A Novel Method to Control Dominating Gray Levels during Image Contrast Adjustment using Modified Histogram Equalization

Krishna Prasad K.[1] & P. S. Aithal[2]

[1]Research Scholar, College of Computer and Information Science, Srinivas University, Mangaluru-575001, Karnataka, India

[2]College of Computer and Information Science, Srinivas University, Mangaluru-575001, Karnataka, India

E-mail: karanikrishna@gmail.com

Type of the Paper: Research Paper.
Type of Review: Peer Reviewed.
Indexed In: OpenAIRE.
DOI: http://dx.doi.org/10.5281/zenodo.896653.
Google Scholar Citation: IJAEML

How to Cite this Paper:

Krishna Prasad., K. & Aithal, P. S. (2017). A Novel Method to Control Dominating Gray Levels during Image Contrast Adjustment using Modified Histogram Equalization. *International Journal of Applied Engineering and Management Letters (IJAEML)*, 1(2), 27-39. DOI: http://dx.doi.org/10.5281/zenodo.896653.

International Journal of Applied Engineering and Management Letters (IJAEML)
A Refereed International Journal of Srinivas University, India.

© With Authors.

This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License subject to proper citation to the publication source of the work.
Disclaimer: The scholarly papers as reviewed and published by the Srinivas Publications (S.P.), India are the views and opinions of their respective authors and are not the views or opinions of the S.P. The S.P. disclaims of any harm or loss caused due to the published content to any party.

A Novel Method to Control Dominating Gray Levels during Image Contrast Adjustment using Modified Histogram Equalization

Krishna Prasad K.[1] & P. S. Aithal[2]

[1]Research Scholar, College of Computer and Information Science, Srinivas University, Mangaluru-575001, Karnataka, India

[2]College of Computer and Information Science, Srinivas University, Mangaluru-575001, Karnataka, India

E-mail: karanikrishna@gmail.com

ABSTRACT

Contrast and Brightness are two major factors, which affect the superiority of an image for easy or stainless or pleasant viewing. Overall lighting condition and darkness condition of the image collectively called as brightness, whereas differences in brightness or intensity range between the low and high-intensity value of an image are called as contrast. Histogram equalization is a very famous approach for image contrast adjustment or enhancement in image processing, but which produces sometimes washed out appearance, especially for a small region of the grayscale image. Contrast adjustment is part of the noise filtering or smoothing process, which is essential in automatic identification or recognition systems like a fingerprint or any other biometric-based recognition systems to get higher efficiency. Histogram-based equalization is simple in terms understandability and implementation, which is referred as one of the greatest advantages of this contrast adjustment method. Histogram equalization is less expensive compared to another similar type of contrast adjustment or enhancement algorithm. The novel approach planned in this paper controls dominating gray levels before applying histogram equalization process so that it performs enhancement of the image without over brightness or over darkness, which makes smaller part of the image invisible or loss of details in that portion of the image. This method outperforms histogram equalization method by enhancing the contrast with intermediate brightness or neither too bright nor too dark. In this paper, we compare different types of the grayscale image using the novel method and global histogram equalization method using MATLAB.

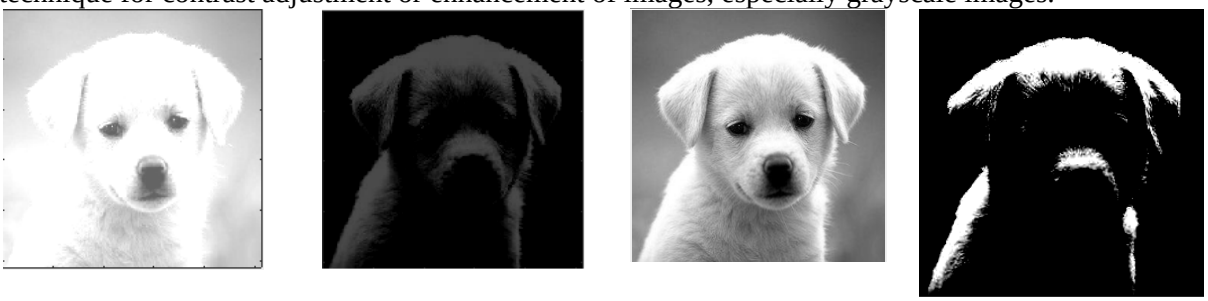
Keywords: Histogram equalization, Contrast enhancement, Washed out appearance, Brightness, Image processing.

1. INTRODUCTION :

Contrast adjustment methods are extensively used for image processing to attain wider dynamic range and which is considered as preprocessing stage, especially in Automatic recognition system based on different types of images like a fingerprint, face, iris etc. The different four possible ways in which brightness and contrast can be misadjusted is shown using Figure 1. When brightness is too high all the pixels of the image turn into lighter, conversely when the brightness is too low all the pixels of the image turn into darker. When the intensity is a too high, lighter area of the image becomes lighter and darker area of the image becomes darker.

