Image Enhancement by Histogram Processing

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Image Histogram

The Histogram of an image is a Graph of Gray Value Vs Frequency of Gray Value in the image

It gives the distribution of grey levels in the image.

Histogram provides a global description of the appearance of an image. Information obtained from histogram is very large in quality.

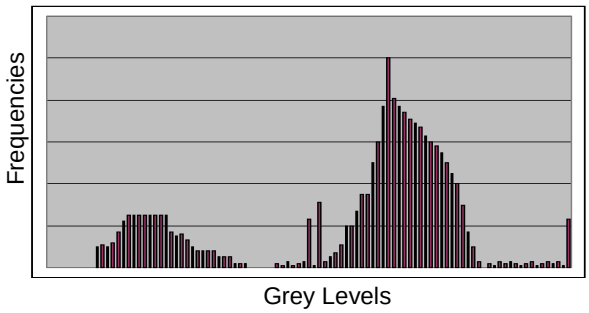
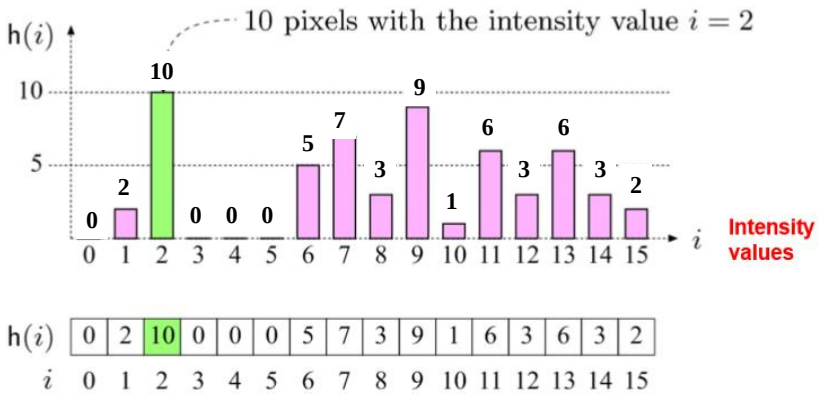


Image Histogram



$h(i)$	0	2	10	0	0	0	5	7	3	9	1	6	3	6	3	2
i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

- Histograms: only statistical information
- No indication of pixels locations

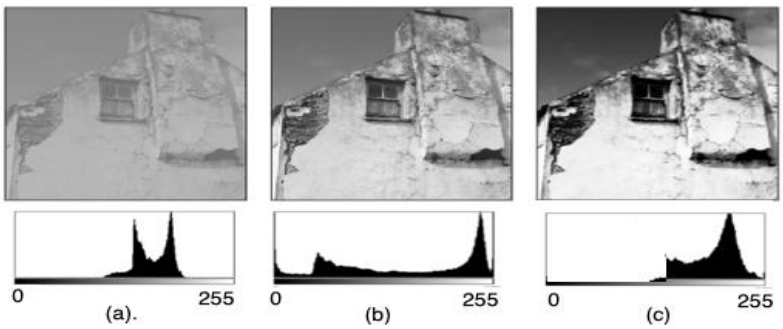
Image Contrast

The contrast of a grayscale image indicates how easily objects in the image can be distinguished

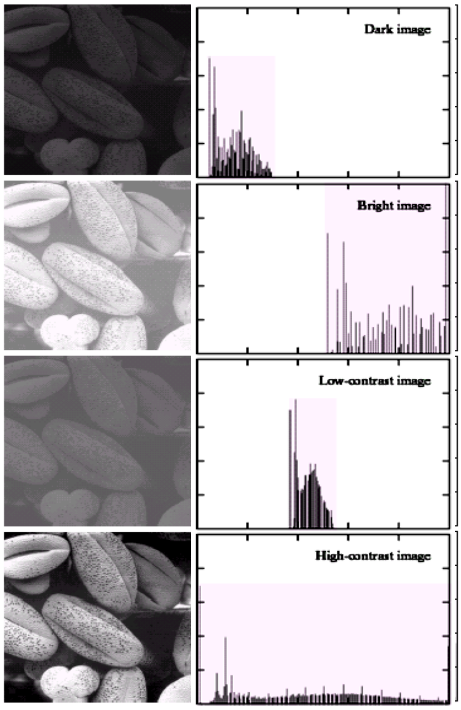
- **High contrast image:** many distinct intensity values.
- **Low contrast:** image uses few intensity values.

