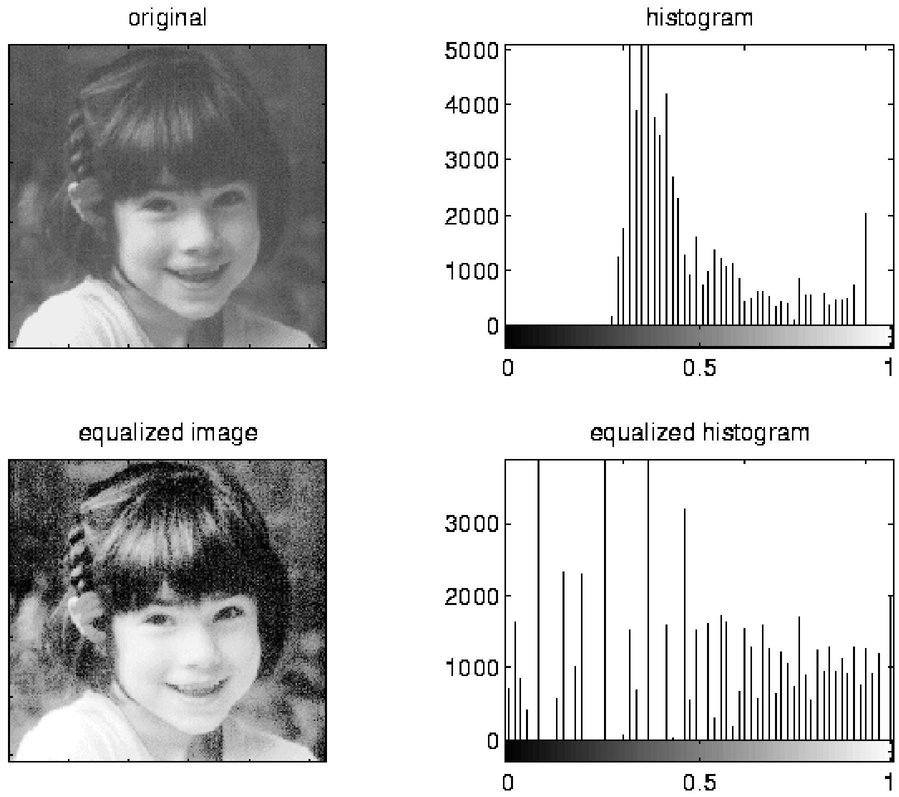


Figure 3.1 The original image and its histogram, and the equalized versions. Both images are quantized to 64 grey levels.

As shown in Figure 3.1, original image does not include black pixel. After HE, image contrast increases histogram of original image spread out to black and white regions. On the other hand, general shape of original image's histogram is distorted as seen equalized histogram. This distortion can be also seen in equalized image. So, AHE must be used to prevent distortion in image.

3.2 Adaptive Histogram Equalization (AHE)

AHE is used to improve contrast of images. AHE differs from normal HE. AHE computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image. Normal HE basically uses a single histogram for an entire image. AHE is considered an image enhancement technique capable of improving an image's local contrast, bringing out more detail in the image. However, AHE also can produce significant noise. A generalization of AHE called contrast limited adaptive histogram equalization

(CLANHE) was developed to address the problem of noise amplification. Actually, it was originally developed for medical imaging and has proven to be successful for enhancement of low-contrast images such as portal films. (http://en.wikipedia.org/wiki/Adaptive_histogram_equalization)

The CLAHE algorithm divides into parts to the images into contextual regions and applies the HE to each one. This evens out the distribution of used grey values and thus makes hidden features of the image more visible. The full grey spectrum is used to express the image.

CLAHE is an improved version of AHE. Both of them overcome the limitations of standard HE.

In MATLAB, there are commands like “histeq” and “adapthisteq” to perform HE. Basic HE is done with “histeq” command. As an alternative to using “histeq”, you can perform CLAHE using the adapthisteq function. While “histeq” works on the entire image, “adapthisteq” operates on small regions in the image, called tiles. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches a specified histogram. After performing the equalization, “adapthisteq” combines neighboring tiles using bilinear interpolation to eliminate artificially induced boundaries.

To avoid amplifying any noise that might be present in the image, you can use optional parameters of “adapthisteq” command to limit the contrast, especially in homogeneous areas. For this purpose, there is “ClipLimit” parameter in “adapthisteq” command to prevent noise and distortion in smooth areas of image. “Clip Limit” is real scalar in the range [0 1] (default 0.01) that specifies a contrast enhancement limit. Higher numbers result in more contrast. (MATLAB Help: histeq and adapthisteq). “Clip Limit”' parameter is changed with respect to histogram width of original image to get better results at HE.

Image in Figure 3.2 is generally bright image as seen its histogram. When standard HE applied to this image with “histeq” command in MATLAB, big distortion occurs in image as seen on Figure 3.3. AHE must be used to reduce this distortion. AHE works locally and general response of image histogram does not change too much. So less distortion occurs in equalized image as seen Figure 3.4. However, small distortion occurs because of fixed clip limit as seen red ellipse in Figure 3.4. Using adaptive clip limit in AHE overcomes this distortion problem as seen Figure 3.5. ClipLimit parameter in AHE algorithm depends on histogram width of image. In this thesis, image histogram width divided into 5 parts as histogram width of image is:

-below 10000
-between 10000 and 20000
-between 20000 and 30000
-between 30000 and 40000
-between 40000 and 50000
-more than 50000

Clip limit is changed with respect to histogram width of image. As histogram width of image increases, clip limit decreases to prevent distortion in image.

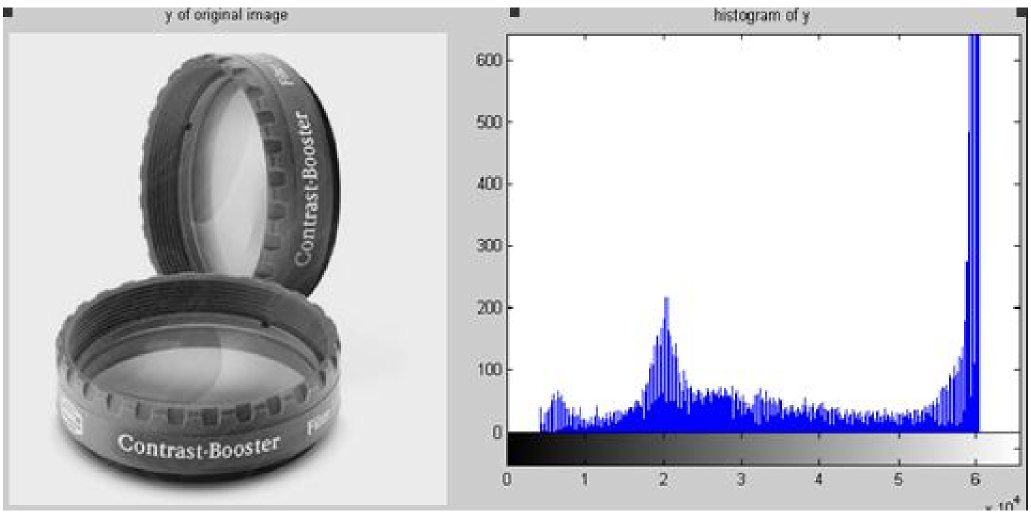


Figure 3.2 Original image and its histogram

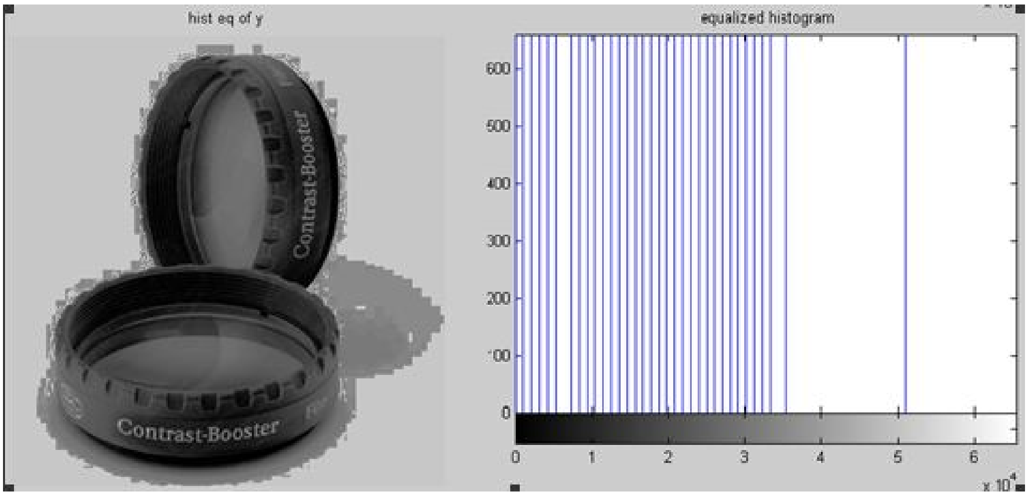


Figure 3.3 Standard HE applied to image and its histogram with “histeq” command

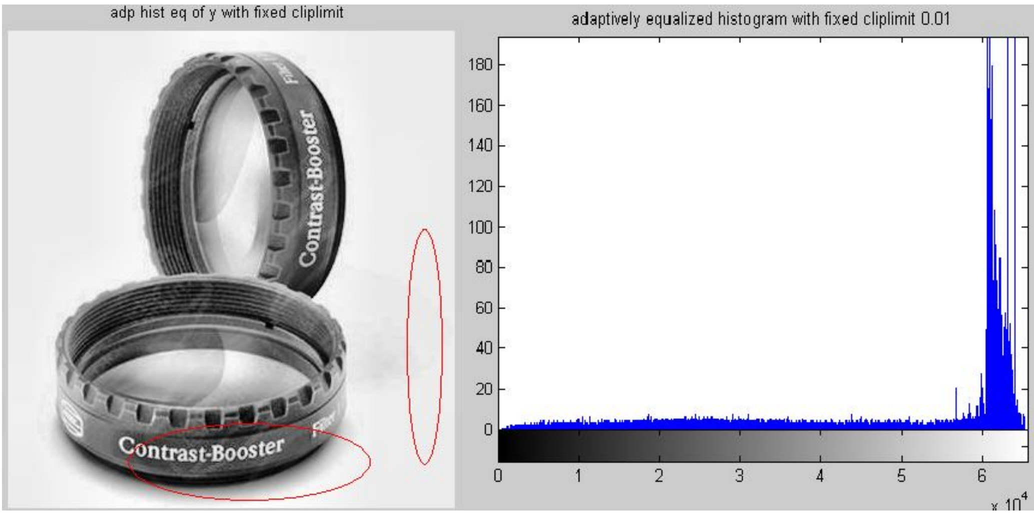


Figure 3.4 AHE applied to image and its histogram with “Adapthisteq” command by fixed clip limit 0.01

