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# Review of Histogram Equalization Techniques

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***Abstract*—Histogram Equalization is a technique that is basically used for Image Enhancement. It is a simple and effective technique that applied to the images captured in bright or dark environment thus becomes the low contrast images. The basic purpose of histogram is to produce the output image, which is much better in the form of appearance than the input image. This paper presents what is histogram and how it is being applied to the image for its enhancement and techniques used to perform Histogram Equalization (HE).**

***Keywords*—Histogram, Image Enhancement, Histogram Equalization(HE).**

## I. INTRODUCTION

Image Enhancement is a process used to make the output images look better by choosing the intensity values of pixels of the input images. Image Enhancement is one of the most important area used in digital image processing. Its main purpose is to improve the quality of output image by highlighting some specific features of image but it does not mean that Image Enhancement will add some information content to the image.

There exist various applications in which image enhancement is used. For example Medical research, in industries, military, textiles etc. Examples of Image enhancement is Sharpening, Noise Filtering, Edge Enhancement, Contrast Enhancement etc. Histogram Equalization is the approach of Contrast enhancement.

## II. HISTOGRAM

In general form, Histogram means representing the frequency in a graphical view. Histogram of a digital image can be defined as a discrete function with gray level in range[0,L-1] as,

$$h(r_k) = n_k$$

where,

$r_k$=the kth gray level.

$n_k$=no.of pixels in digital image having rk.

h=histogram of digital image

Before moving to further, lets having view on different types of images.

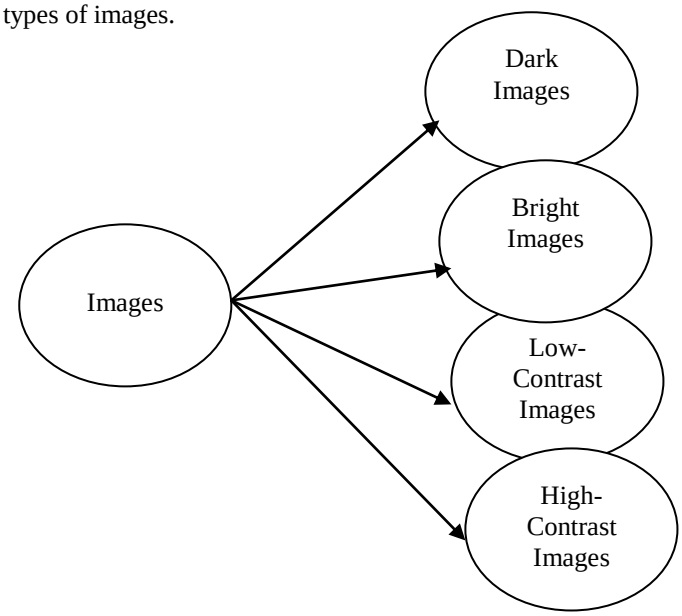



Fig 1.Types of Images

### A. *Dark Images*

Dark images are the images where components are inserted at low side of $r_k$.

$h(r_k)$

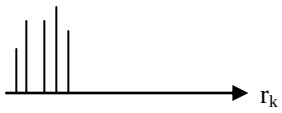



*Fig 2. Dark Images*

*B. Bright Images*

Bright images are the images where components are inserted on high side of $r_k$.

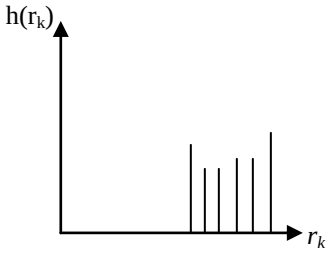



*Fig 3.Bright Images*

*C. Low-Contrast Iimages*

Low-Contrast images are the images where components are inserted at centered of $r_k$.