Histograms and Contrast

Good Contrast?
Widely spread intensity values & large difference between min and max intensity values



Low contrast Normal contrast High contrast



Dark Image
Low contrast

Bright Image
Low contrast

Low contrast

Poor Quality
Image

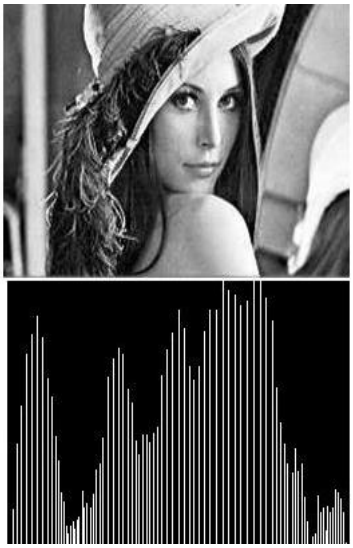
Wide contrast
Good Quality Image

Image Enhancement by Histogram Processing :

(i) Histogram of dark image, bright image and low contrast image is **narrow**

(ii) This can be done by adjusting the Probability Density Function (PDF) of the original Histogram of the image so that the Probability spreads equally

Example :



(iii) Histogram Processing involves the modification of input image histogram to increase the dynamic range of gray values

(iv) This improves the visual quality of image on display device

[1] Histogram Equalization

(i) Histogram Equalization Tx increases dynamic range of gray levels of input image so that they are evenly distributed.

(ii) The histogram of the output image is almost uniform over the entire range of gray levels.

(iii) In Histogram Equalization, output image is obtained by mapping each pixel with value rk in the input image into a corresponding pixel with value Sk in the output image.

Histogram Equalisation

The formula for histogram equalisation is given where

- r_k: input intensity
- s_k: processed intensity
- k: the intensity range (e.g 0.0 – 1.0)
- N_j: the frequency of intensity *j*
- N: the sum of all frequencies

$$s_k = T(r_k) = \sum_{i-1}^{k} p_r(r_j) = \sum_{j=1}^{k} \frac{N_j}{N}$$

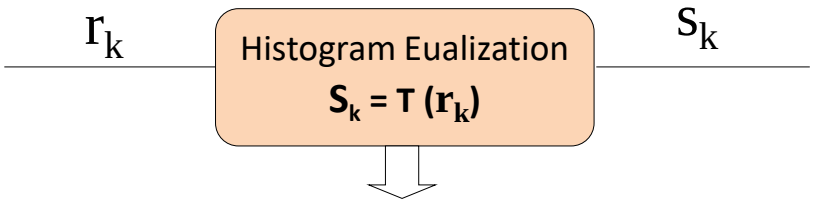
For Example : Consider 3 bit image F such that,
F(x,y) = | x – y | for x,y = 0,1,2,3,4,5,6,7

X \ Y	0	1	2	3	4	5	6	7
0	0	1	2	3	4	5	6	7
1	1	0	1	2	3	4	5	6
2	2	1	0	1	2	3	4	5
3	3	2	1	0	1	2	3	4
4	4	3	2	1	0	1	2	3
5	5	4	3	2	1	0	1	2
6	6	5	4	3	2	1	0	1
7	7	6	5	4	3	2	1	0

Frequency Table

INPUT r_k	Freq. Nr_k
0	8
1	14
2	12
3	10
4	8
5	6
6	4
7	2

- **Step-1 : Equalize Histogram**



$$S_k = \sum_{j=0}^{k} P_r(z_j)$$

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INPUT rk	Norm rk	Freq. Nr_k	PDF Pr	CDF S_k	Equalized Gray Value S_k
0	0	8	0.125	0.125	1
1	1/7	14	0.219	0.344	2
2	2/7	12	0.187	0.531	4
3	3/7	10	0.156	0.687	5
4	4/7	8	0.125	0.812	6
5	5/7	6	0.094	0.906	7
6	6/7	4	0.063	0.969	7
7	1	2	0.031	1	7

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Step-2 : Find Output Image

Replace every r_k by the corresponding value of S_k

INPUT r_k	Equalized Gray Value S_k
0	1
1	2
2	4
3	5
4	6
5,6,7	7

F=

0	1	2	3	4	5	6	7
1	0	1	2	3	4	5	6
2	1	0	1	2	3	4	5
3	2	1	0	1	2	3	4
4	3	2	1	0	1	2	3
5	4	3	2	1	0	1	2
6	5	4	3	2	1	0	1
7	6	5	4	3	2	1	0