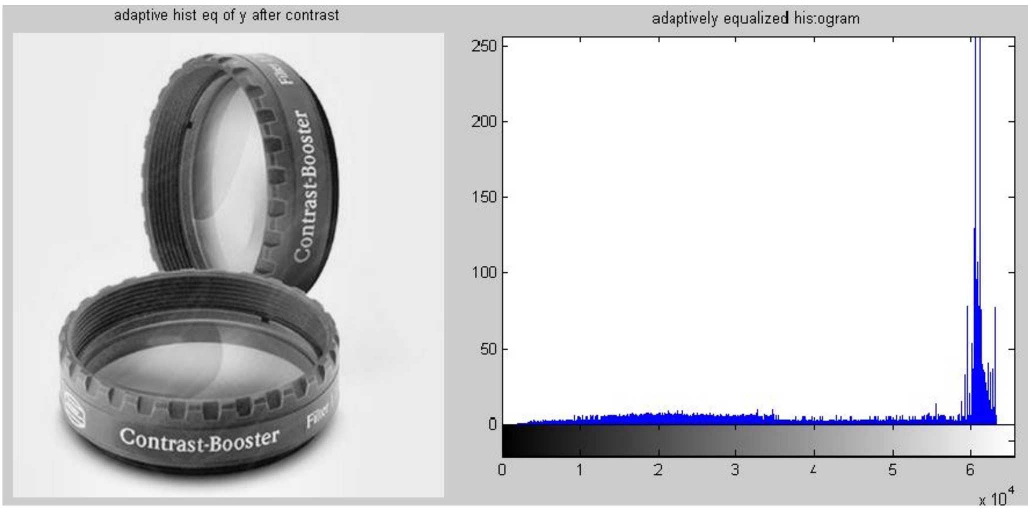


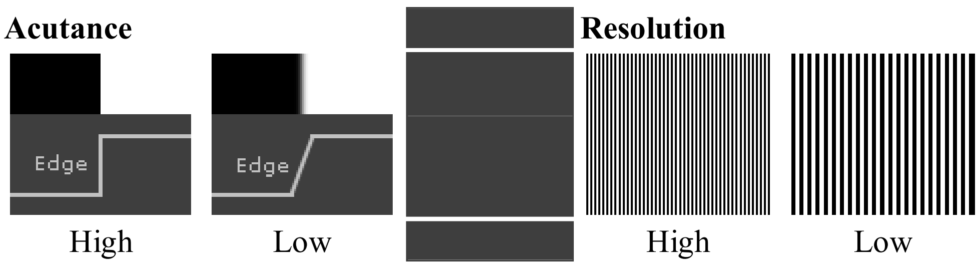
Figure 3.5 AHE applied to image and its histogram with “adapthisteq” command by clip limit depending to histogram width of image

CHAPTER FOUR

SHARPNESS ALGORITHM

4.1 Sharpness in Image Enhancement

Sharpness defines the clarity of detail in an image, and can be a valuable creative tool for emphasizing texture. Proper photographic and post-processing technique can go a long way towards improving sharpness, although sharpness is ultimately limited by your camera equipment, image magnification and viewing distance. There are two fundamental factors contribute to the perceived sharpness of an image: resolution and acutance.



(a) (b)

Figure 4.1 Acutance (a) and Resolution (b)

Acutance uses for how quickly image information transitions at an edge, and so high acutance results in sharp transitions and narrower edges. Resolution describes the camera's ability to distinguish between closely spaced elements of detail, such as the two sets of lines shown in Figure 4.1.

For digital cameras, resolution is limited by your digital sensor, whereas acutance depends on both the quality of your lens and the type of post-processing. Acutance is the only part of sharpness which is can be changed after the shot has been taken, so acutance is what can be enhanced when you digitally sharpen an image.

Photos require both high acutance and resolution to be sensed as sharp. The following Figure 4.2 is shown effect of acutance and resolution in image.

Figure 4.2 Effects of Acutance and Resolution in Image

Sharpness also depends on other factors which affect our perception of resolution and acutance. Noise in image is usually seen as distortion in image, however small amounts can actually increase the appearance of sharpness as shown in Figure 4.3

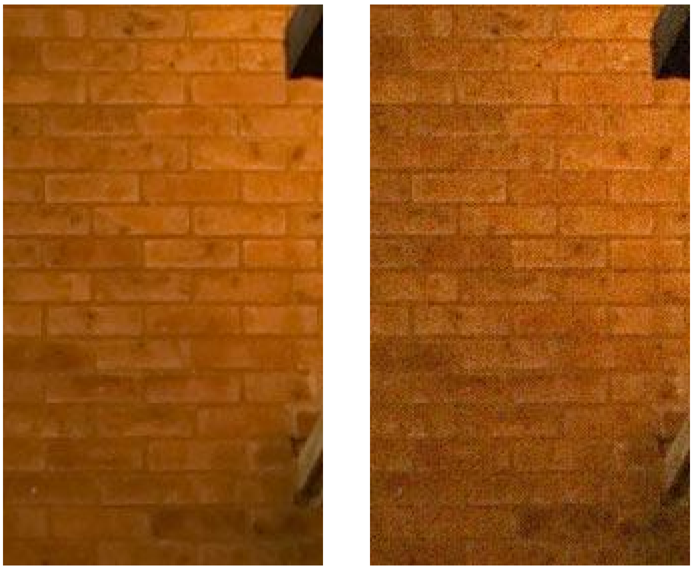


Figure 4.3 Effect of noise in sharpness

Although both images have not been sharpened, the image at left in Figure 4.3 appears softer and less detailed. Noise in image can be both very fine and have a very high acutance tricking the eye into thinking sharp detail is present.

Sharpness also depends on viewing distance. Images which are designed to be viewed from further away, such as posters or billboards, may have much lower resolution than fine art prints in a gallery because of far viewing distance. Image still looks sharp. Because perception of eye decreases as viewing distance increases. (*http://www.cambridgeincolour.com/tutorials/sharpness.htm*)

In this thesis Spatial filtering is used to implement sharpness. Spatial filtering is done via neighborhood processing which consists of defining center point *(x,y)*; performing an operation which involves only the pixels in a predefined neighborhood about that center point; letting the result of that operation be the response of the process at that point; and repeating the process for every in the image. Each pixel in image has own neighborhood. The process of moving the center point creates new neighborhoods. If the computations performed on the pixels of the neighborhoods are linear, the operation is called linear spatial filtering; otherwise it is called nonlinear spatial filtering.

The drawing in Figure 4.4 shows a 3x3 mask and corresponding image neighborhood directly under it. The neighborhood is shown displaced out from under the mask for ease of readability.

The mechanics of linear spatial filtering are illustrated in Figure 4.4. The process consists simply of moving the center of the filter mask w from point to point in an image, f. At each point (x, y), the response of the filter at that point is sum of products of the filter coefficients and the corresponding neighborhood pixels in the area spanned by filter mask. For a mask size m x n, we assume typically that $m = 2a + 1$ and $n = 2b + 1$, where a and b are nonnegative integers. It certainly is not a requirement; working with odd-size masks is more useful. Because they have a unique center point, other-wise it will not easy to define center point. (Gonzalez, Woods & Eddins, 2003)