Distinct contrast enhancement methods have already been developed and advanced which make use of easy linear or non-linear gray level transformation functions in addition to complicated evaluation

of special image capabilities. Amongst them, histogram equalization (HE) [1-4] is a very popular technique for contrast adjustment or enhancement of images, especially grayscale images.

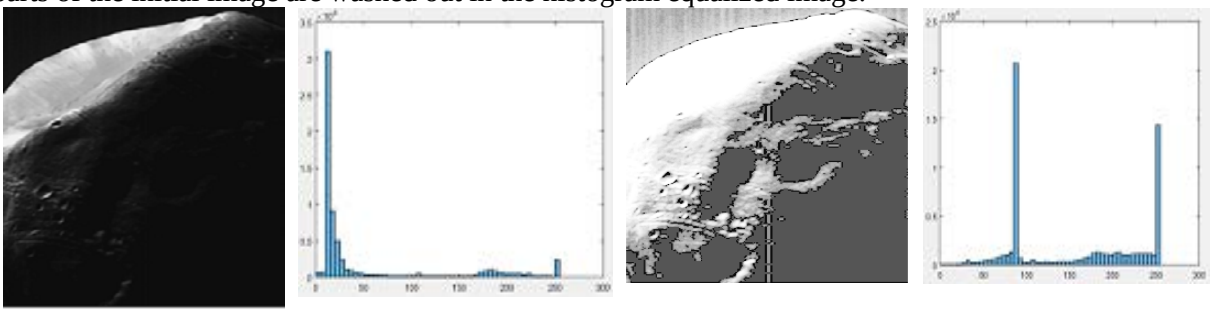


(a) Brightness too high (b) Brightness too low (c) Contrast too high (d) Contrast too low [5]

Fig. 1: Brightness and Contrast misadjusted [5]

In general, the histogram equalization distributes pixel values consistently and produces an outcome in a superior image with the linear increasing histogram. Some useful applications of HE enhancement consist of scientific image processing, speech recognition, fingerprint identification and texture synthesis, which might be typically employed with histogram adjustment [6-9].

Histogram based techniques strategies for image enhancement is in most cases primarily based on equalizing the histogram of the image and increasing the dynamic variety corresponding to the image. Histogram equalization (HE) technique has two foremost flaws which affect performance of this technique. Histogram equalization assigns one gray level into two diverse neighbor gray levels with distinctive intensities. If maximum of an image consists of a grey level, histogram equalization assign a gray level with higher intensity to that gray level and it causes a phenomenon as we referred to as it washed out. Figure 2 indicates this effect. Even though in histogram after washout appearance dominating bins appears, this is part of another area of the image. Compared to initial image, some parts of the initial image are washed out in the histogram equalized image.



Original Image [10] Histogram of original image Image after applying Histogram equalization Histogram of image after applying HE

Fig. 2: Washout appearance of an image after Histogram equalization [10]

In this study, a new method is proposed to overcome the domination of the gray levels, which increases the image contrast based on histogram equalization without making the loss of any details of the image. Usually, in global histogram equalization, some gray level of the image having more accumulations compared to some other gray levels which have fewer accumulations. Usually, a higher bin component dominates over lower bin points. In this new method more or fewer accumulations or frequencies are equalized by shorting the higher bins and adding an extra bin to lower bin gray levels. The contrast adjustment can be used for fingerprint image enhancement process [11-13].The remaining part of the paper is arranged as follows. Section 2 describes Review on existing work. Section 3 explains the objective the study. Section 4 describes the methodology of the proposed method. Section 5 describes the Global histogram equalization and proposed a new method using the algorithm. Section 6 presents some experimental results of using novel approach and Histogram

equalization with the aid of MATLAB. Section 7 shows the snapshots of the coding of the new method used in this study through MATLAB programming. Section 8 makes concluding remarks.

