Analysis of Variations of Histogram Equalisation Algorithms on Grey Scale Images

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Abstract- *Image processing is one of the most rapidly growing and challenging fields of Computer Science. It has extensive applications in several fields some of which are robot vision, meteorology, defence, pattern recognition, video processing, face recognition etc. It is widely used in medical and healthcare for gamma ray imaging, PET scan, X-Ray imaging, UV Imaging, CT Scan etc. One of the most common image enhancement algorithms is histogram equalization. It is used to improve the contrast of the images on which it is applied. The most frequent intensity values of the image are spread out which stretches out the range of the intensity of the image. There are several modifications of histogram equalization algorithms. In this paper, we explore variations of the convention histogram equalization algorithm, and apply them on grey scale images We will compare the performance of these algorithms to predict the optimum procedure to enhance the image.*

Keywords- Histogram Equalization, Grey scale images, Brightness Preserving Histogram Equalization, Dualistic Sub Image Histogram Equalization, Recursive Sub Image Histogram Equalization, Bi Histogram Equalization with a Plateau Limit, Contrast Limited Adaptive Histogram Equalization, Weber Function, Michelson Function, Image Contrast Function, Adaptive Trilateral Contrast Enhancement

I. INTRODUCTION

GREY SCALE IMAGES

A greyscale (or greylevel) image is simply one in which the only colors are shades of grey. The reason for differentiating such images from any other sort of color image is that less information needs to be provided for each pixel. In fact a `grey' color is one in which the red, green and blue components all have equal intensity in RGB space, and so it is only necessary to specify a single intensity value for each pixel, as opposed to the three intensities needed to specify each pixel in a full color image. Often, the greyscale intensity is stored as an 8-bit integer giving 256 possible different shades of grey from black to white. If the levels are evenly spaced then the difference between successive grey levels is significantly better than the grey level resolving power of the human eye. Greyscale images are very common, in part because much of today's display and image capture hardware can only support 8-bit images. In addition, greyscale images are entirely sufficient for many tasks and so there is no need to use more complicated and harder-to-process color images.
source:https://homepages.inf.ed.ac.uk/rbf/HIPR2/gryimage.htm

CONVENTIONAL HISTOGRAM EQUALISATION (CHE)

1. Let there be an image matrix I with intensity levels k=0,1,2…255.
2. Let H(Ik) be the frequency distribution of the kth level of image I.
3. Let N be the total size of the image.
4. Let P(Ik) = H(Ik)/N, be the probability density function
5. Let C(Ik) = **Σ** P(Ii), where i -> 0 to k-1
6. I2(x,y) = C(x,y)*255 , where I2 is the enhanced image.

BRIGHTNESS PRESERVING HISTOGRAM EQUALISATION (BBHE)

The BBHE algorithm[1] is explained as follows :

1. Let I be the image matrix
2. I is broken into 2 images X and Y
3. X contains the grey levels whose frequency is less than the mean frequency of the grey levels of the entire image
4. Y contains the grey levels whose frequency is more than the mean frequency of the grey levels of the whole image.
5. The CHE algorithm is applied on the 2 images independently.
6. The 2 enhanced images are combined to form the enhanced version of the original image.
7. I2 = Xe U Ye whereXe and Ye are the enhanced subimages and I2 is the enhanced image.

DUALISTIC SUB-IMAGE HISTOGRAM EQUALIZATION METHOD (DSIHE)

The DSIHE algorithm[2] is explained as follows :

1. Let I be the image matrix
2. I is broken into 2 images X and Y
3. X contains the grey levels whose value is less than a grey levelXe (here taken as 128 for implementation purposes)
4. Y contains the grey levels whose value is more than a grey levelXe (here taken as 128 for implementation purposes)
5. The CHE algorithm is applied on the 2 images independently.
6. The 2 enhanced images are combined to form the enhanced version of the original image.
7. I2 = Xe U Ye whereXe and Ye are the enhanced subimages and I2 is the enhanced image.

RECURSIVE SUB-IMAGE HISTOGRAM EQUALIZATION (RSIHE)

The RSIHE algorithm[3] is as follows:

1. Let I be the image matrix
2. A grey level Te is chosen as the intermediate value whose corresponding cumulative probability density function's value isequal to 0.5
3. I is broken into 2 images X and Y
4. X contains the grey levels whose frequency is less than thegrey levelTe
5. Y contains the grey levels whose frequency is more than thegrey levelTe
6. When cumulative probability density is equal to 0.5, the total pixel in a sub-image, X, and the total pixels in the other sub-image, Y, are the same.
7. The CHE algorithm is applied on the 2 images independently.
8. The 2 enhanced images are combined to form the enhanced version of the original image.
9. I2 = Xe U Ye whereXe and Ye are the enhanced subimages and I2 is the enhanced image.