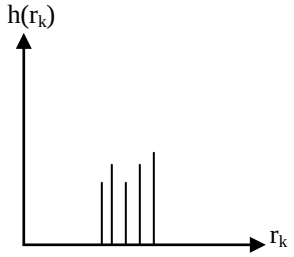



*Fig 4.Low-Contrast Images*

*D. High-Contrast Images*

High-Contrast Images are the images where components spread equally with very few vertical line not equal.

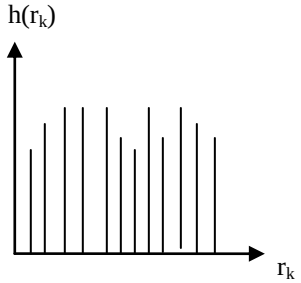



*Fig 5.High-Contrast Images*

*Example*—Let's take 4*4 sized image and performing histogram on it.

| | | | |
|---|---|---|---|
| 3 | 4 | 2 | 4 |
| 2 | 3 | 3 | 5 |
| 3 | 2 | 5 | 3 |
| 5 | 4 | 2 | 4 |

gray scale($r_k$)=[0,9]

$r_k$(gray level) $n_k$(no.of pixels repeated)

2 4
3 5
4 4
5 3

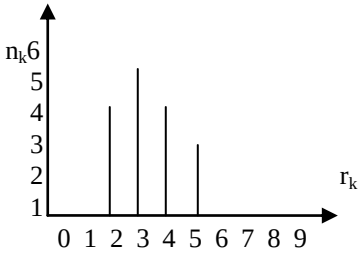



*Fig 6.Histogram of 4*4 Sized image*

## III . NORMALIZED HISTOGRAM

Normalized Histogram $p(r_k)$ can be defined as dividing for each histogram at $r_k$ (gray level) by the total no. of pixels (n) available in the image.

$$p(r_k) = n_k/n$$

The fact is that the sum of all its components are always equal to 1.

Let's continue the previous example by applying the normalized histogram.

| | | | |
|---|---|---|---|
| 3 | 4 | 2 | 4 |
| 2 | 3 | 3 | 5 |
| 3 | 2 | 5 | 3 |
| 5 | 4 | 2 | 4 |

Gray scale ($n_k$)=[0,9]

| $p(r_k)$ | $n_k/n$ |
|---|---|
| p(2) | 4/16 |
| p(3) | 5/16 |
| p(4) | 4/16 |
| p(5) | 3/16 |

where n is 16 as we are taking 4*4 sized image. So total components are16.

SUM=4/16+5/16+4/16+3/16
SUM=1

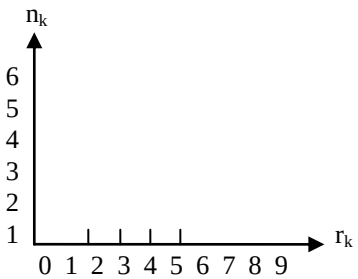



*Fig 7. Normalized Histogram*

## IV.HISTOGRAM EQUALIZATION

Histogram Equalization (HE) can be performed by distributing the histogram to a wider range of quality by adjusting the density function,

$$h(r_k)=n_k,$$

So that it spreads equally. Following figure shows the histogram equalization performed on a image histogram.

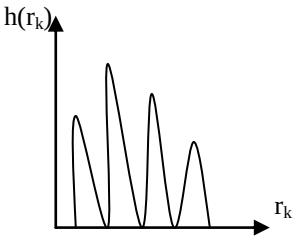
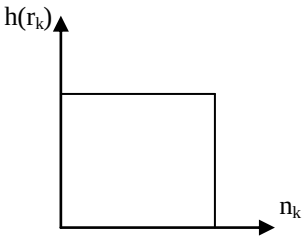