2. RELATED RESEARCH :

Different techniques of making use of histogram equalization are determined in the literature. Global histogram equalization (GHE) [1] makes use of the entire information of the input image to map into new distinct intensity levels of the image. Although this Global technique is suitable for ordinary or general enhancement, it fails to consider with the local brightness capabilities of the entered image. The gray ranges with very excessive frequencies (wide variety of occurrences) dominate over the opposite gray levels having decrease frequencies in an image. In any such situation, GHE remaps the gray levels in a way that the contrast stretching turns into confined in some dominating gray levels having large image histogram components, and it causes sizable contrast loss for other small ones.
Local histogram equalization (LHE) [1] can overcome the problem encountered in GHE. LHE uses a small window that slides on all pixel of the image sequentially and handiest the block of pixels that fall within this window are taken into consideration for HE and then gray level mapping for enhancement is carried out for the center pixel of that window. Therefore, it may make splendid use of local information also. But, LHE requires excessive computational cost and occasionally reasons over enhancement in some part of the image. Another shortfall of this approach is that it also enhances the noises inside the input image. To overcome the problem of high computational cost one more approach is to use the non-overlapping block for HE [1]. But almost all times this method produces checkerboard effect.
In literature, many types of research are centered on image or video contrast adjustment or enhancement [14-19]. Mean preserving bi-histogram equalization (MPBHE) proposed to get rid of the brightness problem issues [15, 17]. MPBHE separates the entered or captured input image or video histogram into two classifications as mean of the input before equalizing them independently. Some other variants of bi-histogram equalization are a similar area or equal area or place dualistic sub-image or picture histogram equalization (DSIHE) [20], minimum or lower mean brightness or luminance error bi-histogram equalization (MMBEBHE) [19-20]. DSIHE [7] technique uses entropy value for histogram separation. MMBEBHE [19-20] is the extension of BBHE technique that offers maximal brightness maintenance. Even though these strategies can carry out exact contrast adjustments, additionally they generate some side effects depending on the variation of gray level distribution in the histogram [21]. Recursively Separating the mean and finding histogram Equalization (RMSHE) another up gradation of BHE [19] however, it additionally is not free from drawbacks. Moreover, such strategies won't ensure desirable upgrades of all of the partitions [10]. The difference in the ranges of upgrades of various components might also create undesired artifacts in the image. There are many variations MPBHE are Recursive Separated and Weighted HE (RSWHE) [23], Multipeak HE (MPHE) [24], Brightness preserving Weight Clustering HE (BPWCHE) [25], Brightness preserving Dynamic HE (BPDHE) [26] and HE with Range Offset (HERO) [27-28].
The related research reveals that even though there are a lot of modifications for HE are proposed and implemented, still, there is scope for improvement in terms reducing noise, improving brightness, contrast adjustment and equalizing accumulations or larger bins. This paper focuses on cutting the accumulations or bins of dominating gray levels of the image and reassigning them to lower bin points of the image.

3. OBJECTIVE OF THE STUDY :

The objectives of the study are;

- To remove the domination of the gray levels and reassign them to lower accumulation gray level with an intention to equalize more or less accumulation of all intensity levels of the image.
- To increase contrast, which exists in the image as a range of gray levels and to overcome the washout appearance occurs for small part of the image.
- To compare the new method with GHE with the aid of MATLAB coding.

4. METHODOLOGY :

The methodology used in this research work is explained using workflow diagram using Figure 3. We use MATLAB R2015a for implementing the new approach to control dominating gray level. Initially, the image is loaded into MATLAB. The image is resized into 256 x 256 grayscale intensity image even though the image is any dimensional image like 3D or 2D with a different count of pixels in the first dimension (row) and a second dimension (column). So intensity levels of grayscale image range between 0-255. Next, we have to find the occurrence of each gray level or frequency from zero to two fifty-five. Find the mean of accumulations or frequencies, considering all grayscale intensity levels. Next check any intensity level of the input grayscale image having individual frequency value greater than mean. If so, find the difference between frequencies of that intensity level and mean. The new value of that particular intensity level is reassigned with mean value. Next, we have to add difference value to all pixels uniformly. This is done, dividing the difference value by mean value. Find the some of the frequencies all intensity value; usually, it should be equal to a maximum number of pixels. In 256 x 256 sized image maximum number of pixels is 65536 (i.e. 256 x 256). We have altered the count above. So there is a necessity of checking sum of frequencies of intensity levels. If the sum crosses the maximum number of pixels, then we simply subtract the excess value from highest frequency or accumulation value of the intensity levels. If the sum is less than the maximum number of pixels then find the count of frequencies of all gray levels. Take the difference of sum and a total number of pixels. Divide the difference by count and distribute the value to all gray levels which are having a value less than the mean. Next, we use Global histogram equalization for finding probability density function cumulative density function and mapping function. Finally, the intensity adjusted output image is generated.

5. PROPOSED NOVEL APPROACH :

In this section first, the usual procedure of global histogram equalization is explained (GHE). In the second phase, we explain the procedure of novel approach using a pseudo algorithm to overcome shortfalls of GHE. Suppose that an image k (x, y) consists of distinct gray levels in the range of [0, R-1]. The transformation function T (d_k) is defined as

$$G_k = \mathrm{T}(d_k) = \sum_{j=0}^{l} \mathrm{P}(d_j) = \sum_{j=0}^{l} \frac{m_i}{m} \qquad (1)$$

Where $0 \leq Gk \leq 1$ where l=0, 1, 2 ...R-l. In Eq. 1, mi depict the count of pixels having gray level d_k, m is the maximum count of pixels in the entered image and P (d_j) correspond to Probability Density Function (PDF) of the input d_j. The cumulative density function here refereed as T (d_k). G_k, is a mapping function, which maps to dynamic range of [0, R-1] values by multiplying it with R-1.