Input Image

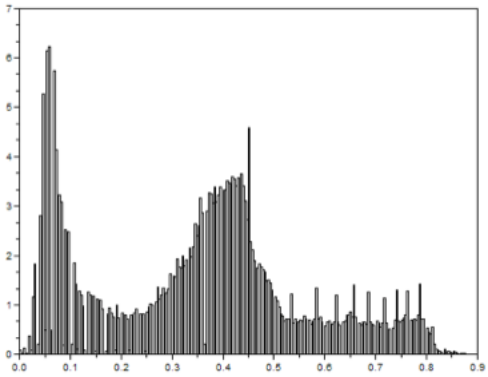
A=

1	2	4	5	6	7	7	7
2	1	2	4	5	6	7	7
4	2	1	2	4	5	6	7
5	4	2	1	2	4	5	6
6	5	4	2	1	2	4	5
7	6	5	4	2	1	2	4
7	7	6	5	4	2	1	2
7	7	7	6	5	4	2	1

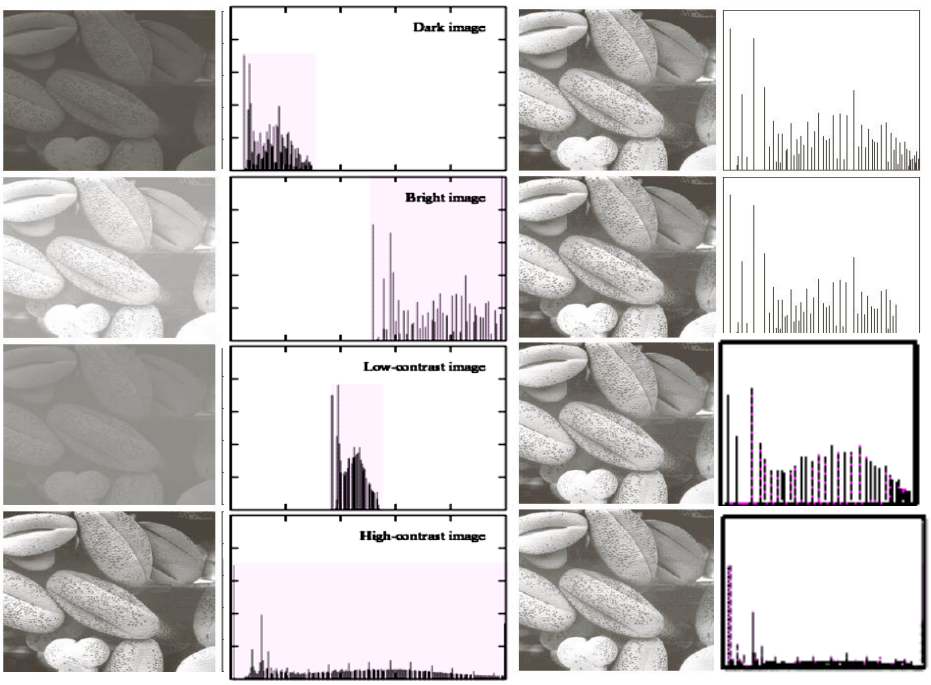
Equalized Output Image

Example :

Image



Histogram : (Good contrast)



[2] Histogram Specification

(i) Histogram Specification Tx modifies histogram of input image as per the specified image histogram.

(ii) Histogram of the output image closely matches with the histogram of the specified image.

Histogram Specification Algorithm

(I) **Equalize Histogram A**

$S_k = T(r_k)$

$$S_k = \sum_{j=0}^{k} P_r(r_j)$$

(II) **Equalize Histogram B**

$v_k = T(z_k)$

$$V_k = \sum_{j=0}^{k} P_r(z_j)$$

Histogram Specification Algorithm…..

(III) Equalize Histogram A as per Histogram B

Express Z_k as a function of r_k

$Z_k = G^{-1} (V_k)$

Now, Equate S_k with V_k

Put V_k = Appropriate value of S_k

$Z_k = G^{-1} (S_k)$

Put $S_k = T (r_k)$

$Z_k = G^{-1} [T (r_k)]$

Q1 Histogram of Input Image A is given below.

(a) Modify the histogram A as given in histogram B.

(b) Plot the histogram of the Input and Output Image.

