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Research Article

Contrast Enhancement Techniques using Histogram Equalization: A Survey

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Abstract

Contrast enhancement techniques are used for improving visual quality of low contrast images. Histogram Equalization (HE) method is one such technique used for contrast enhancement. In this paper, various techniques of image enhancement through histogram equalization are overviewed. On comparing them we see that Background Brightness preserving Histogram Equalization (BBPHE) technique provides better and scalable brightness preservation for images with poor contrast.

Keywords: *CHE, AHE, BBPHE, RMSHE, BPBHE.*

1. Introduction

Image processing is a vast and challenging domain with its applications in fields like medical, aerial and satellite images, industrial applications, law enforcement, and science. Image enhancement is used in the following cases: Removal of noise from image, enhancement of the dark image and highlight the edges of the objects in an image. The goal of image enhancement is to improve the image quality so that the processed image is better than the original image for a specific application or set of objectives. These methods include histogram equalization, gamma correction, high pass filtering, low pass filtering, homomorphic filtering, etc. Histogram equalization is one of the operations that can be applied to obtain new images based on histogram specification or modification. It is a contrast enhancement technique with the objective to obtain a new enhanced image with a uniform histogram. In plain or medical images the background level is much higher than the other non background levels, so while performing Classical Histogram Equalization over enhancement of background levels occurs. Here in this paper an algorithm known as the Background Brightness preserving Histogram Equalization (BBPHE) is discussed. In BBPHE the histogram is divided based on the background levels and is enhanced separately, thus avoiding the over enhancement of the background level and improving the contrast of the image.

2. Histogram Equalization

The histogram of bad images is usually narrow while that of good images are wide. Image enhancement is a process involving changing the pixels intensity of the input image, so that the output image should subjectively look better. A histogram simply plots the frequency at which each grey-level occurs from 0 (black) to 255 (white). Histogram represents the frequency of occurrence of all gray-level in the image, that means it tell us how the values of individual pixel in an image are distributed.

There are various histogram equalization techniques with their own advantages and disadvantages.

- Classical Histogram Equalization (CHE)
- Adaptive Histogram Equalization (AHE)
- Brightness preserving Bi- Histogram Equalization (BPBHE)
- Recursive Mean Separate Histogram Equalization (RMSHE)
- Background Brightness Preserving Histogram Equalization (BBPHE)

3. Methodology

3.1 Classical Histogram Equalization (CHE)

The Classical Histogram Equalization is a global operation. Here the Equalization is applied to the whole image. For a given image X, the probability density function $P(X_k)$ is defined as

$$P(X_k)=n^k/n \qquad (1)$$

for $k = 0, 1\ldots L-1$, where n^k represents the number of times that the level (X_k) appears in the input image **X** and n is the total number of samples in the input image .The cumulative density function is defined as

$$C(X)=\sum_{j=0}^{k} P(Xj) \qquad (2)$$

Note that $C(X_{L-1}) = 1$

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Transform function *f*(*x*) based on the cumulative density function as

$$f(x)=X_0+(X_{L-1}-X_0)C(x) \quad (3)$$

Then the output image of the HE, **Y** = {Y *(i, j)}*, can be expressed as

$$\mathbf{Y} = f(\mathbf{X})$$
$$= \{f(X(i, j) \,|\forall X(i, j) \in \mathbf{X}\} \quad (4)$$

The algorithm for Classical Histogram Equalization

Step 1: Start the program.
Step 2: Read the image from the current folder.
Step 3: Find the size of the image.
Step 4: Get the histogram of the image
Step 5: Calculate new values via general histogram equalization formula
Step 6: Get the probability density function and cumulative distribution function
Step 7: Build new image by replacing original gray values with the new gray values
Step 8: Optionally, get the histogram and originals image to compare them with the cumulative histogram of the new
Step 9: Show graphics results
Step 10: Stop

Disadvantage

- The Classical Histogram Equalization method does not take the mean brightness of an image into account.
- The CHE method may result in over enhancement and saturation artifacts due to the stretching of the gray levels over the full gray level range.

To overcome these drawbacks and increase contrast enhancement and brightness preserving many HE-based techniques have been proposed

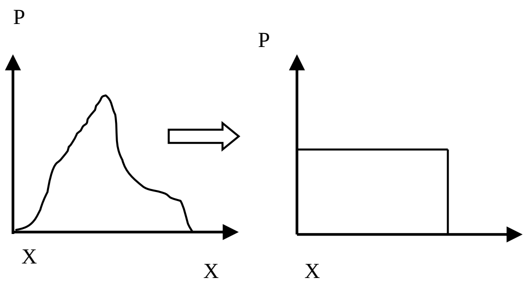

Fig 1: Histogram and its Equalized Histogram for H.E.