In 256 × 256 sized gray scale images Eq. 1 value of G_k is $0 \leq G_k \leq 255$ where l can take distinct 256 values from zero to 255 and a maximal number of pixels are 65536 (256 × 256). G_k, is a mapping function, which maps to a dynamic range of [0, 255] values by multiplying it with 255.

GHE typically offers a good image enhancement, but sometimes ends up with some artifacts and unwanted aspect results along with the washed out look. In Eq. 1, larger values of m_i purpose the respective gray levels to be mapped aside from every different that guarantees precise enhancement. However, the mapping of the grey levels having smaller m_i values, are forced to be condensed in a small range that makes much less enhancement in such gray levels. Furthermore, rounding problems might also occur inside the transformation such gray levels while the output gray levels are quantized into integer values. In such cases, there is the possibility mapping a couple of input gray levels to the equal output gray level that ends in the loss of image information. These phenomena are the main sources of the washed out appearances within the output image, which is shown in figure 4.

The figure 4 (c) shows the histogram of Figure 4 (a). The small frequencies in the rightmost point the histogram comes due to the flower image in the original image (Fig. 4 (a)). Compare to the other high accumulations, these are very small, which might be not observed sometimes and may cause washout appearance. In this study, our main focus is to control the dominating gray levels over other small gray levels and making all gray levels more or less equal. This study also focuses on improving or adjusting the contrast of the image. Section 5.1 is explained with the pseudo algorithm.