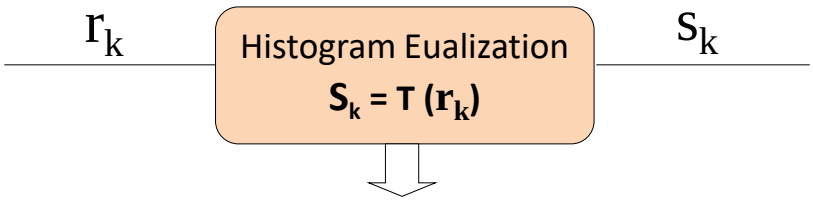
- **Input Image Histogram (A) :**

Gray Level r_k	0	1	2	3	4	5	6	7
No of Pixels N_{rK}	790	1023	850	656	329	245	122	81

- **Specified Histogram (B) :**

Gray Level Z_k	0	1	2	3	4	5	6	7
No of Pixels N_{ZK}	0	0	0	614	819	1230	819	614

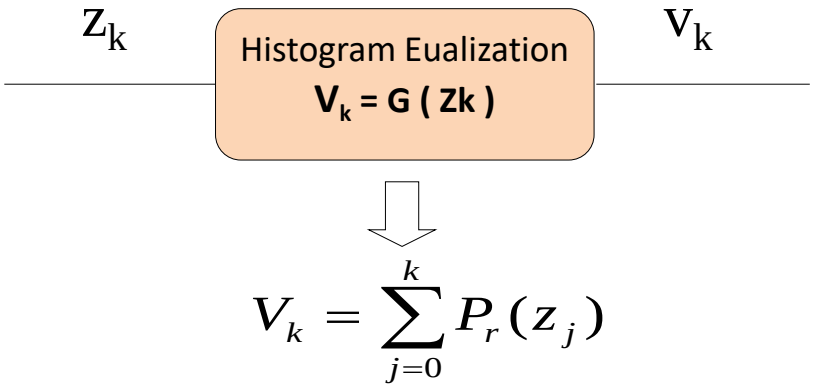
- **Step-1 : Equalize Input Image Histogram A**



$$S_k = \sum_{j=0}^{k} P_r(r_j)$$

INPUT **rk**	Norm **rk**	Freq. Nr_k	PDF Pr	CDF S_k	Equalized Gray Value S_k
0	0	**790**	**0.192**	**0.192**	**1**
1	1/7	**1023**	**0.249**	**0.441**	**3**
2	2/7	**850**	**0.207**	**0.648**	**5**
3	3/7	**656**	**0.160**	**0.808**	**6**
4	4/7	**329**	**0.080**	**0.888**	**6**
5	5/7	**245**	**0.059**	**0.947**	**7**
6	6/7	**122**	**0.029**	**0.976**	**7**
7	1	**81**	**0.019**	**1**	**7**

- **Step-2** : Equalize Specified Histogram **B**



$$V_k = \sum_{j=0}^{k} P_r(z_j)$$

INPUT Zk	Norm Zk	Freq. Nz_k	PDF Pr	CDF V_k	Equalized V_k
0	0	0	0	0	0
1	1/7	0	0	0	0
2	2/7	0	0	0	0
3	3/7	614	0.150	0.150	1
4	4/7	819	0.200	0.350	2
5	5/7	1230	0.300	0.650	5
6	6/7	819	0.200	0.850	6
7	1	614	0.150	1.00	7

- **Step-3** : Equalize Histogram A as per Histogram B

Express Z_k as a function of r_k $Z_k = G^{-1}[T(r_k)]$

Col 1 Col 2 Col 3 Col 4 Col 5

INPUT rk	Equalized Sk	Closest V_k	Inverse Z_k	Freq. of Z_k In the output Image N_k
0	1	1	3	790
1	3	2	4	1023
2	5	5	5	850
3 , 4	6	6	6	985
5, 6, 7	7	7	7	448

- **Step-4** : Find Frequency Table of Output Image

Output Image Gray Value : Z_k	Freq. of Z_k In the output Image N_k
0	0
1	0
2	0
3	790
4	1023
5	850
6	985
7	448

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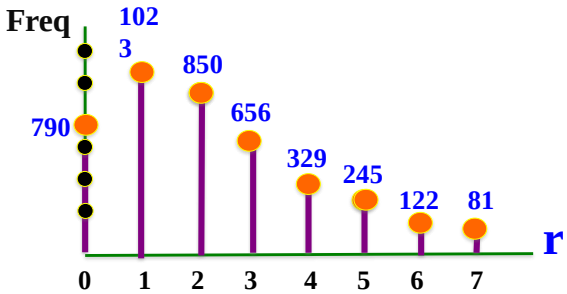
Input Histogram (A) and Equalized Histogram