3.2 Adaptive Histogram Equalization (AHE)

Adaptive histogram equalization is a computer image processing technique used to improve contrast in images. It differs from ordinary histogram equalization in the respect that 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. Ordinary histogram equalization simply uses a single histogram for an entire image.

It operates on small regions in the image, called tiles, rather than the entire image. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the histogram specified by the 'Distribution' parameter. The neighboring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited to avoid amplifying any noise that might be present in the image

Algorithm for Adaptive Histogram Equalization

Step 1: Start the program.
Step 2: Obtain all the inputs like image, no of regions, dynamic range and clip limit
Step 3: Pre-process the inputs
Step 4: Process each contextual region producing gray level mapping
Step 5: Interpolate gray level mapping in order to assemble the final image
Step 6: Stop.

Disadvantages

- It can produce significant noise because it tends to amplify noise.
- It also fails to retain the brightness with respect to the input image.

3.3 Brightness Preserving Bi- Histogram Equalization (BPBHE)

In bi-histogram equalization the histogram of the original image is separated into two sub histograms based on the mean of the histogram of the original image, the sub-histograms are equalized independently using refined histogram equalization, which produces flatter histogram.

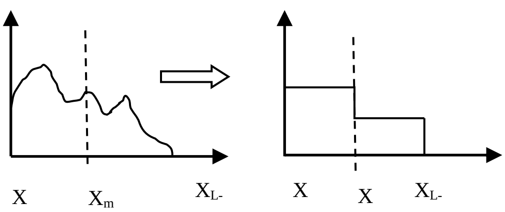

Fig2*:* BI-histogram Equalization Method

Let X_m be the mean of the image X and assume that $X_m \in \{X_0, X_1 \ldots X_{L-1}\}$. Based on the mean, the input image is decomposed into two sub-images X_L and X_U as

$$X=X_L \cup X_U \quad (5)$$

Note that the sub-image X_L is composed of $\{X_0, X_1 \ldots X_m\}$ and the other image X_U is composed of $\{X_{m+1}, X_{m+2} \ldots X_{L-1}\}$

$$X_{m=} (X_0 + X_{L-1}) / 2 \quad (6)$$

This indicates that the BPBHE preserves the brightness compared to HE where output mean is always the middle gray level.

Algorithm

Step 1: Start the program
Step 2: Read the original image.
Step 3: Make the histogram of the image.
Step 4: Calculate the mean of the histogram.
Step 5: Divide the Histogram into two parts Based on the mean
Step 6: Equalize each Partition independently using Probability Density Function and Cumulative Density Function
Step 7: Stop

Disadvantage

- Higher degree of brightness preservation is not possible to avoid annoying artifacts.

In some images, this level of brightness preservation is not sufficient to avoid unpleasant artefacts. They clearly show that higher degree of brightness preservation is required for these images to avoid unpleasant artefacts. In this case RMSHE produce better result as discussed below.

3.4 Recursive Mean Separate Histogram Equalization (RMSHE)

Recursive Mean-Separate Histogram Equalization (RMSHE) is another technique to provide better and scalable brightness preservation for gray scale and colour images. While the separation is done only once in BHE, RMSHE performs the separation recursively based on their respective mean. It is analyzed mathematically that the output images mean brightness will converge to the input images mean brightness as the number of recursive mean separation increases. The outputs mean E(Y) for RMSHE recursion level r=n is given as;

For, $r=0, E(Y)=X_G$ (7)
$r = 1, E(Y) = (X_m + X_G) / 2$ (8)
$r = 2, E(Y) = (3X_m + X_G) / 4$ …. (9)
$r = n, E(Y) = ((2n - 1) + X_m + X_G) / 2^n$
$= X_m - [(X_G - X_m)/2^n]$
Here $X_G=(X_0 + X_{L-1}) / 2$

Indicates that as the recursion level, n grows larger; E(Y) will eventually converge to the input mean, X_m.

Therefore, this algorithm allows a desirable property to adjust the brightness level depending on the image requirement. The recursive nature of RMSHE also allows scalable brightness preservation, which is very useful in consumer electronics.