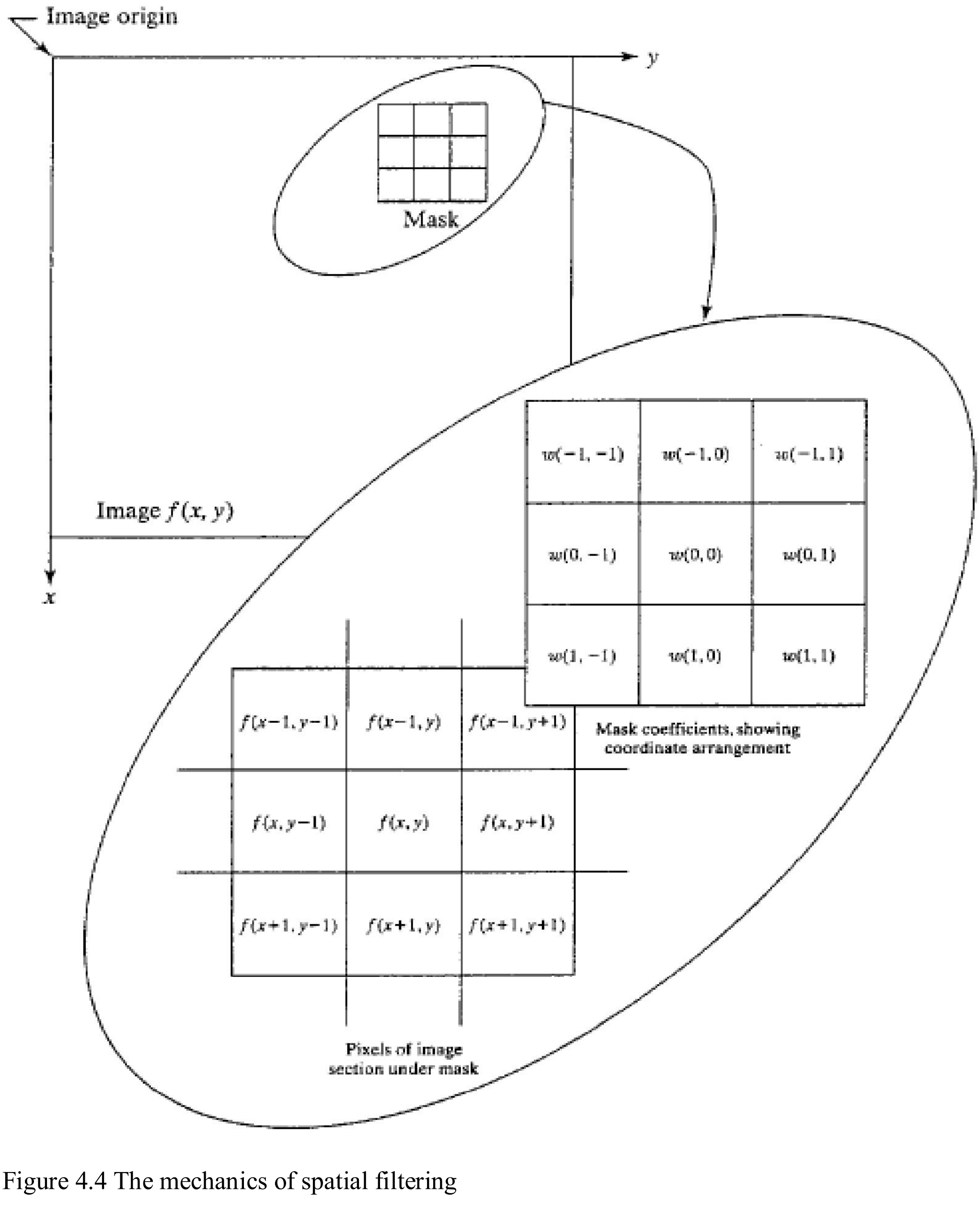


Figure 4.4 The mechanics of spatial filtering

In MATLAB the usages of "imfilter" by enhancing an image with Laplacian filter. The Laplacian of an image *f (x, y)* is defined as

$$\nabla^2 f(x,y) = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2} \tag{4.1}$$

Commonly used digital approximations of second derivatives are

$$\frac{\partial^2 f}{\partial x^2} = f(x+1,y) + f(x-1,y) - 2f(x,y) \tag{4.2}$$

And

$$\frac{\partial^2 f}{\partial x^2} = f(x,y+1) + f(x,y-1) - 2f(x,y) \tag{4.3}$$

So than

$$\nabla^2 f = |f(x+1,y) + f(x-1,y) + f(x,y+1) + f(x,y-1)| - 4f(x,y) \tag{4.4}$$

This expression can be implemented at all points *(x, y)* in an image by convolving the image with the following spatial mask:

$$\begin{matrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{matrix}$$

An alternate definition of the digital second derivatives takes into account diagonal elements, can be implemented using the mask

$$\begin{matrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{matrix}$$

The linear operations of interest consist of multiplying each pixel in the neighborhood by a corresponding coefficient and summing the results to obtain the response at each point *(x, y)*.

As shown at Figure 4.5, there is a smooth transition dark region to bright region at the edge of letter ‘T’ in blue area. The original image brightness level can be seen at like S shape curve. The ideal sharpness will be done with very strict transition in edges. On the other hand, sharpness algorithm causes overshoot/undershoot while making this transition narrower. Dark pixel becomes darker and bright pixels becomes brighter during transition which are called undershoot and overshoot in image enhancement. Strong sharpness filters may cause these overshoot/undershoot effect on image, however visibility of overshoot/undershoot will be decreased as viewing distance increased. That is why; strong sharpness can be applied to image as the viewing distance increased as explained at Section 4.2 adaptive sharpness algorithm.

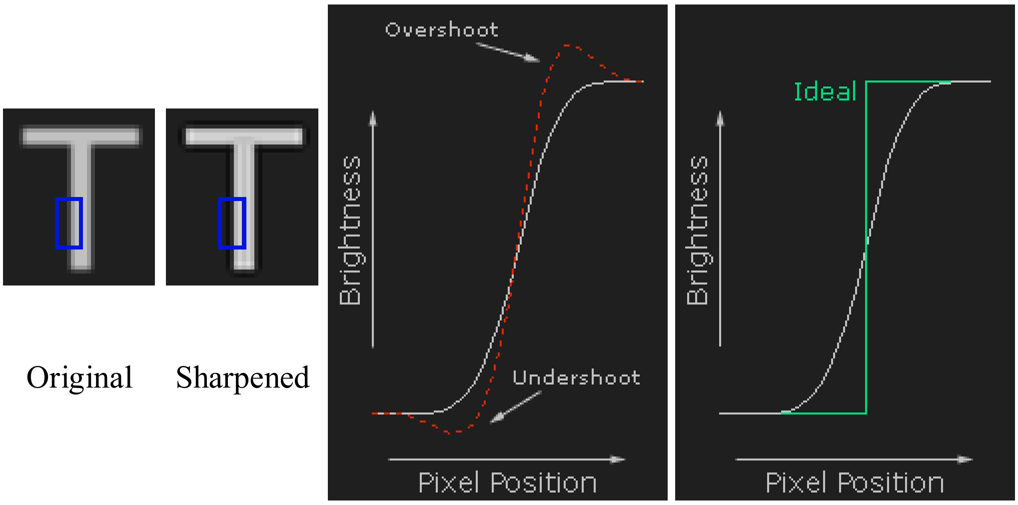


Figure 4.5 The response of sharpness algorithm in image

4.2 Adaptive Sharpness Algorithm

Adaptive sharpness algorithm changes the response and the coefficients of the sharpness filter mask with respect to viewing distance. The size of mask used for sharpness algorithm is also important for the algorithm. 3 x 3 sharpness filter mask will not be useful, because this mask consider only one pixel around center pixel. On the other hand, optimum transition can not be done as mask size increased like 7 x 7 sharpness filter mask. Because, sharpness filter mask will effect in 7 pixels in vertical and horizontal directions which can cause smooth transition in narrow edges.

So, 5x 5 sharpness filter mask is decided in this thesis. One pixel neighborhood of this sharpness filter mask is including high band filter coefficients and neighborhood with two pixels is used as low band coefficients. The ratio between coefficients of high band to low band will define amount of overshoot/undershoot and transition of edges. Also, these coefficients are multiplied with general gain to increase sharpness with respect to viewing distance.

Three different sharpness filter type is used with respect to viewing distance in this thesis. General idea is using strong sharpness filter mask as viewing distance increases. For this purpose, coefficients of high band (one pixel neighborhood of center pixel) is selected is higher with respect to low band (two pixel neighborhood of center pixel) as viewing distance increases. Transition of edge will be narrow and more overshoot/undershoot will occur in image as viewing distance increases.

Also, there is another coefficient depending to viewing distance in adaptive sharpness algorithm. All three different sharpness filter mask have general sharpness parameter ‘k’ which increases with respect to viewing distance. As a result of these, both sharpness filter mask type and gains for the sharpness filter mask are changing with respect to viewing distance to get optimum result in sharpness.

Strong sharpness may cause artificial image with ringing, halo, overshoot/undershoot effects. As the viewing distance increases, these effects become less visible and sharpness feeling becomes more.

Sharpness algorithm is used after contrast algorithm. These ringing, halo, overshoot/undershoot effects will be exaggerated by contrast algorithm if contrast algorithm is used after sharpness algorithm.

Adaptive sharpness algorithm is also affected on Y domain as adaptive contrast and HE algorithms. Unless sharpness is applied on Y domain, there will be coloring around edges as shown Figure 4.5. As a result of difference between red and gray, cyan coloring can be seen around edges. So, adaptive sharpness algorithm affected on Y domain and merged with color components U and V.

Soft Original | Normal RGB Sharpening (Visible Cyan Outline) | Luminance Sharpening

Figure 4.5 The response of sharpness algorithm in image

General multiburst pattern can be used to see effect of sharpness in image enhancement. As shown at Figure 4.6, original multiburst pattern consists of vertical lines from low frequency to high frequency. After adaptive sharpness algorithm applied to image, mid and high frequency vertical lines becomes more visible as result of sharpness algorithm. Viewing distance is selected 10 meter to see effect of adaptive contrast algorithm easily.