BI HISTOGRAM EQUALISATION WITH A PLATEAU LIMIT (BHEPL)

The BHEPL algorithm [4] is as follows :

1. Let I be the image matrix
2. I is broken into 2 images X and Y
3. X contains the grey levels whose frequency is less than the mean frequency of the grey levels of the entire image
4. Y contains the grey levels whose frequency is more than the mean frequency of the grey levels of the whole image.
5. Separate upper plateau limits are calculated for the 2 images.
6. Let Hx and Hy be the frequency distribution of X and Y.
7. Let Xm be the maximum grey level of X.
8. For sub image X, upper limit T_x is:T_x= **Σ**(H1)/(Xm+1)
9. For sun image Y, upper limit T_yis : T_Y = **Σ**(H2)/(255-Xm)
10. For image X if any value of Hx goes is above T_x, it assigned the value of T_x.
11. Likewise, for image Y if any value of Hy is above T_y, it is assigned the value of T_y
12. The CHE algorithm is applied on Hx and Hy to enhance X and Y
13. The union of X and Y gives the complete enhanced image
14. Enhanced image = X U Y

CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALISATION (CLAHE)

The CLAHE algorithm [5] is as follows:

1. Let I be the image matrix.
2. And H be the frequency distribution.
3. In order to limit the contrast to a desired level, the maximum slope of is limited to a desired maximum slope. One approach in limiting the maximum slope is to use a clip limit β to clip all histograms.
4. The image is then divided into sub images
5. CHE algorithm is carried out on each image
6. The images are then merged by bilinear interpolation.
7. Matlab function =>adapthiseq(image)

ADAPTIVE TRILATERAL CONTRAST ENHANCEMENT (ATCE)

ATCE Algorithm [7] is as follows :

- In ATCE [7], the concept of plateau histogram equalisation(PHE) is adopted as the underlying principle for image contrast manipulation due to its simplicity and flexibility.

- However, unlike conventional PHE, the image contrast manipulation in ATCE utilises two plateau threshold values.
- An upper plateau threshold value is deployed to restrain the severity of over-equalisation and noise amplification artefacts, while an additionallowerplateauthresholdvalueisusedtoprevent subtleimagedetailsfromoverwhelmingbydrasticcontrastgain.
- However, rather than using an arbitrarily selected threshold to globally restrict the height of histogram distribution, the proposed image contrast manipulation attempts to study the nature of such inequality to adaptively derive an optimal threshold value to remodel the histogram distribution .A good general measure for analysing the in-equality of distribution is known as the Lorenz curve

PERFORMANCE MEASUREMENTS :

The quantitative valuation is being conducted by 3 performance metrics :Weber function, Michelson function and Image Contrast function.

The **Weber function (EMEE)**[7] :

$$EMEE = \frac{1}{b_1 b_2} \sum_{u=1}^{b_2} \sum_{v=1}^{b_1} \alpha \left(\frac{I_{max}(u,v)}{I_{min}(u,v)+c} \right)^{\alpha} \times \ln \frac{I_{max}(u,v)}{I_{min}(u,v)+c},$$

The **Michelson function (AME)** [7] :

$$AME = \frac{1}{b_1 b_2} \sum_{u=1}^{b_2} \sum_{v=1}^{b_1} \alpha \left(\frac{I_{max}(u,v) - I_{min}(u,v)}{I_{max}(u,v)+I_{min}(u,v)+c} \right)^{\alpha} \times \ln \frac{I_{max}(u,v) - I_{min}(u,v)}{I_{max}(u,v)+I_{min}(u,v)+c}$$

where Imax(u,v) and Imin(u,v) represent the maximum and minimum grey intensity level in a given sub-blockI(u,v);c is a small constant introduced to avoid division by zero; b1×b2 is the equally-sized sub-blocks; α is an additional coefficient introduced to control the optimal parameters.[7]

The **Image Contrast Function** [8] :

$$C_{contrast} = \frac{1}{PQ} \sum_{x=1}^{P} \sum_{y=1}^{Q} g^2(x,y) - \left| \frac{1}{PQ} \sum_{x=1}^{P} \sum_{y=1}^{Q} g(x,y) \right|^2$$

$$C^{*}_{contrast} = 10 \log_{10} C_{contrast}$$

where P is the width of the image and Q is the height of the image, g(x, y) is the grey level of the pixel at (x, y). Contrast represents the deviation of grey levels. Higher value of Contrast implies larger dynamic range of grey levels and therefore better contrast and moredetailed information of image. [8]