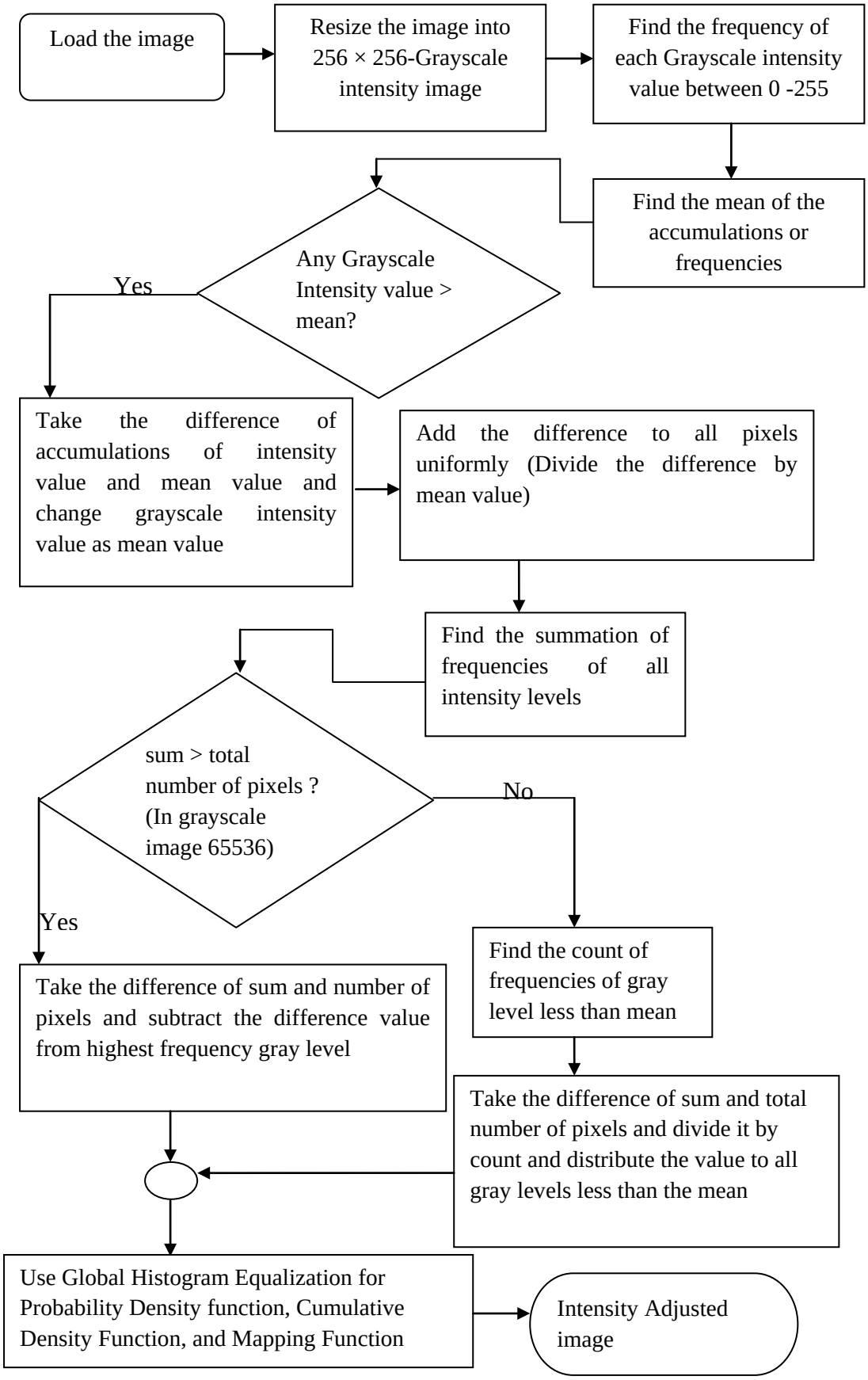


Fig. 3: Work Flow diagram of Methodology used in this study

(a) Original image [5]

(b) GHE image

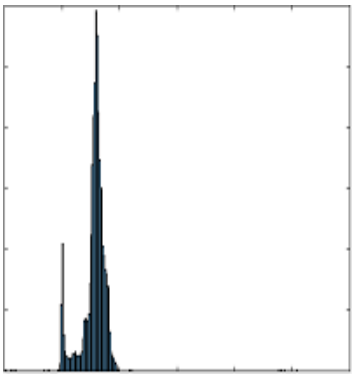

(c) Histogram plotted for the original image

Fig. 4: GHE of the image and histogram showing loss of information [25].

5.1 Controlling of Dominating Gray levels

We make a modification for the Global Histogram Equalization at first step while calculating accumulations or frequencies of all gray level values. Our intention is to preserve even small part of the image. The algorithms of the approach used in this study referred as Novel Histogram Equalization (NHE) are shown below;

Step 1: Load the image of any size (input)
Step 2: Resize the image into 256 × 256 sized grayscale intensity image
Step 3: Find the frequency of the each gray level
for i= 1 to row_size_of_image
for j= 1 to column_size_of_image
find frequency of individual pixels of i^{th} row and j^{th} column (freq [i] [j])
end
end
Step 4: Find mean of frequencies (mean_freq)
Step 5**:** Find the frequency of intensity levels > mean
for i=1 to size_of_frequency_array
if freq [i] > mean_freq
Step 6: Find the difference value of frequency [i] and mean_freq
remaining_values = freq [i] - mean_freq
Step 7: Divide the difference value by mean
remaining_values = remaining_values / mean
Step 8: Assign the value of mean to freq[i]
freq [i] = mean
Step 9: Move from initial gray level frequency to last gray level frequency and add the remaining value to all intensity levels equally
for j= 1 to size_of_frequency_array
freq [j] = freq [j] + remaining_values
end
end
end
Step 10: find summation of all frequencies and difference value of maximum number of pixels and sum of the frequency as sum_freq
diff= maximal number pixels (65536) – sum_freq // find difference
Step 11: if the difference greater or more than or equal to 1 (sum_freq less than maximum number of pixels) if diff > = 1
Step 12: Initialize a count for finding number of gray levels less than mean value
count = 0
Step 13: Find all intensity levels less than mean frequency and increment counter

```
for i=1 to size (freq)
  if freq[i] < mean_feq
      count++;
  end
 end
end
```

Step 14: Divide the difference by count assign this value to all gray levels frequencies whose value is less than mean value

```
diff / count
for i=1 to size (freq)
  if freq[i] < mean
     freq[i] = freq[i]+difference
  end
end
```

Step 15: if difference found in step 11 is less than 0 (sum_freq greater than maximum number of pixels)

```
if diff < 0
```

Step 16: Find the maximum frequency gray level

```
max_freq = max(freq)
```

Step 17: Locate the maximum frequency gray level and subtract the difference value from it.

```
for i=1 to size(freq)
  if freq[i] =max_freq
      freq[i] = freq[i]-diff
  end
end
```

Step 18: Follow the steps of GHE to find probability density function for each gray level
Step 19: Follow the steps of GHE to find cumulative density function for each gray level
Step 20: Follow the steps of GHE to find mapping function by rounding for each gray level obtaining by multiplying CDF with maximal intensity level or bin value
Step 21: Intensity adjusted image (output)