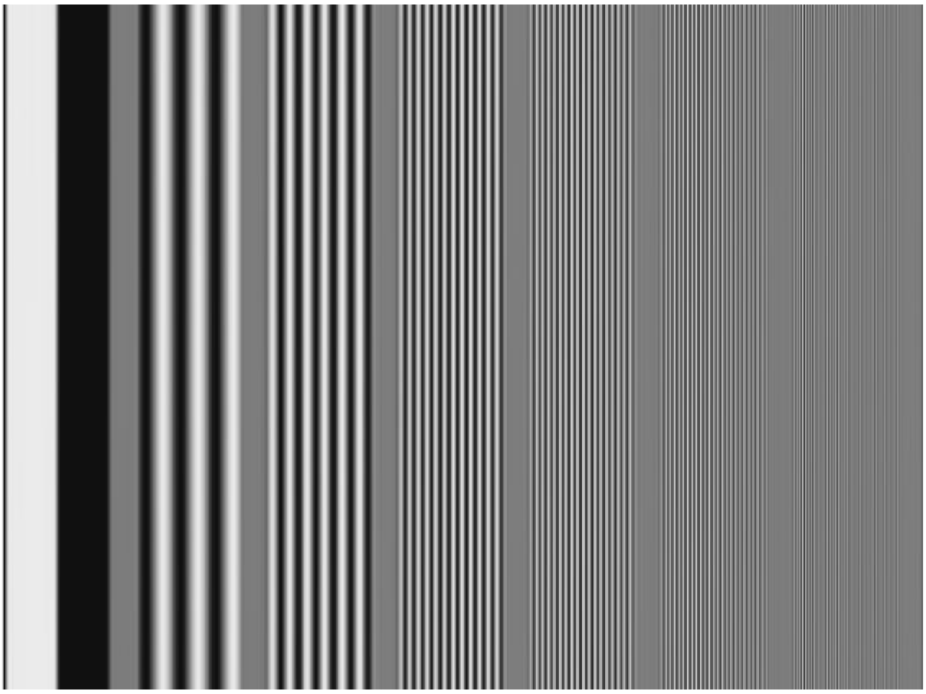


Figure 4.6 Original multiburst image

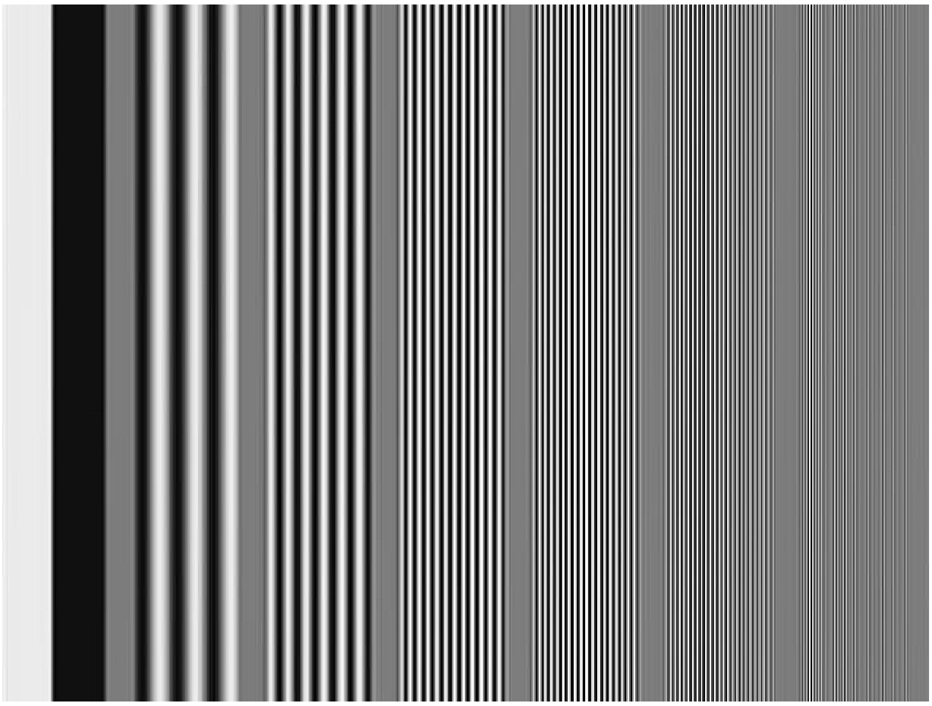


Figure 4.7 Sharpened multiburst image

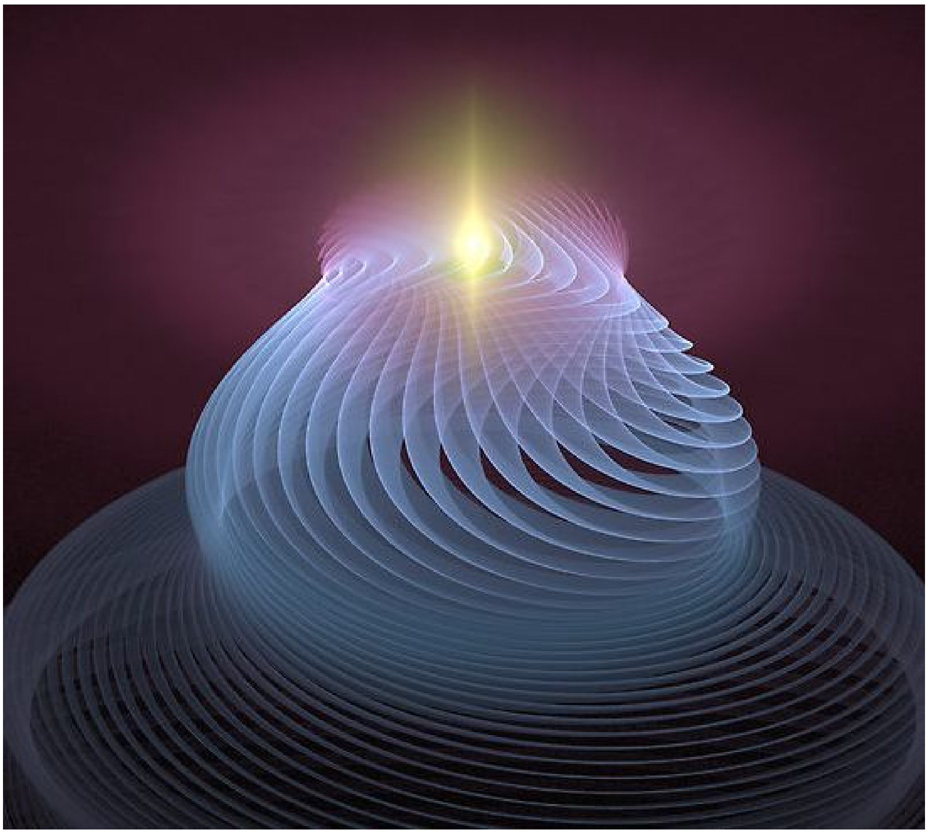


Figure 4.8 original image

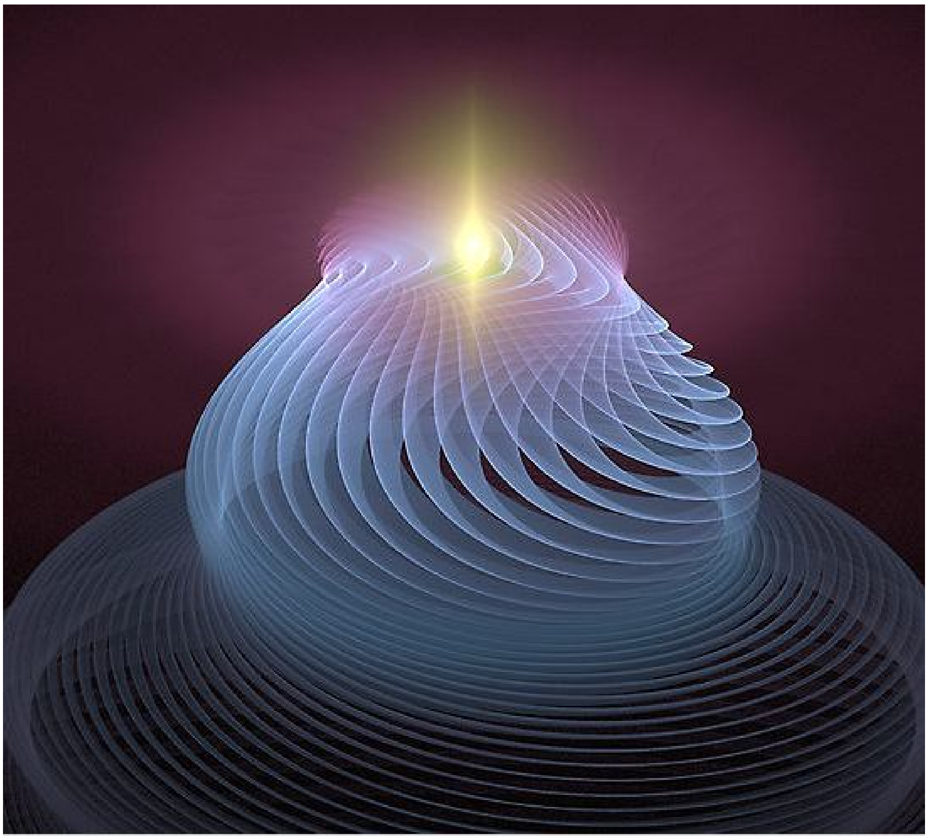


Figure 4.9 Adaptive sharpness applied image for viewing distance 1 meter

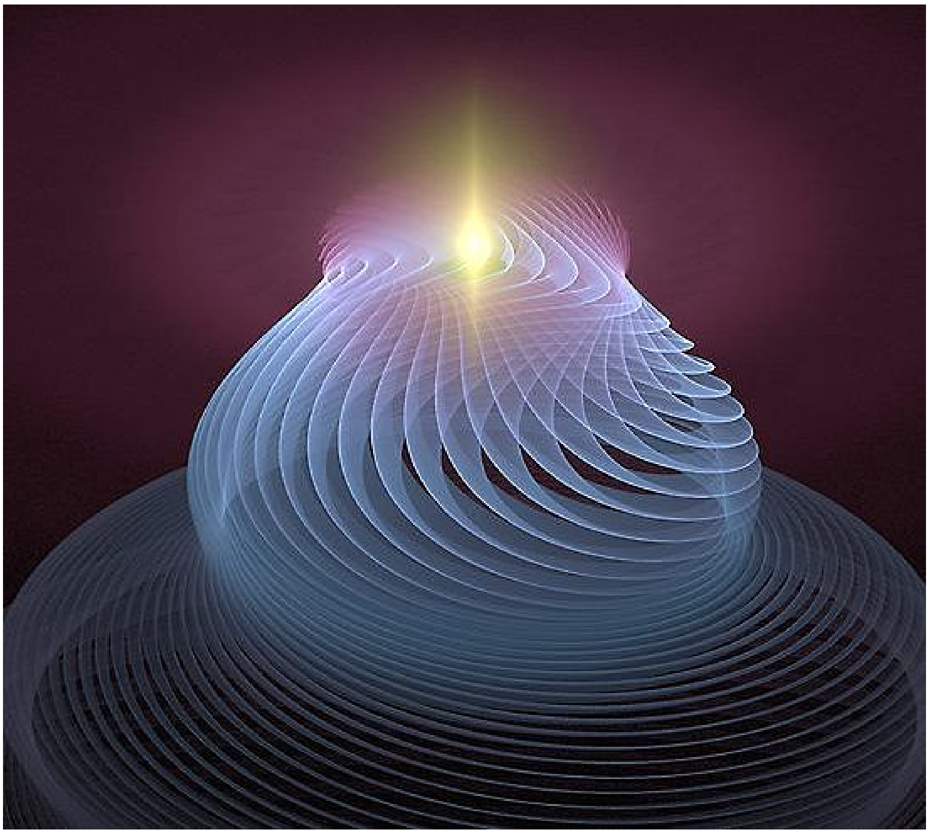


Figure 4.10 Adaptive sharpness applied image for viewing distance 5 meters

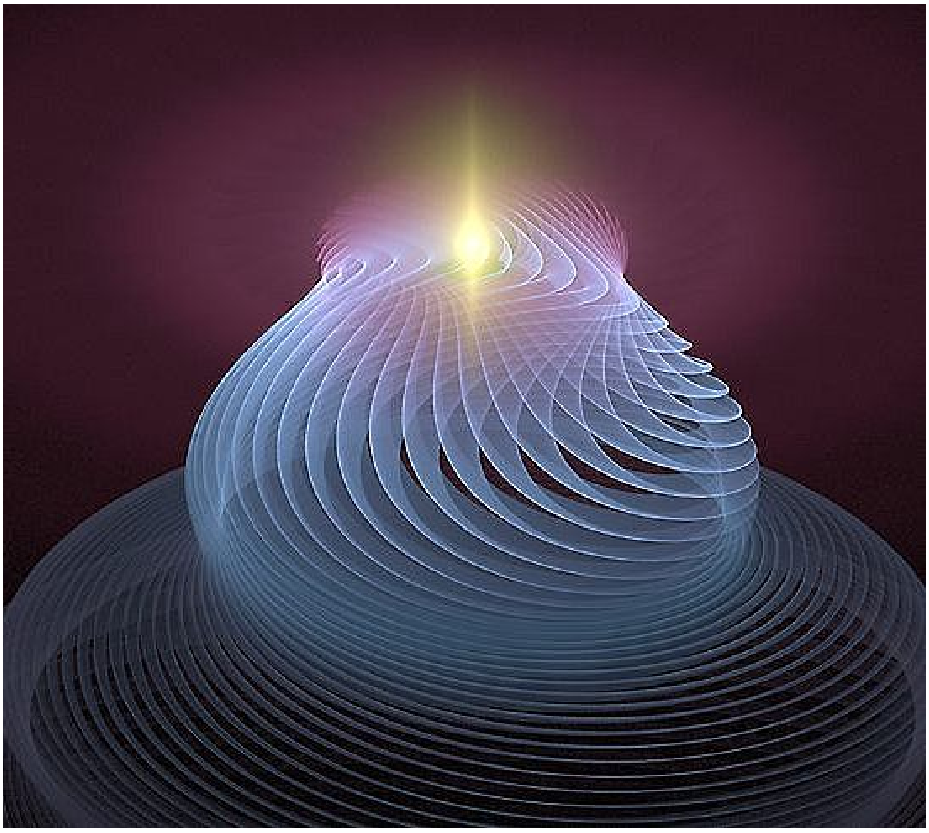


Figure 4.11 Adaptive sharpness applied image for viewing distance 10 meters

The response of adaptive sharpness algorithm can be seen from Figure 4.8 to Figure 4.11. Adaptive sharpness algorithm response is changing with respect to viewing distance. Viewing distance is defined with near distance for 0-3 meters; mid distance for 3-6 meters and far distance for more than 6 meters in this thesis. Sharpness filter mask type and coefficients are changed depending to viewing distance.

Original image is shown at Figure 4.8. After adaptive sharpness algorithm applied to original image with viewing distance 1 meter is shown at Figure 4.9. Smooth sharpness applied to original image because of close viewing distance 1 meter. Overshoot/undershoot, ringing effects can disturb human eye in this close viewing distance. So, reduced sharpness applied to image for close viewing distances up to 3 meters.

As shown at Figure 4.10, stronger adaptive sharpness algorithm applied to original image rather than Figure 4.9. As viewing distance increases, type and coefficients of sharpness filter mask changes. General sharpness gain parameter ‘k’ is changing with respect to viewing distance and filter masks for near, mid and far viewing distances are below:

$$k = 0.5 + 0.2 * distance \tag{4.5}$$

Adaptive sharpness mask for near distance up to 3 meters:

*h0_3 = [0 0 -0.035*k 0 0 ; 0 -0.045*k -0.06*k -0.045*k 0 ; -0.035*k -0.06*k 1+0.56*k -0.06*k -0.035*k ; 0 -0.045*k -0.06*k -0.045*k 0 ; 0 0 -0.035*k 0 0]* (4.6)

Adaptive sharpness mask for mid distance up to 3 meters:

*h3_6 = [0 0 -0.03*k 0 0 ; 0 -0.04*k -0.07*k -0.04*k 0 ; -0.03*k -0.07*k 1+0.56*k -0.07*k -0.03*k ; 0 -0.04*k -0.07*k -0.04*k 0 ; 0 0 -0.03*k 0 0]* (4.7)

Adaptive sharpness mask for near distance up to 3 meters:

*h6_ = [0 0 -0.025*k 0 0 ; 0 -0.04*k -0.075*k -0.04*k 0 ; -0.025*k -0.075*k 1+0.56*k -0.075*k -0.025*k ; 0 -0.04*k -0.075*k -0.04*k 0 ; 0 0 -0.025*k 0 0]* (4.8)

Filter type also changing with respect to viewing distance close, mid and far. There are three impendent filter band used in sharpness filter mask as shown at Table 4.1.

Table 4.1 adaptive sharpness filter mask

0	0	Band 3	0	0
0	Band 2	Band 1	Band 2	0
Band 3	Band 1	center pixel	Band 1	Band 3
0	Band 2	Band 1	Band 2	0