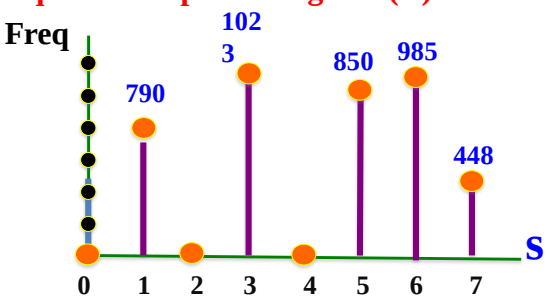
rk	Nr_k
0	790
1	1023
2	850
3	656
4	329
5	245
6	122
7	81

Sk	Ns_k
0	0
1	790
2	0
3	1023
4	0
5	850
6	985
7	448

Input Histogram (A) :



Equalized Input Histogram (A)

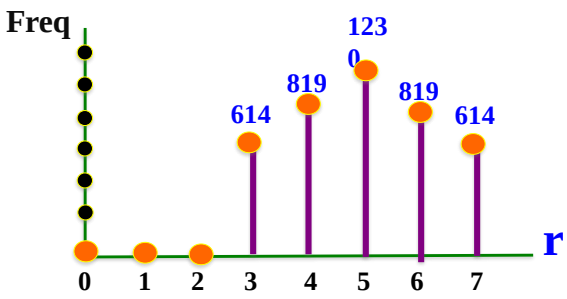


Specified Histogram (B) & Equalized Histogram

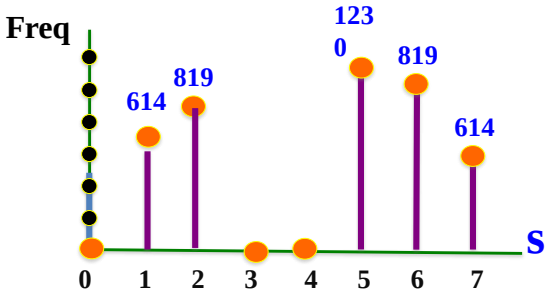
Zk	Nz_k
0	0
1	0
2	0
3	614
4	819
5	1230
6	819
7	614

Vk	Nv_k
0	0
1	614
2	819
3	0
4	0
5	1230
6	819
7	614

Specified Histogram (B) :



Equalized Histogram (B) :

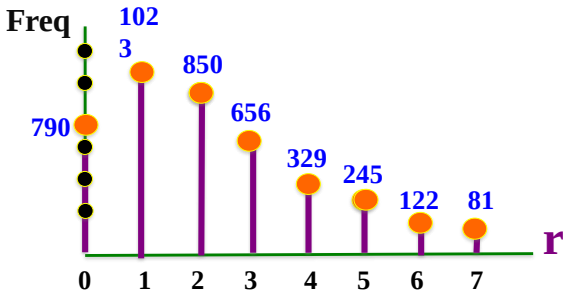


Input Histogram (A) and Equalized Histogram as per B

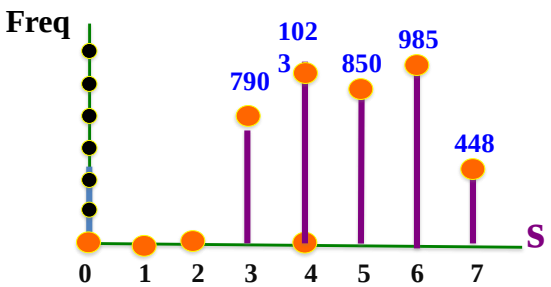
rk	Nr_k
0	790
1	1023
2	850
3	656
4	329
5	245
6	122
7	81