*Fig 8..Histogram*




*Histogram Equalization*

*Example—*

| | | | |
|---|---|---|---|
| 3 | 4 | 2 | 4 |
| 2 | 3 | 3 | 5 |
| 3 | 2 | 5 | 3 |
| 5 | 4 | 2 | 4 |

gray scale($r_k$)=[0,9]

| $r_k$(gray level) | $n_k$(no.of pixels repeated) |
|---|---|
| 2 | 4 |
| 3 | 5 |
| 4 | 4 |
| 5 | 3 |

| Gray Level (j) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| No.of pixels ($n_k$) | 0 | 0 | 4 | 5 | 4 | 3 | 0 | 0 | 0 | 0 |
| $\sum_{j=0}^{k} n_j$ | 0 | 0 | 4 | 9 | 13 | 16 | 16 | 16 | 16 | |
| $S = \sum_{j=0}^{k} n_j/n$ | 0 | 0 | $\frac{4}{16}$ | $\frac{9}{16}$ | $\frac{13}{16}$ | $\frac{16}{16}$ | $\frac{16}{16}$ | $\frac{16}{16}$ | $\frac{16}{16}$ | |
| S*9 | 0 | 0 | 3 | 5 | 8 | 9 | 9 | 9 | 9 | |

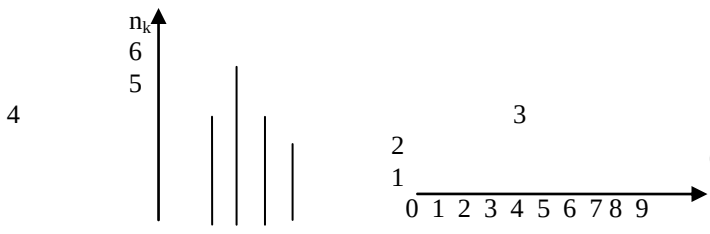



*Fig 9.Output Image*

The output image is shown above. Now let's perform equalization on this outputted image.

| Gray Level (j) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| No.of pixels ($n_k$) | 0 | 0 | 0 | 4 | 0 | 5 | 0 | 0 | 4 | 3 |
| $\sum_{j=0}^{k} n_j$ | 0 | 0 | 0 | 4 | 4 | 9 | 9 | 9 | 13 | 16 |
| $S = \sum_{j=0}^{k} n_j/n$ | 0 | 0 | 0 | $\frac{4}{16}$ | $\frac{4}{16}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{13}{16}$ | $\frac{13}{16}$ |
| S*9 | 0 | 0 | 0 | 3 | 3 | 5 | 5 | 5 | 8 | 9 |

| | | | |
|---|---|---|---|
| 5 | 8 | 3 | 8 |
| 3 | 5 | 5 | 9 |
| 5 | 3 | 9 | 5 |
| 9 | 8 | 3 | 8 |

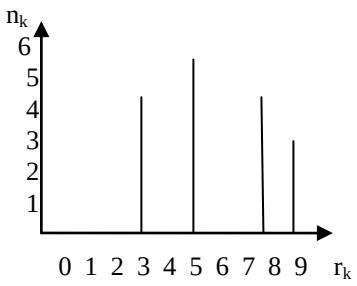



*Fig 10.Output Image*

## V.HISTOGRAM EQUALIZATION TECHNIQUES

### *A. Local Histogram Equalization*

In this technique, a small window is traversed over every pixel of image .Which enhance the contrast by applying local function based on intensity value of pixel and its neighboring pixels. It majorly works for enhancement of local texture of image.

It is also known as Adaptive Histogram Equalization.

*1) Methods of LHE are :*

Non-Overlapped Block HE(NOBHE)
Block Overlapped HE (BOHE)
Interpolated Adaptive HE (IAHE)
Weighted Adaptive HE (WAHE)
Contrast Limited Adaptive HE(CLAHE)
Variable Region Adaptive HE(VRAHE)
Local Information HE (LIHE)
Spatio-Temporally Adaptive HE (STAHE)

| | | | |
|---|---|---|---|
| 5 | 8 | 3 | 8 |
| 3 | 5 | 5 | 9 |
| 5 | 3 | 9 | 5 |
| 9 | 8 | 3 | 8 |

Partially Overlapped Sub-Block HE (POSHE)
Conditional Sub-Block Bi-HE (CSBHE)
Multiple Layers Block Overlapped HE (MLBOHE)

*2) Drawback :*

It can make a dravasting change in gray level value of original image
It is not a monotonic mapping technique so it may distort original image.