0	0	Band 3	0	0

Band 1 is one pixel neighborhood of center pixel in vertical and horizontal directions. Band 2 is one pixel neighborhood of center pixel in diagonal direction.

Band 3 refers two pixels neighborhood of center pixel in vertical and horizontal directions. Other neighborhood pixels are ignored in this thesis, because they do not affect sharpness of the image too much. All these three bands depending to viewing distance with sharpness gain parameter 'k'. Also coefficients of each band are changing with viewing distance near, mid and far. As the viewing distance increases, coefficients of band 1 become higher with respect to band 2 and band 3 to get stronger sharpness. As shown at Tables 4.2, Tables 4.3 and Tables 4.4; both sharpness filter mask and its coefficients are changing with respect to viewing distance. Bigger coefficients are used for stronger sharpness as viewing distance increases.

Table 4.2 adaptive sharpness filter mask for viewing distance 1 meter

0	0	-0,0245	0	0
0	-0,0315	-0,042	-0,0315	0
-0,0245	-0,042	1,392	-0,042	-0,0245
0	-0,0315	-0,042	-0,0315	0
0	0	-0,0245	0	0

Table 4.3 adaptive sharpness filter mask for viewing distance 5 meters

0	0	-0,045	0	0
0	-0,06	-0,105	-0,06	0
-0,045	-0,105	1,84	-0,105	-0,045
0	-0,06	-0,105	-0,06	0
0	0	-0,045	0	0

Table 4.4 adaptive sharpness filter mask for viewing distance 10 meters

0	0	-0,0625	0	0
0	-0,1	-0,1875	-0,1	0
-0,0625	-0,1875	2,4	-0,1875	-0,0625
0	-0,1	-0,1875	-0,1	0
0	0	-0,0625	0	0

CHAPTER FIVE

RESULTS

5.1 Algorithm Steps

Images are made of pixels which includes combinations of primary colors (Red/Green/Blue). YUV color space encodes a color image or video taking human perception into account, allowing reduced bandwidth for chrominance components, thereby typically enabling transmission errors or compression artifacts to be more efficiently masked by the human perception than using a "direct" RGB-representation. Both RGB and YUV domains have 3 channels for image. RGB has 3 color channels and YUV has one gray or luminance channel (Y) and two color channels (U and V). Each pixel in image has own Red Green Blue values; although contrast, HE and sharpness algorithms have been affected to Y (luminance). In this thesis first step of algorithm is conversion of image from RGB domain to YUV domain. Formulas used for these conversions are given below:

From RGB to YUV

$$Y = 0.299R + 0.587G + 0.114B \quad (5.1)$$
$$U = 0.492\ (B-Y) = -0.147R - 0.289G + 0.436B \quad (5.2)$$
$$V = 0.877\ (R-Y) = 0.615R - 0.515G - 0.100B \quad (5.3)$$

From YUV to RGB

$$R = Y + 1.140V \quad (5.4)$$
$$G = Y - 0.395U - 0.581V \quad (5.5)$$
$$B = Y + 2.032U \quad (5.6)$$

After conversion; contrast, HE and sharpness algorithms applied to Y (luminance). Figure 5.1 shows steps of algorithm simply.