Drawback

- The number of decomposed sub-histograms is a power of two.

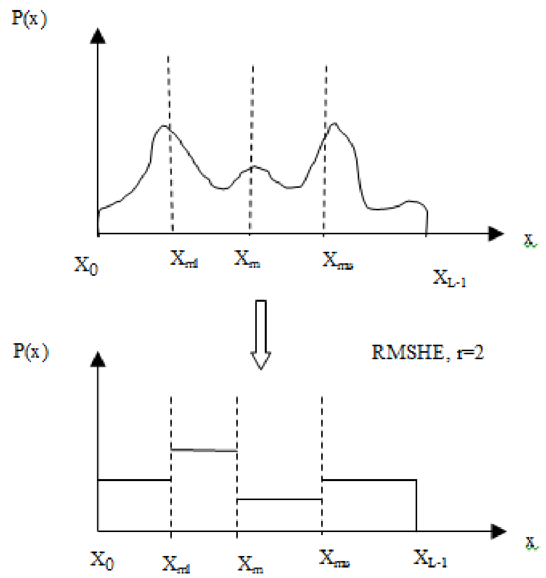

Fig3: Shows Histogram equalization for RMSHE, r=2

3.5 Background Brightness Preserving Histogram Equalization (BBPHE)

We have seen in all the previous methods that the background brightness is not preserved, and hence it leads in over enhancement of the background. For plain images like in medical images the density of the background levels is much higher than the other levels. So a method known as the Background Brightness Preserving Histogram Equalization is proposed. This method is able to enhance the image contrast while preserving the background brightness for images with well-defined background brightness.

In this method the histogram is divided according to the foreground and the background levels
The steps for performing this method are as follows:.

- Input the image
- Find the histogram of the image
- Separate the input image into sub-images based on background levels and non-background levels range
- Each sub-image is then equalized independently, and
- Combine the sub-images and then we get the final output image.

Figure shows the flowchart of background brightness preserving Histogram Equalization method; consider the following cases for separating the histogram of an image I having M background gray levels.

Case 1: Consider an image I having K gray levels. If region R_b is the background level having M gray levels in the range N to N+M-1, where M < K and region R_1 and R_2 has non- background levels in the range 0 to N-1 and N+M to K-1 levels respectively.

Let X_b be the background level, the image is then divided

$$A=R_1 \cup R_2 \cup R_b \quad (11)$$

The PDFs of the sub-images R_1, R_2 and R_b can be defined as,

Table 1 Comparison between different histogram equalization techniques

Parameters	CHE	AHE	BPBHE	RMSHE	BBPHE
Losses	more	Since corrupted neighborhood pixel is considered for calculating, information is loss.	Some information is loss since it fails to control the overall enhancement of the image.	Information loss is less.	Loss of information is Minimum.
Noise	Since the background as well as the image is considered to calculate the CDF, it adds noise to the output image.	AHE has behaviour of amplifying noise, thus it has some limitations,	Noise is less as compared to CHE and AHE.	less	BBPHE avoids unwanted noise
Brightness preservation	The CHE method does not take the mean brightness of an image into account	It fails to retain the brightness with respect to the input image.	Preserves the overall mean brightness of the original images	It provides better and scalable brightness preservation as compared to BBHE	Both the background and the image brightness is preserved.
SNR	While increasing the contrast of its background, the signal gets distorted. It depends upon contrast.	Less	moderate	more	highest
Complexity	Easy to implement.	Very highly complex.	Low complexity.	Moderate complexity.	Simple to implement
Processing time	Fast but produces unnatural image and artifacts.	Takes the longest computational time as compared to all other techniques.	fast	More as compared to CHE and BBPHE	Less