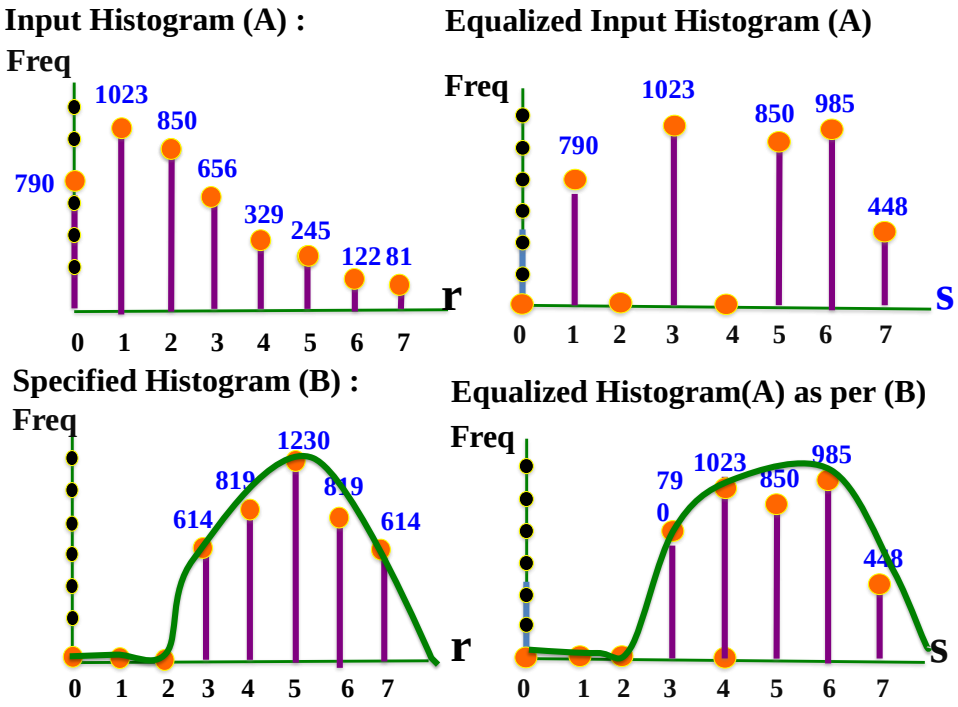
Zk	Nz_k
0	0
1	0
2	0
3	790
4	1023
5	850
6	985
7	448

Input Histogram (A) :



Equalized Input Histogram as per (B)





[3] Histogram Stretching

Histogram Stretching Tx increases the dynamic range of Gray values of input image linearly.

Eg **Frequency table of 3 bit input image is given below. Increase the dynamic range to [0 to 7] and find new image frequency table.**

Gray Level r_k	0	1	2	3	4	5	6	7
Frequency N_{rk}	100	90	85	70	0	0	0	0

[4] Local Histogram Equalization

Local HE is done by applying Transformation function over the intensity distribution in neighborhood of every pixel

At each pixel, Histogram of the points in the neighbourhood is computed and either Histogram equalization or Histogram Specification is either obtained

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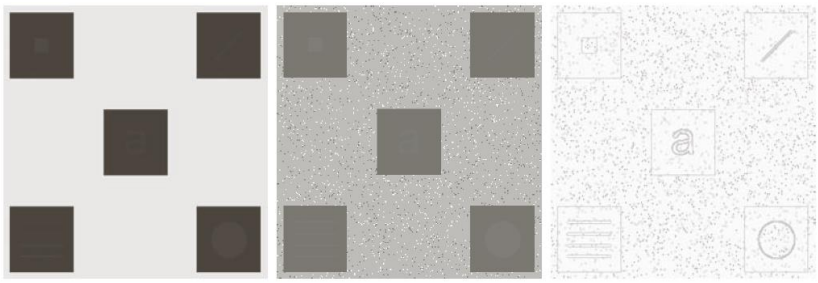
Local Histogram Processing….



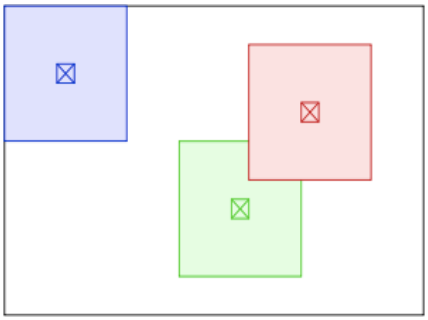
a b c

(a) Original Image (b) Result of Global HE (c) Result of Local HE

- Image in (a) is slightly noisy but the noise is imperceptible.
- HE enhances the noise in smooth regions (b).
- Local HE reveals structures having values close to the values of the squares and small sizes to influence HE (c).

[4] Adaptive Histogram Equalization (AHE)

The adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image.



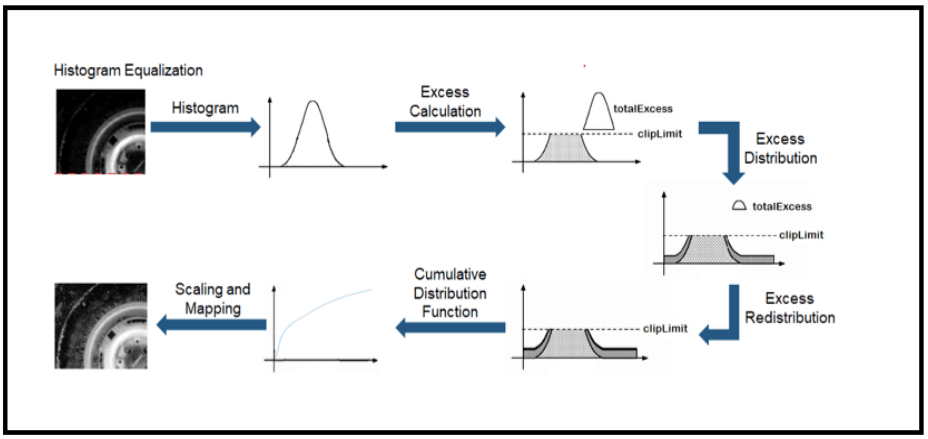
It is therefore suitable for improving the local contrast and enhancing the definitions of edges in each region of an image.