The NHE is mainly focused on controlling the dominating Gray levels. This algorithm takes into account the larger frequency gray level. If any gray level frequency value more than the mean value of the accumulations or frequencies, are cut-off or removed and the same value is equally distributed among all other gray levels including the same gray level, which had value more than the mean. There might be some time more than one gray level having value more than the mean value of the accumulations. The count of a total number of frequencies is always equal to the maximum count of pixels usually an image contains. In a 256 × 256 image, it will be 65536. In order to maintain this value after above operation we check sum of frequencies of all gray level and if it is less than the maximum count of pixels, then we equally assign the difference to all gray level frequencies, which is lower than the mean value. If it is more than the maximum count of pixels then we identify the maximum value of gray level frequency value and subtract the difference from it. By this way we try to keep a maximum number of frequencies is more or less or almost equal to the maximum count of pixels of the image. Because of round off calculations, there may be a small scale or very small difference in the maximum count of frequencies. We neglect these small differences. The NHE produces more range of intensity levels compare to GHE. Some of the comparisons of NHE and GHE are shown in Table 1.

Table 1: Comparison between NHE and GHE

Sr. No	NHE	GHE
1	Gray level frequencies or accumulations are more or less equal	Some Gray level count of frequencies or accumulations dominates over small gray level

		frequencies count.
2	Produces more range of intensity levels.	Produces less range of intensity levels.
3	The Brightness of the image is average, neither high nor less.	Some part of the image having high brightness.
4	Washout appearance is reduced maximum extent.	Washout appearance of the small part of the image is more.

6. EXPERIMENTAL RESULTS :

The algorithm for Novel Histogram Equalization mentioned above is implemented using MATLAB 2015a. In this section, we will compare proposed NHE with GHE to know the performances of the enhancement techniques. In figure 5 (a) low contrast boy image enhancement or contrast adjustment is done using Global Histogram Equalization (GHE) and Novel Histogram Equalization (NHE). In GHE is image becomes brighter but contrast is not adjusted as much as an image obtained through NHE.

(a) Original image [5] (b) GHE image (c) NHE

Fig. 5: Contrast adjustment outputs for a boy image (a) original image (b) GHE image (c) NHE image (using proposed method)

In Figure 6 (a) grayscale image of a lion is considered for testing. Initially, GHE equalization is done for initial lion image. The lion image becomes brighter but background grass is not clear in GHE. But which is clearer in NHE and also contrast is more adjusted.

Original image [5]	GHE image	(c) NHE

Fig. 6: Contrast adjustment outputs for a lion image (a) original image (b) GHE image (c) NHE image (using proposed method)

The real power of the NHE method we can observe in Figure 7. The butterfly is sitting in a flower. The flower image in GHE has become brighter and its contrast is lost. In figure 7 (c), even though flower image is not too bright it has good contrast compare to GHE image.

Original image [5]	GHE image	(c) NHE

Fig. 7: Contrast adjustment outputs for a butterfly with background flower image (a) original image (b) GHE image (c) NHE image (using proposed method)

7. SNAPSHOT OF THE CODING OF NHE USING MATLAB PROGRAMMING :

Figure 8 shows the snap shot of the Novel Histogram equalization MATLAB coding. In this snapshot we focus mainly the code of proposed method, without giving emphasis on Global Histogram Equalization (GHE) steps.

```
global in
%Load the image of any size (input)
[fi,p]=uigetfile('\Contrast Adjustment\*','.*');
in=imread([p fi]);
% convert the input image to gray scale
in=rgb2gray(in);
%Resize the image into 256 × 256 sized gray scale intensity image
in=imresize(in,[256 256]);
normalizedImage =in;
%freq counts the occurrence of each pixel value.
freq=zeros(256,1);
%Find the frequency of the each gray level
for i=1:size(normalizedImage,1)
    for j=1:size(normalizedImage,2)
        value=normalizedImage(i,j);
        freq(value+1)=freq(value+1)+1;

    end
end
  %Find mean of frequencies
  mean1=round(mean(freq,1));
for i=1:size(freq,1)
     %Find the frequency of intensity levels > mean
      if freq(i)>mean1
      %Find the difference value of frequency  and mean of Frequency
         remaining=freq(i)-mean1;
         remain=round(remaining/mean1);
      %Assign the value of mean to freq[i]
         freq(i)=mean1;
      % Move from initial gray level frequency to last gray level frequency
      % and add the remaining value to all intensity levels equally
          for v=1:size(freq,1)
            freq(v)=freq(v)+remain;
         end
     end
end
```

```
numofpixels=size(normalizedImage,1)*size(normalizedImage,2);
s=0;
%find summation of all frequencies and difference value of maximum
%number of pixels and sum of frequency
s=numofpixels-sum(freq,1);
%if the difference greater than or equal to 1
%(sum_freq less than maximum number of pixels)
if s >=1
%Initialize a count for finding number of gray levels less than mean value
 count=0;
   for i=1:size(freq,1)
     if freq(i)< mean1
       count=count+1;
     end
   end
```

```
%Divide the difference by count assign this value to all gray levels
%frequencies whose value is less than mean value
  snew=round(s/count);
for v=1:size(freq,1)
    if freq(v)< mean1
     freq(v)=freq(v)+snew;
    end
end
end
%if difference found in step 11 is less than 0 (sum_freq greater
%than maximum number of pixels)
if s<0
  s=abs(s);
%Find the maximum frequency gray level
  t=max(freq,1);
 %Locate the maximum frequency gray level and subtract the
 %difference value from it.
  for i=1:size(freq,1)
      if t==freq(i);
       freq(i)=freq(i)-t;
      end
  end
end
```