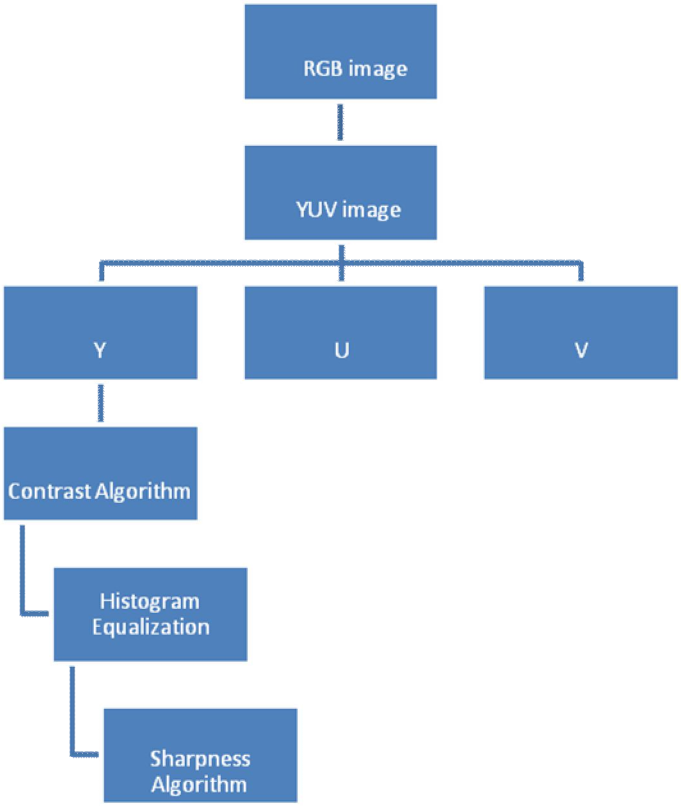


Figure 5.1 Algorithm steps

As shown on Figure 5.1, sequences of algorithms are as contrast, HE and lastly sharpness. Contrast algorithm has been chosen as first algorithm. Histogram of image is changed by contrast algorithm. HE algorithm takes this new contrast applied data as an input. Finally, sharpness applied to image after HE.

Strong HE and sharpness algorithms can cause artificial image. If contrast algorithm was at last step, image would be seen more artificial. That is why; contrast algorithm is the first step. Figure 5.2 and Figure 5.3 shows difference between algorithm sequences. Contrast and HE algorithms applied to image is exactly same for these two images. Sequence of the algorithms is the only difference between them. In Figure 5.2, contrast is applied to image before HE. Transition between bright areas to low areas is smooth in this image. On the other hand, contrast is applied to image after HE in Figure 5.3 and transition between bright areas to dark areas contour effect becomes more visible in this image as seen red areas.

Also, adaptive sharpness algorithm response will be strong as viewing distance increases. Overshoot/undershoot occurs on edges as a result of adaptive sharpness algorithm. If contrast algorithm applied after sharpness algorithm, amount of overshoot/undershoot would be more and image would be more artificial.

So, artifacts would be seen in image more unless contrast was applied first in image enhancement. As a result of this, contrast has been chosen as first algorithm in image enhancement.

Figure 5.2 Image with contrast applied first

Figure 5.3 Image with contrast applied last

After contrast, HE and sharpness algorithms had been applied to Y; Y would be combined with U and V. Displays are using RGB data instead of YUV data. Finally, YUV image data would be converted to RGB image to show enhanced image.

In this part, algorithms, which are used in image enhancement with respect to image content and viewing distance thesis, are investigated step by step. Original image can in Figure 5.4 is in RGB domain. First step is converting this RGB image to YUV domain. Then, Y (luminance) component of original image is affected by adaptive contrast, HE and sharpness algorithms. Y (luminance) of image can be seen at Figure 5.5. Histogram of original image, as shown at Figure 5.6, is also important feedback for adaptive contrast and HE algorithms. As explained in Chapter 2, adaptive contrast algorithm divides and affects image in dark, mid and bright regions of the image as seen at Figure 5.7, 5.8 and 5.9. Different gains applied to image in dark, mid and bright regions with respect to image distance and number of pixels in dark, mid and bright area in histogram of image. Y of enhanced image after adaptive contrast algorithm is shown at Figure 5.10. Y of enhanced image after adaptive contrast algorithm is used as input of AHE. HE gain is altered by contrast of image. Lower HE gain applied to image as contrast of image increases. The output of AHE is shown at Figure 5.11. Image contrast is high as seen histogram of image, so low gain HE is applied to image. After HE, adaptive sharpness algorithm uses the output of HE as shown at Figure 5.12. Finally, luminance component of image merged with color components U and V; and image is converted YUV domain to RGB domain to show at display.

Figure 5.4 Original RGB image

Figure 5.5 Y (luminance) of original image

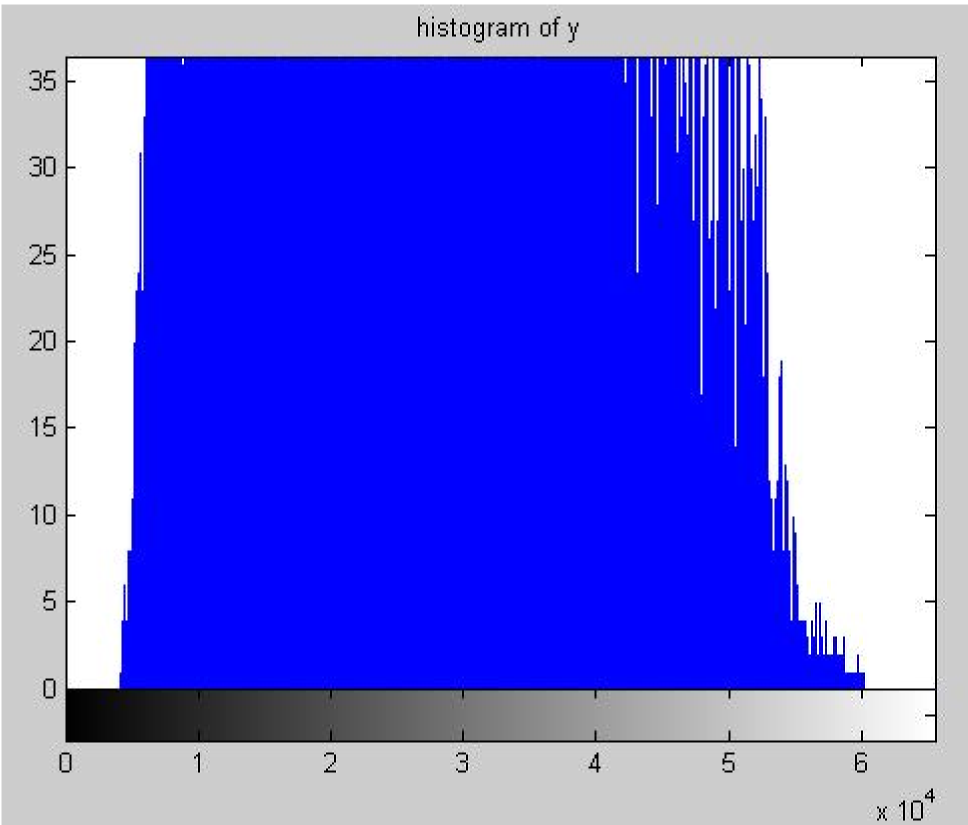


Figure 5.6 Histogram of original image

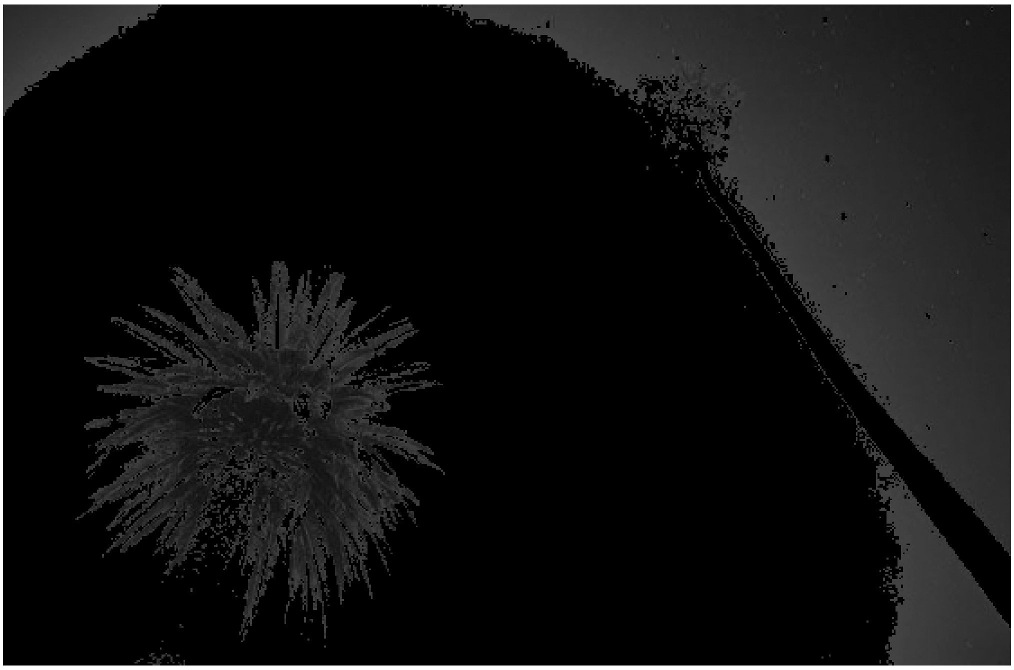


Figure 5.7 Dark region of original image

Figure 5.8 Mid region of original image

Figure 5.9 Bright region of original image

Figure 5.10 Y of enhance image after contrast algorithm

Figure 5.11 Y of enhance image after HE algorithm

Figure 5.12 Y of enhance image after sharpness algorithm

Figure 5.13 New enhanced RGB image

5.2 Algorithm Results with respect to Image Content

Histogram of image is main feedback for adaptive contrast and HE algorithms. Number of pixels in dark and bright regions in image; histogram start and stop points are used as a parameter to change response of adaptive contrast and HE algorithms. Fixed viewing distance parameter is chosen as 3 meters to see the effect of algorithm results with respect to image content.