[6] Contrast Limited Adaptive Histogram Equalization (CLAHE)

CLAHE is a variation of Adaptive histogram equalization (AHE) that prevents contrast over-amplification.

The input image is first divided into sections. Each section is called a tile. The input image is divided into four tiles. Histogram equalization is then performed on each tile using a pre-defined clip limit.

Histogram equalization is then performed on each tile using a pre-defined clip limit.



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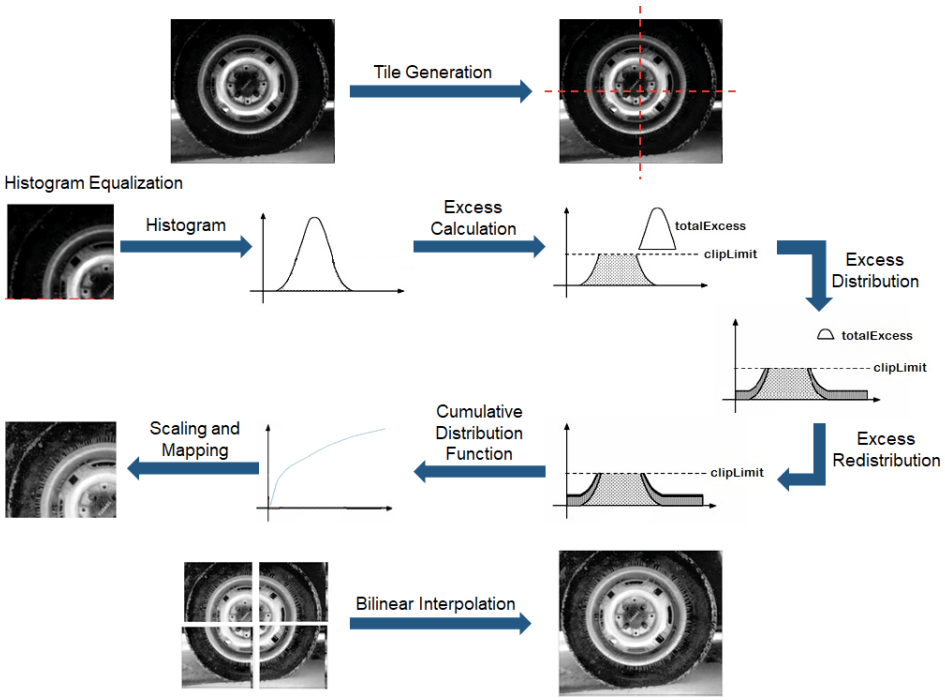
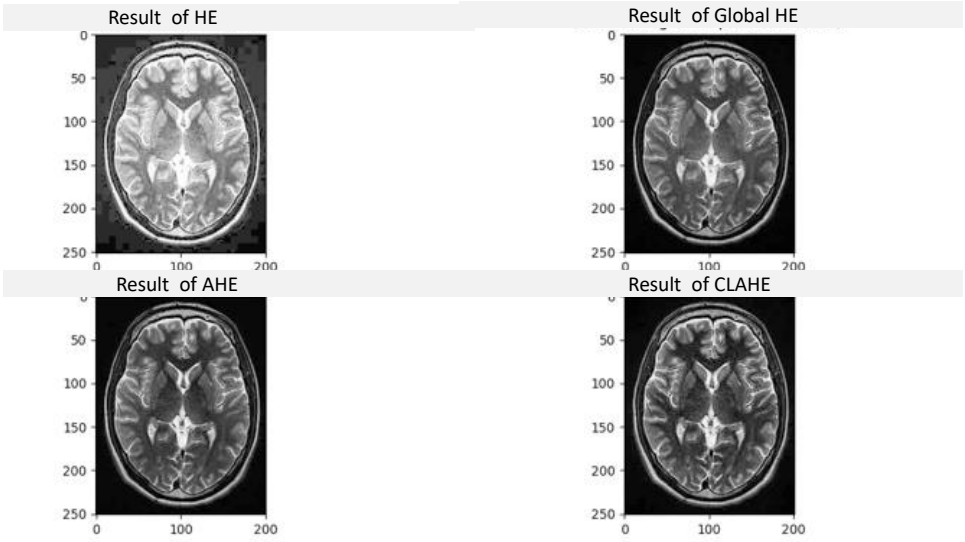
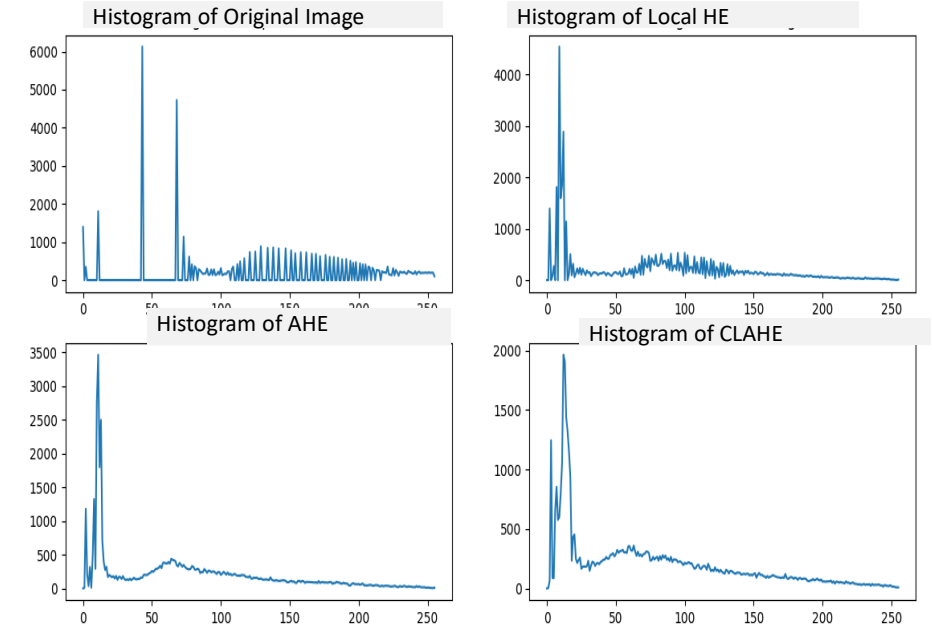