Fig. 8: Snapshot of MATLAB coding for Novel Histogram Equalization (NHE)

8. CONCLUSION :

Contrast adjustment is a critical aspect or an important part of the enhancement or filtering process in image processing or recognition system. Their many variations of Global histogram equalization are mentioned in the literature. The new approach used in this study-Novel histogram equalization mainly focuses on controlling the dominating gray levels in terms of accumulations or frequencies over other small gray levels accumulations and making all gray levels more or less equal. This study also focuses on improving or adjusting the contrast of the image. This new method is computationally also simple to implement and any image processing applications easily can adopt this method. The limitation of the study is:

- In this study, the method is only implemented for a gray level image with size 256 x 256.

- The contrast adjustment is not too good but better than GHE
- Not works well with color image.
- More testing is required in order to generalize this approach.

In this study, a true attempt is made to improve the GHE method in terms of improving or adjusting the contrast of the 256 x 256 sized grayscale image.

REFERENCES :

[1] Gonzalez, R. C., Woods, R. W. (2002). *Digital Image Processing*. *Education*. DOI: https://doi.org/10.1049/ep.1978.0474.

[2] Jain, A. K. (1989). *Fundamentals of Digital Image Processing*. *Portalacmorg* (Vol. 14). DOI: https://doi.org/10.1002/9780470689776.

[3] Zimmerman, J. B., Pizer, S. M., Staab, E. V., Perry, J. R., Mccartney, W., & Brenton, B. C. (1988). An Evaluation of the Effectiveness of Adaptive Histogram Equalization for Contrast Enhancement. *IEEE Transactions on Medical Imaging*, 7(4), 304–312. DOI: https://doi.org/10.1109/42.14513.

[4] Kim, Y. T. (1997). Contrast enhancement using brightness preserving bi-histogram equalization. *IEEE Transactions on Consumer Electronics*, 43(1), 1–8. DOI: https://doi.org/10.1109/30.580378.

[5] https://images.google.com/. (2017). Google. [online] Available at: https://images.google.com/ Low contrast Gray scale images [Accessed 15 September 2017].

[6] Pei, S. C., Zeng, Y. C., & Chang, C. H. (2004). Virtual restoration of ancient Chinese paintings using color contrast enhancement and Lacuna texture synthesis. *IEEE Transactions on Image Processing*, 13(3), 416–429. DOI: https://doi.org/10.1109/TIP.2003.821347.

[7] Wahab, A., Chin, S., & Tan, E. (1998). Novel approach to automated fingerprint recognition. *IEE Proceedings - Vision, Image and Signal Processing*. DOI: https://doi.org/10.1049/ip-vis:19981809.

[8] De La Torre, Á., Peinado, A. M., Segura, J. C., Pérez-Córdoba, J. L., Benítez, M. C., & Rubio, A. J. (2005). Histogram equalization of speech representation for robust speech recognition. *IEEE Transactions on Speech and Audio Processing*, 13(3), 355–366. DOI: https://doi.org/10.1109/TSA.2005.845805.

[9] Pizer, S. M. (2003). The Medical Image Display and Analysis Group at the University of North Carolina: Reminiscences and philosophy. *Medical Imaging, IEEE Transactions on*, 22(1), 2–10. DOI: https://doi.org/10.1109/TMI.2003.809707.

[10] Ziaei, A., Yeganeh, H., Faez, K., & Sargolzaei, S. (2008). A novel approach for contrast enhancement in biomedical images based on histogram equalization. In *International Conference on Computer and Communication Engineering 2008* (Vol. 1, pp. 855–858). DOI: https://doi.org/10.1109/BMEI.2008.300.

[11] Krishna Prasad, K. & Aithal, P. S. (2017). A Conceptual Study on Image Enhancement Techniques for Fingerprint Images. *International Journal of Applied Engineering and Management Letters (IJAEML)*, 1(1), 63-72. DOI: http://dx.doi.org/10.5281/zenodo.831678.