IMPLEMENTATION AND RESULTS

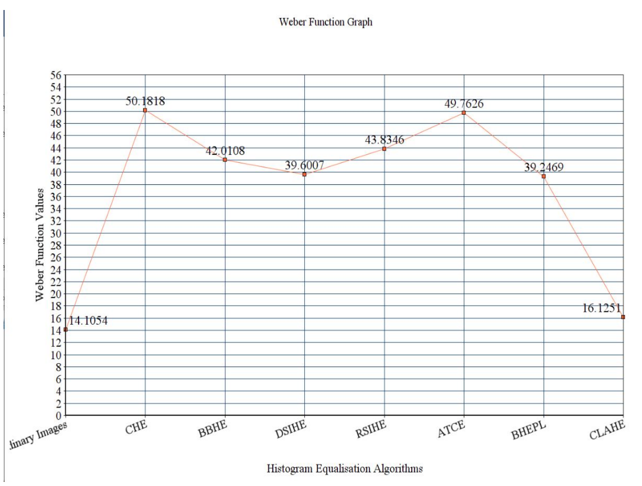
A dataset of 100 random grey scale images was taken. Each of the above mentioned histogram equalisation algorithms was applied on the dataset, and the average values of Weber function, Michelson function and Image Contrast function was calculated. The algorithms were programmed in MATLAB.

MathWorks Image Processing Toolbox provides a comprehensive set of reference-standard algorithms and workflow apps for image processing, analysis, visualization, and algorithm development. You can perform image segmentation, image enhancement, noise reduction, geometric transformations, image registration, and 3D image processing.[11]

	AVERAGE WEBER FUNCTION	AVERAGE MICHELSON FUNCTION	AVERAGE IMAGE CONTRAST FUNCTION
Original Images	14.1054	-0.23339	33.4727
CHE	50.1818	-0.21536	37.5023
BBHE	42.0108	-0.21816	37.5629
DSIHE	39.6007	-0.22176	36.8046
RSIHE	43.8346	-0.21642	37.434
ATCE	49.7626	-0.21175	35.7156
BHEPL	39.2469	-0.21756	37.7562
CLAHE	16.1251	-0.23218	35.7447

Plotted using : https://www.onlinecharttool.com/

WEBER FUNCTION GRAPH



MICHELSON FUNCTION GRAPH

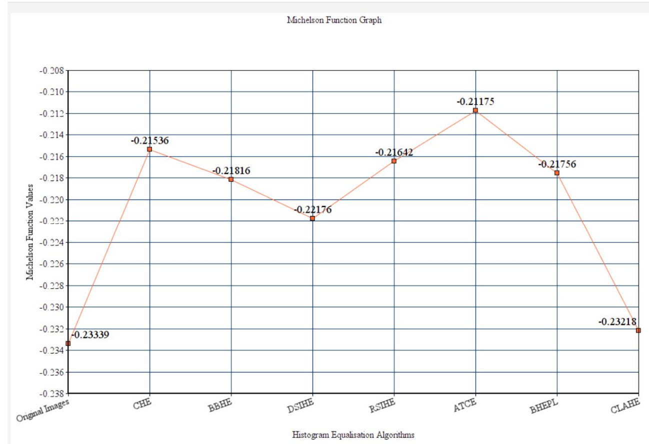
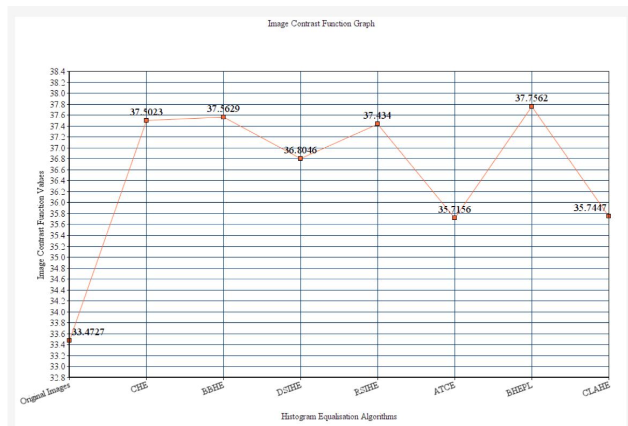


IMAGE CONTRAST FUNCTION GRAPH



II. CONCLUSION

According to the Weber Function, the ordinary histogram equalisation method CHE works best with the highest value of 50.1818, followed by ATCE, RSIHE, BBHE, DSIHE, BHEPL and CLAHE with the least value of 16.1251.

According to Michelson Function, ATCE algorithm works best with highest value of -0.21175, followed by CHE, RSIHE,BHEPL, BBHE, DSIHE and CLAHE with the least value of -0.23218.

According to the Image Contrast Function, BHEPL takes the highest value of 37.7562, followed by BBHE,CHE,RSIHE, DSIHE, CLAHE and least value is ATCE with 35.7156

Therefore, we can conclude that there is no one enhancement algorithm which will be best for each and every image. Each algorithm has it’s own strength and weaknesses, and implementation depends on the dataset, and experimental conditions. This study’s main aim was to give an analysis of different histogram equalisation algorithms, and their corresponding performance metric values calculated with 3 different standard enhancement measurement algorithms.

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