Results of HE, Local HE, AHE and CLAHE:





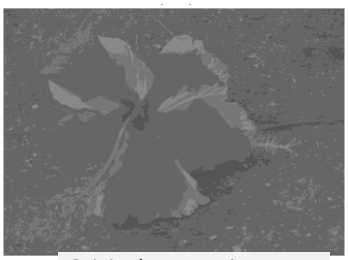
[7] Gray Level Grouping (GLG)

. Group the histogram components into a proper number of gray-level *bins* according to their amplitudes

- This creates empty gray levels on the grayscale
- Redistribute these groups of histogram components *uniformly* over the grayscale.
- The concentrated histogram components spread out and image contrast is increased.
- **The grayscale is utilized efficiently**
- **Over-contrast problem is also avoided**.

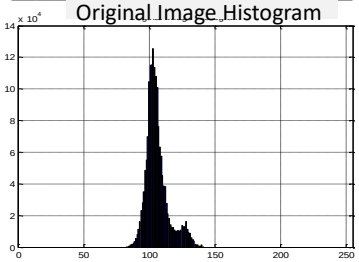
Gray Level Grouping (GLG)….

Original Image

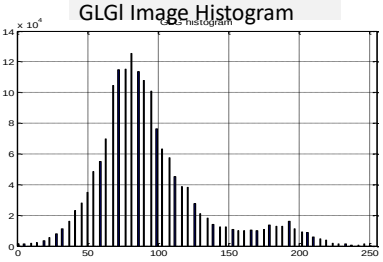


GLG Image

Original Image Histogram



GLGI Image Histogram



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- **Dr. Kiran TALELE** is an Associate Professor in Electronics & Telecommunication Engineering Department of Bharatiya Vidya Bhavans' Sardar Patel Institute of Technology, Mumbai with 33+ years experience in Academics.
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- He is a Treasurer of IEEE Bombay Section and Mentor for Startup Incubation & Intellectual Asset Creation.
- He received incentives for excellent performance in academics and research from Management of S.P.I.T. in 2008-09. He is a recipient of P.R. Bapat IEEE Bombay Section Outstanding Volunteer Award 2019.


Thank
you