*B. Global Histogram Equalization*
It stretches the resultant histogram of original image to cover a wider gray scale values. There by enhancing the low contrast of image. It uses all the intensities of original image for evaluating transformation function. Resulting in enhancement of image globally.
It increases the entropy of image up to maximized range.

*1) Drawback :*
It work equally good for both background and foreground section of an image. hence sometimes increase noise and dusts present in image.
GHE pushes the intensities towards right or left i.e. bright or dark. So it creates level saturation effects on some visibly important areas.
GHE works globally without considering local information which sometimes have loud impacts.

**C.** *Mean Brightness Preserving Histogram Equalization (Mbphe)*
This technique is also known as extension of histogram equalization. It decomposes the original input image into sub images. Equalize the sub images individually. This technique preserves the artistic value of image without enhancing the artificial effects.

*1) Methods of MBPHE are :-*
Brightness Preserving Bi-HE (BBHE),
Quantized Bi-HE (QBHE)
Dual Sub-Image HE (DSIHE)
Minimum Mean Brightness Error Bi-HE (MMBEBHE)
Recursive Mean-Separate HE (RMSHE)
Recursive Sub-Image HE (RSIHE)
Recursive Separated and Weighted HE (RSWHE)
Multipeak HE (MPHE)
Dynamic HE (DHE)
Multi-HE (MHE)
Brightness Preserving Weight Clustering HE (BPWCHE)
Brightness Preserving Dynamic HE (BPDHE)
HE with Range Offset (HERO) .

*2) Out Of These Some Popular Techniques Are:-*
a) BBHE
b) DSIHE
c) RMSHE
d) RSWHE
e) RSIHE
f) MMBEBHE
g) DHE
h) BPDHE

*a) BBHE (Brightness Preserving Bi-Histogram Equalization*)
This technique decomposes the input image by calculating mean function .i.e. A sub image consist of value whose values are less than mean. Another sub image consist which is having values more than mean. It provides natural enhancement to input image.
b) *DSIHE (Dualistic Sub Image Histogram Equalization)*
In this decomposition of images is done on the basis of gray scale level CPD (Cumulative probability Density) which equals to value 0.5 Resultant image is enhanced one with proper luminosity so it has major application area i.e. Video system directly.
c) *RMSHE (Recursive Mean Separate Histogram Equalization)*
This technique is extension of BBHE, where decomposition of image is done once only. In it decomposition of input images i to sub images is done recursively depending on mean function also. As the number of recursive decomposition increases preservation of brightness of images also increases results in highly brightness preserved image.
d*) RSWHE (Recursive Separated and Weighted Histogram Equalization*)
This technique works in three steps-
i. Histogram Segmentation
ii. Histogram Weighting
iii. Histogram equalization
A better result is obtained after this technique and unwanted noise is easily avoided in it.
e*) RSIHE (Recursive Sub image Histogram Equalization)* –
this technique is much similar to RSWHE but it completes its task in two steps only i.e.
i. Histogram Segmentation
ii. Histogram equalization
f) *MMBEBHE (Minimum Mean brightness Error Bi-HE)*
This technique uses the basic principles of both BBHE and DSIHE techniques. It includes three steps-
i. Evaluating AMBE( Absolute Mean brightness error)
ii. Evaluating threshold value
iii. Segmentation and equalization
This technique is well suited for Real Time images.
g) *DHE (Dynamic Histogram equalization)*
This technique make enhancement in image without providing harm to image details. It includes three steps-
i. Histogram segmentation
ii. Allocation of Gray level ranges
iii. Histogram equalization
h) *BPDHE (Brightness Preserving Dynamic Histogram equalization)*
This technique is extension of traditional DHE technique. It partitions the input image as per local maximums of smoothed one.
It includes following steps.
i. Histogram segmentation
ii. Mapping of new dynamic values
iii. Equalization
iv. Normalization
If compared with DHE, it is far better.