As shown at Figure 5.14, image is dark, so histogram of image is weighted in dark area. As mentioned in Chapter 2, dark ratio is ratio of pixels between 0% to 30% brightness levels to entire pixels in image. Bright ratio is ratio of pixels between 70% to 100% brightness levels to entire pixels in image.

Also, halved right gain and left gain applied to image's too dark and too bright regions to prevent saturation in black and white as seen at Equations 2.2 and 2.4.dark ratio of image at Figure 5.14 is 0.6646 and bright ratio of this image is 0.1151. Leftgain and leftgain10 will be positive value which will increase the brightness in dark region, because 66 percent of image's pixels are dark region. General contrast algorithm aims to make dark pixels darker and bright pixels brighter. On the other hand, adaptive contrast algorithm compensates image with respect to image histogram. If image is too dark as Figure 5.14, adaptive contrast algorithm will make it brighter. Details in dark region of image become more visible with adaptive contrast algorithm as shown at figure5.15.

Image contrast level is used by HE algorithm coefficient in MATLAB code. Histogram start/stop points of image at Figure 5.14 are 4504 and 60395 as seen at histogram of image. ClipLimit parameter in AHE algorithm depends on histogram width of image. In this thesis, image histogram width divided into 5 parts as histogram width of image is:

-below 10000

-between 10000 and 20000

-between 20000 and 30000

-between 30000 and 40000

-between 40000 and 50000

-more than 50000

ClipLimit parameter is chosen low for this image because of its histogram width is more than 50000. If the image contains too bright and too dark pixels at the same time, strong HE would not be applied to make histogram wider and equal.

As seen Figure 5.15, new enhanced image histogram width becomes wider after AHE algorithm. As seen on original image histogram, pixels are existed in dark areas below 20000 as brightness level around %30 white. As a result of adaptive contrast algorithm, pixels in dark region become brighter with positive right gain because of dark ratio of original image. So, general histogram distribution of original image moves to brighter left side after adaptive contrast algorithm.

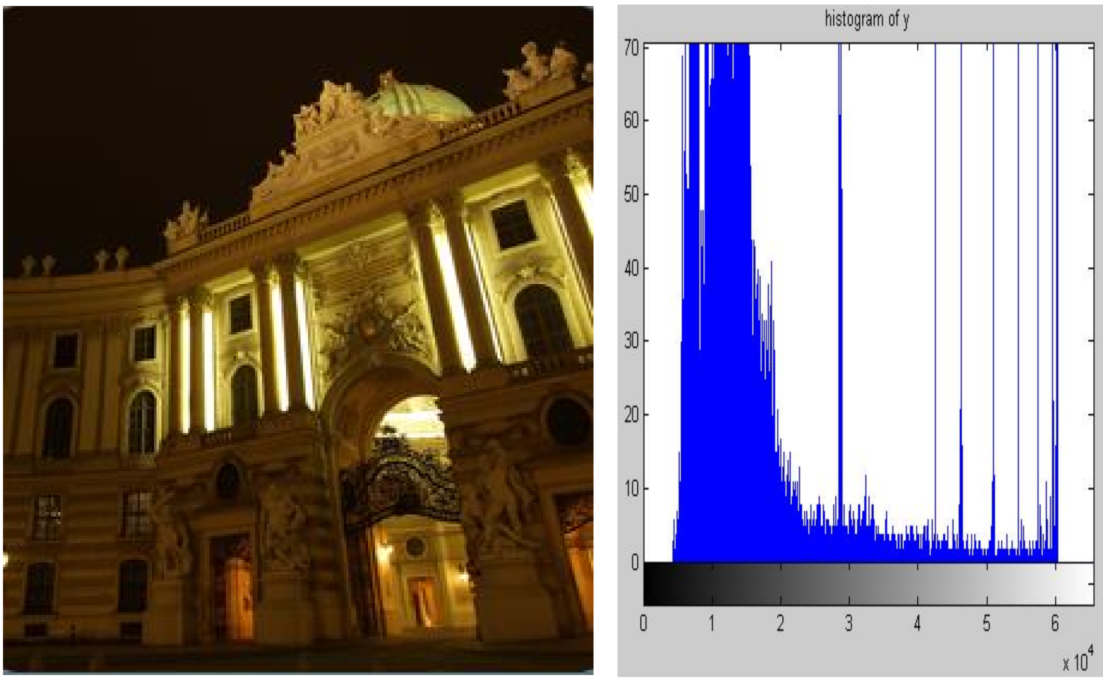


Figure 5.14 Original RGB image and its histogram

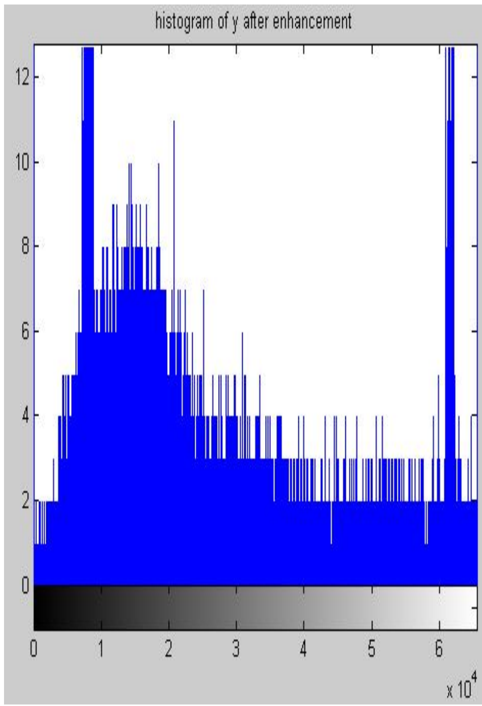
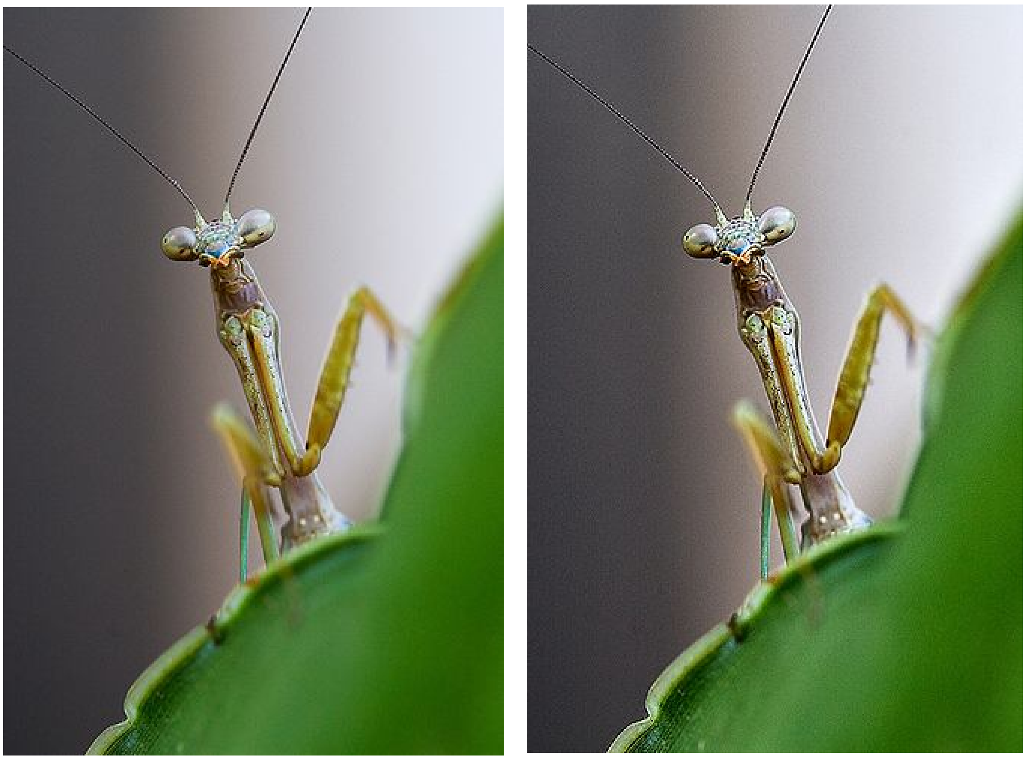


Figure 5.15 New enhanced RGB image for viewing distance 3 meters and its histogram