[12] Krishna Prasad, K. & Aithal, P. S. (2017). Literature Review on Fingerprint Level 1 and Level 2 Features Enhancement to Improve Quality of Image. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, 2(2), 8-19. DOI: http://dx.doi.org/10.5281/zenodo.835608.

[13] Krishna Prasad, K. & Aithal, P. S. (2017). Fingerprint Image Segmentation: A Review of State of the Art Techniques. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, 2(2), 28-39. DOI: http://dx.doi.org/10.5281/zenodo.848191.

[14] Lau, S. S. Y. (1994). Global image enhancement using local information. *Electronics Letters*, 30(2), 122–123. DOI: https://doi.org/10.1049/el:19940081.

[15] Kim, Y.-T. (1997). Quantized bi-histogram equalization. *Acoustics, Speech, and Signal Processing, 1997. ICASSP-97., 1997 IEEE International Conference on*, 4, 2797–2800 vol.4. DOI: https://doi.org/10.1109/ICASSP.1997.595370.

[16] Zhang, Y. J. (1992). Improving the accuracy of direct histogram specification. *Electronics Letters*, 28(3), 213-214.

[17] Xu, J., Zhang, Z., Xiao, X., Yang, Y., Yu, G., & Winslett, M. (2013). Differentially private histogram publication. *VLDB Journal*, 22(6), 797–822. DOI: https://doi.org/10.1007/s00778-013-0309-y.

[18] Yao, Z., Lai, Z., & Wang, C. (2017). Image Enhancement Based on Equal Area Dualistic Sub-image and Non-parametric Modified Histogram Equalization Method. In *Proceedings - 2016 9th International Symposium on Computational Intelligence and Design, ISCID 2016* (Vol. 1, pp. 447–450). https://doi.org/10.1109/ISCID.2016.1110.

[19] Chen, S. Der, & Ramli, A. R. (2003). Contrast enhancement using recursive mean-separate histogram equalization for scalable brightness preservation. *IEEE Transactions on Consumer Electronics*, 49(4), 1301–1309. DOI: https://doi.org/10.1109/TCE.2003.1261233.

[20] Chen, S. Der, & Ramli, A. R. (2003). Minimum mean brightness error bi-histogram equalization in contrast enhancement. *IEEE Transactions on Consumer Electronics*, 49(4), 1310–1319.DOI: https://doi.org/10.1109/TCE.2003.1261234.

[21] Chi-Chia, S., Shanq-Jang, R., Mon-Chau, S., & Tun-Wen, P. (2005). Dynamic contrast enhancement based on histogram specification. *Consumer Electronics, IEEE Transactions on*, 51(4), 1300–1305. DOI: https://doi.org/10.1109/TCE.2005.1561859.

[22] Abdullah-Al-Wadud, M., Kabir, M., Akber Dewan, M., & Chae, O. (2007). A Dynamic Histogram Equalization for Image Contrast Enhancement. *IEEE Transactions on Consumer Electronics*, 53(2), 593–600. DOI: https://doi.org/10.1109/TCE.2007.381734.

[23] Jagatheeswari, P., Kumar, S. S., & Rajaram, M. (2009). Contrast stretching recursively separated histogram equalization for brightness preservation and contrast enhancement. In *ACT 2009 - International Conference on Advances in Computing, Control and Telecommunication Technologies* (pp. 111–115). DOI: https://doi.org/10.1109/ACT.2009.37.

[24] Wongsritong, K., Kittayaruasiriwat, K., Cheevasuvit, F., Dejhan, K., & Somboonkaew, A. (1998, November). Contrast enhancement using multipeak histogram equalization with brightness preserving. In *Circuits and Systems, 1998. IEEE APCCAS 1998. The 1998 IEEE Asia-Pacific Conference on* (pp. 455-458). IEEE.

[25] Sengee, N., & Choi, H. K. (2008). Brightness preserving weight clustering histogram equalization. *IEEE Transactions on Consumer Electronics*, 54(3), 1329–1337. DOI: https://doi.org/10.1109/TCE.2008.4637624.

[26] Ibrahim, H., & Kong, N. S. P. (2007). Brightness preserving dynamic histogram equalization for image contrast enhancement. *IEEE Transactions on Consumer Electronics*, 53(4), 1752–1758. DOI: https://doi.org/10.1109/TCE.2007.4429280.

[27] Ibrahim, Haidi. "Histogram equalization with range offset for brightness preserved image enhancement." *International Journal of Image Processing (IJIP)* 5, no. 5 (2011): 599-609.

[28] Abdullah-Al-Wadud, M. (2012). A modified histogram equalization for contrast enhancement preserving the small parts in images. *International Journal of Computer Science and Network Security (IJCSNS)*, 12(2), 1.

******