for r = 0, 1, ...,N− 1,

$$P_1(X_r)=n^r/n_1 \quad (12)$$

for r= N, N + 1, . . ., N + M -1, and

$$P_b(X_r)=n^r/n_b \quad (13)$$

for r = N + M ,N + M + 1, . . . , K – 1

$$P_2(X_r)=n^r/n_2 \quad (14)$$

The respective CDFs are then obtained by

$$C_1(X_r)=\sum_{k=0}^{r} P_1(X_k) \quad (15)$$

$$C_b(X_r)=\sum_{k=0}^{r} P_b(X_k) \quad (16)$$

$$C_2(X_r)=\sum_{k=0}^{r} P_2(X_k) \quad (17)$$

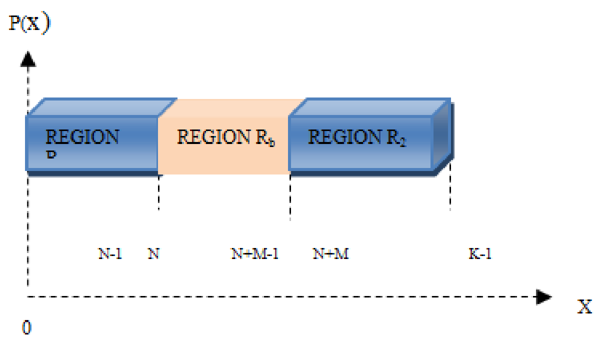

Fig 4: Decomposition of image into sub-images based on background levels for case 1

Similar to the CHE, the transform functions of R_1, R_2 and R_b can be defined as

Transform function $f(x)$ based on the cumulative density function as

$$f(x)=X_0+(X_{K-1}-X_0)C(x)$$

The output image G can be expressed as

$$f = f_1 \cup f_b \cup f_2 \quad (18)$$

Case II:

Input image A = $R_b \cup R_1$, where the background level $R_b = \{X \leq X_{K-1}\}$,and lies from 0 to M-1 gray levels and the non background level $R_1 = \{X_M \leq X \leq X_{K-1}\}$,N = 0, M ≠K, and R_b starts from X_0, hence,

$X_b \in \{X_0, X_1, ..., X_{M-1}\}$ and $X_1 \in \{X_M, X_{M+1} ..... X_{K-1},\}$

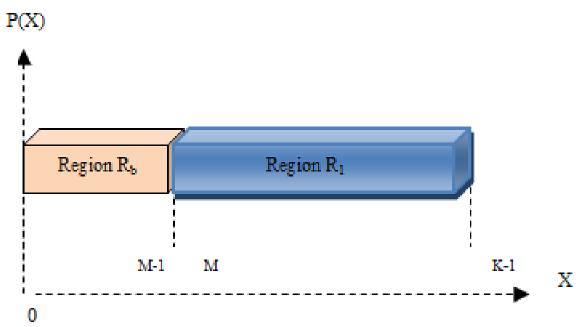

Fig 5: .Decomposition of image into sub-images based on background levels for case II

Case III: Input image $A = R_1 \cup R_b$, where $R_1 = \{X_0 \leq X \leq X_{N-1}\}$, $R_b = \{X_N \leq X \leq X_{K-1}\}$, $N \neq 0$, $N + M= K$, and X_b

ends at X_{K-1}, hence $X_1 \in \{X_0, X_1 ......X_{N-1}\}$ and $X_b \in \{X_N, X_{N+1}, ...X_{K-1}\}$.

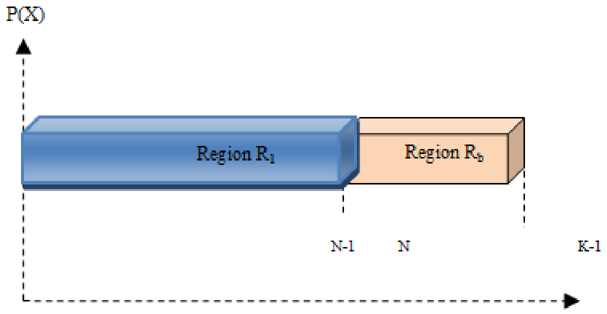

Fig 6: .Decomposition of image into sub-images based on background levels for case III

The proposed BBPHE solves the problem by maintaining the background levels in the same intervals, and it avoids the over enhancement of background levels. The presented method is capable of enhancing the objects while preserving the background brightness and the over enhancement of images can be avoided.

Application: Image contrast enhancement techniques are of particular interest in photography, satellite imagery, medical applications and display devices. Producing visually natural is required for many important areas such as vision, remote sensing, dynamic scene analysis, autonomous navigation, and biomedical image analysis.

4. Comparison between different histogram equalization techniques

The comparison is shown in table 1

Conclusions

In this paper we have studied different HE techniques. The classical HE gives a flat image and the local details are not preserved. We have seen that BBPHE gives better result as compared to other Techniques. The key advantage behind BBPHE is it allows higher level of brightness preservation to avoid unwanted noises.

As a result BBPHE algorithm superiority can be proved by improving feature which has low intensity and broadly distributes intensities without distortion. And it can be useful in medical images to allow scaling of brightness preservation suited for individual image.

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