*D. Bin Modified Histogram Equalization*
As GHE works by stretching the region of high histogram values and by compressing down the region with low histogram values. So the resultant image is not the appropriate or desired one. To overcome this extension of GHE a new technique BMHE is introduced.
It not only blindly stretching or compressing any value it simply modify the input histogram by increasing or decreasing value of bin's in histogram. After this change only final equalization is applied.

*1) Methods of BMHE*
Bin Underflow and Bin Overflow HE (BUBOHE)
Weighted and Threshold HE (WTHE)
Self-Adaptive Plateau HE (SAPHE)
E. *Histogram Expansion*
In it from Input histogram, a sub range is selected, which is remapped in full range output histogram. Various techniques of histogram expansions are –
1) *Modified Histogram Expansion*

2) *Dynamic Range Expansion*
3) *Linear Contrast Expansion*
4) *Symmetrical Histogram Expansion*

Histogram expansion results in enhanced output image. Different technique have their own pros and cons which is compared and shown with the help of table I

| Techniques | Merits | Demerits |
|---|---|---|
| Dynamic Range Expansion | Works best for shadow like images | |
| | | |
| Linear Contrast Expansion | Very dark images can be made clearly visible.<br>Simple to implement | Gray value must not be very wide spread, otherwise poor performance |
| Symmetrical histogram Expansion | For embedding purpose all the bins are not made empty.<br>Pivot bins are shifted. | |

TABLE-1
COMPARISON OF EXPANSION TECHNIQUES

*F. Cumulative Histogram Equalization*

It is good technique for enhancement of images. In it extra cumulative distribution Function Histogram is also evaluated. So as compared to others technique it is bit time consuming.

*G. Par Sectioning*

It is one of the easy equalization techniques. But sbest suited in case of hardware implementations.

*H. Odd Sectioning*

It is also good contrast enhancement technique. It is best suited if gray scale range is narrow and not wide spread.

| TECHNIQUE | MERITS | DEMERITS |
|---|---|---|
| **LHE** | • Represents small area content too.<br>• Easily depict the hidden details of input image | • Theoretical and long procedure<br>• Produce Artificial results<br>• Also enhances noises area |
| **LHE** | • Represents small area content too.<br>• Easily depict the hidden details of input image | • Theoretical and long procedure<br>• Produce Artificial results<br>• Also enhances noises area |
| **GHE** | • Optimized way of enhancing image contrast | • Noise area also amplified<br>• Creates unsaturated level |
| **MBPHE** | • Works excellently to preserve brightness | • Less capable in enhancing contrast |
| **BMHE** | • Do not enhances the noise area of image | • Contrast enhancement is within limits only |
| **Histogram Expansion** | • Rich and easy enhancement technique | • Not suited for images whose gray scale level is wide spread |
| **Cumulative Histogram Equalization** | • Good technique | • Take extra time and effort as cumulative histogram function is needed to be evaluated |
| **PAR Sectioning** | • Simple and Easily implemented | • Works not good for other than hardware implementation |
| **ODD Sectioning** | • Results in good contrast image | • Not suited for images whose gray scale level is fully spread. |

TABLE II
COMPARISON OF DIFFERENT EQUALIZATION TECHNIQUES

## VI. CONCLUSION

The Present paper gives the review of Histogram and its various techniques. All the techniques discussed have their own Prons and Cons.Depending upon the type of input image and desired output any above mentioned technique can be applied. As shown in the example that if we apply Basic Histogram Equalization Technique on the outputted image again,It gives the same result as previous.Out of other techniques some works best on shadow image, some on low resolution image and some on real time image.

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