5.3 Algorithm Results with respect to Viewing Distance

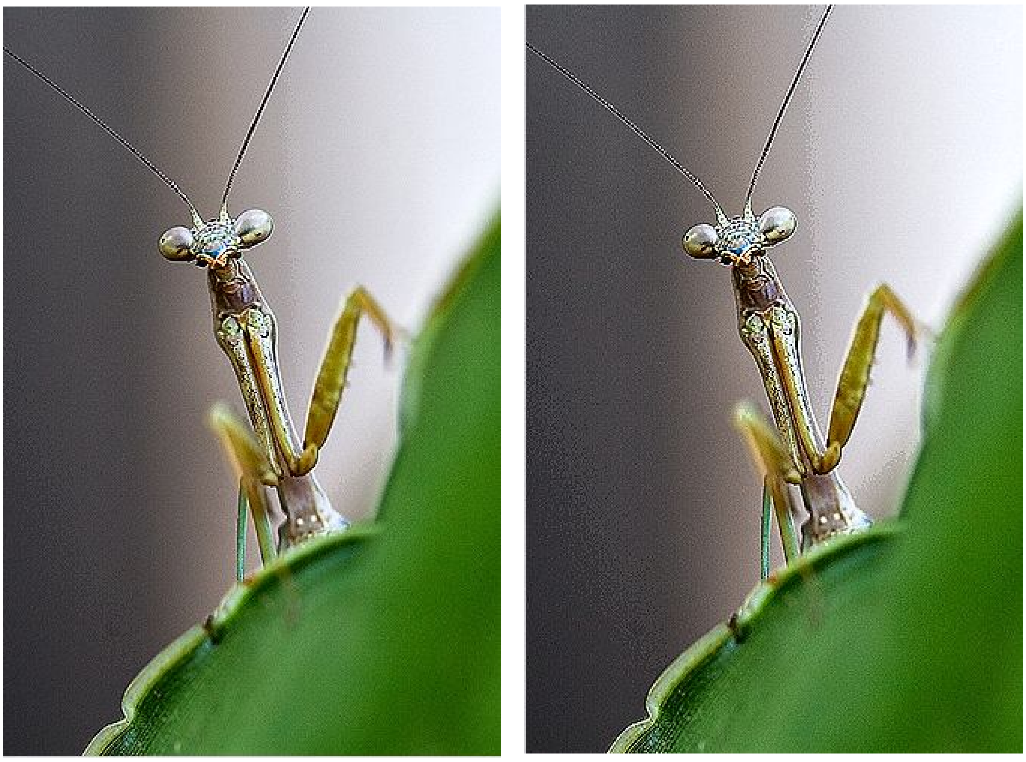
Viewing distance is used as feedback by adaptive contrast and sharpness algorithms. As shown at Equation 2.1 and 2.3, left gain and right gain changes with respect to viewing distance to enhance contrast of image. Left gain becomes smaller than 1 and right gain becomes more than 1 as viewing distance increases. Adaptive contrast algorithm makes dark area darker and bright area brighter as the viewing distance increases. Also, adaptive sharpness algorithm response becomes stronger as viewing distance increases. Both filter type and filter coefficients changes with respect to viewing distance in adaptive sharpness algorithm. As the viewing distance increases, coefficients of band 1 become higher with respect to band 2 and band 3 to get stronger sharpness. There are three different sharpness filter type for up to 3 meters, between 3 and 6 meters, more than 6 meters. Adaptive sharpness filter types for 1, 5 and 10 meters is shown at Tables 4.2, 4.3 and 4.4 in chapter 4 adaptive sharpness algorithm. In this part, response of adaptive contrast and adaptive sharpness algorithms is shown for viewing distance 1, 5 and 10 meters.

Original image is shown at Figure 5.16(a). Background of image contains dark and bright pixels from left to right. Response of adaptive contrast algorithm can be seen easily in background area. Also, focus of image is in center area which contains edges between background and locust. As a result of adaptive sharpness algorithm, overshoot/undershoot occurs around edges depending to viewing distance. Edges become more visible as viewing distance increases by increasing level of overshoot/undershoot.



(a) (b)

Figure 5.16 (a) Original image and (b) adaptive contrast and sharpness algorithms applied image for viewing distance 1 meter



(a) (b)

Figure 5.17 (a) Adaptive contrast and sharpness algorithms applied image for viewing distance 5 meter and (b) 10meters

Response of adaptive contrast and sharpness algorithms for viewing distance 1 meter is shown at Figure 5.16(b). Adaptive contrast and sharpness algorithm affected image slightly for near viewing distance a meter. Dark area in background of original image becomes darker and bright area in background of original image becomes brighter in new enhanced image as result of adaptive contrast algorithm. Also, adaptive sharpness algorithm is applied to image for viewing distance 1 meter. Sharpness filter mask applied to image can be seen at Table 4.2. Response of sharpness filter is not too strong; however focus of image is better than original image with adaptive sharpness algorithm.

As viewing distance increases, response of adaptive contrast and sharpness algorithm will be stronger as shown at Figures 5.17 (a) and (b). Transition between dark and bright regions on background becomes more visible as result of strong left gain/right gain parameters which depend viewing distance. As viewing distance increases, response of adaptive contrast algorithm applies stronger left/right gains which make dark pixels darker and bright pixels brighter. So, transition from dark pixels to bright pixels becomes more visible as result of adaptive contrast algorithm by increasing viewing distance at shown Figure 5.17 (a) and (b). Viewing distance is also used as feedback by adaptive sharpness algorithm. Strong sharpness filter type and coefficients are used depending to viewing distance. As a result of strong sharpness filter type and coefficients, overshoot/undershoot level increases which makes image sharper as shown at Figures 5.17 (a) and (b). Image can be distorted as a result of strong contrast and sharpness algorithms. The amount of overshoot/undershoot and contour may disturb human eye, however adaptive contrast and sharpness algorithm prevent this distortion in close viewing distance. Stronger settings can be applied to image for far viewing distances, because artifacts of contrast and sharpness algorithm will be less visible as viewing distance increases. As an artifact of strong contrast settings, contour is seen at smooth background of image in Figure at 5.17 (b). Also, image becomes noisier after strong sharpness settings. On the other hand, these artifacts slightly seen with viewing distance 10 meters. Human eye detects enhanced image better than original image for far viewing distance like 10 meters.

Measurement of image quality is not as easy as seen. There is no formulation about measurement of sharpness, contrast and histogram equalization techniques. As written in Why Is Image Quality Assessment So Difficult by Zhou Wang and Alan C. Bovik; the best way to assess the quality of an image is perhaps to look at it because human eyes are the ultimate receivers in most image processing environments. So; adaptive contrast, histogram equalization and sharpness algorithms are compared with conventional algorithms to detect improvement in image enhancement. (Wang & Bovik, 2002)

5.4 Additional Scaler Work

Proper viewing distance is related to size of display and image resolution. Proper viewing distance for HD TV sets are depends on resolution or quality of image. Resolution of 16:9 HD TV sets are commonly 1080*1920 for FullHD display; 768*1366 for WXGA display. In example, display resolution is FullHD, which is 1080*1920.If image shown at this display is also FullHD; proper viewing distance will be three times of display screen width. However, if image shown at this display is SD (576*1024); proper viewing distance will be almost five times of display screen width. So, proper viewing distance depends on display screen width and resolution of display and image as shown figure 5.18.

In this thesis, proper viewing distance is calculated with resolution of display and image and width of display. If the viewing distance is more than proper viewing distance, scaling can be applied to improve perception of image, but image can be disturbed as result of big scaling ratio. On the other hand, scaling can not improve the resolution of image. Nowadays, many chip manufacturers are working for super scaler algorithms to enhance image resolution.

Figure 5.18 viewing distance depending to screen and image resolution

(http://www.homeappliancegallery.com/images/articles/720p-1080p-viewing-distance-tv-size-chart.jpg)

CHAPTER SIX

CONCLUSION

Contrast, histogram equalization, sharpness algorithms are one of most used algorithms used in image enhancement. The aim of image enhancement is to improve the perception of information in images for humans. However, perception of information in images depends on both image content and viewing distance. Standard image enhancement algorithms do not use image content and viewing distance as feedback. As a result of these, optimum image enhancement can not be done via standard image enhancement techniques.

In this thesis; adaptive contrast, histogram equalization and sharpness algorithms responses relatively change with respect to image content and viewing distance to improve the perception of information in image. If the image is too dark, adaptive contrast algorithm compensates it and makes image brighter in dark region. On the other hand, adaptive contrast algorithm decreased left gain and increased right gain parameter as viewing distance increases to get better deepness effect for far distances. Adaptive histogram equalization is used for wider histogram range depending to image’s histogram width. Likely, response of adaptive sharpness algorithm makes image sharper as viewing distance increases. Perception of image will be effected by image content which means image histogram and viewing distance. As a result of these, using image content and viewing distance as feedback of adaptive contrast, histogram equalization and sharpness algorithms improve the perception of information in image.

Optimizing MATLAB code will be done as future work. If the processing time of adaptive algorithms becomes faster, the MATLAB code can be used slide shows and presentations. Also, MATLAB code gets only one image as an input. The MATLAB code will be modified for using array of images in a folder or presentation as an input. Also, response of each algorithm can be selected depending to viewing distance and image content. So that, gains of adaptive contrast, histogram equalization and sharpness algorithms becomes independent and response of algorithm can be changed with respect to viewing distance and image content. As an example, gain of adaptive contrast algorithm can be adjustable for general contrast gain. Moreover, response of adaptive contrast algorithm can care about just viewing distance or image content via selection of gain parameter between viewing distance and image content. As a result of these, responses of each algorithm can be adjustable with separate gains for viewing distance and image content. So, response of total image enhancement can be decided by user with respect to taste of his/her eye.

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