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Images Enhancement Using Cumulative Histogram Equalization Technique

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Abstract
Image enhancement is a mean as the improvement of an image appearance by increasing dominance of some features or by decreasing ambiguity between different regions of the image. Image enhancement processes consist of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form better suited for analysis by a human or machine. Many images such as medical images, remote sensing images, electron microscopy images and even real life photographic pictures, suffer from poor contrast. Therefore it is necessary to enhance the contrast. The purpose of image enhancement methods is to increase image visibility and details. Enhanced image provide clear image to eyes or assist feature extraction processing in computer vision system.

Numerous enhancement methods have been proposed but the enhancement efficiency, computational requirements, noise amplification, user intervention, and application suitability are the common factors to be considered when choosing from these different methods for specific image processing application.

Keywords
Enhancement, Histogram processing techniques, cdf, pdf, PSNR, MSE.

Introduction
Histogram processing is the act of altering an image by modifying its histogram. Common uses of histogram processing include normalization by which one makes the histogram of an image as flat as possible. This is also known as contrast enhancement. Intensity transformation functions based on information extracted from image such as enhancement, compression, segmentation and description.
The Histogram of digital image with the intensity levels in the range [0, L-1] is a discrete function.

$$h(r_k) = n_k$$

Where
• r_k is the intensity value.
• n_k is the number of pixels in the image with intensity n_k
• $h(r_k)$ is the histogram of the digital image with Gray Level r_k
Histograms are frequently normalized by the total number of pixels in the image. Assuming a $M \times N$ image, a normalized histogram.

$$p(r_k) = \frac{n_k}{MN}$$

k=0, 1, 2, 3……….L-1.
is related to probability of occurrence of r_k in the image.
Where
• $p(r_k)$ gives an estimate of the probability of occurrence of gray level r_k.
• The Sum of all components of a normalized histogram is equal to1.
Histograms are Simple to calculate in software and also lend themselves to economic hardware implementations, thus making them a popular tool for real-time image processing.

Literature review of histogram processing techniques
Image enhancement the image to a form better suited for analysis by a human or machine processes consist of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form better suited for analysis by a human or machine.

Histogram Equalization
Histogram Equalization is a technique that generates a gray map which changes the histogram of an image and redistributing all pixels values to be as close as possible to a user –specified desired histogram. HE allows for areas of lower local contrast to gain a higher contrast. Histogram equalization automatically determines a transformation function seeking to produce an output image with a uniform Histogram. Histogram equalization is a method in image processing of contrast adjustment using the image histogram. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. Histogram equalization automatically determines a

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transformation function seeking to produce an output image with a uniform Histogram.

Let *X={X(i,j)}* denotes a image composed of L discrete gray levels denotes as

X= $\{X_0, X_1, \ldots, X_{L-1}\}$.For a given Image X, the probability density function $p(X_k)$.

$$p(X_k) = \frac{n^k}{n}$$

Where,

- k =0, 1,……$L-1$.
- n^k represents the number of times that the level X_k apperes in the input image *X*.
- n is the total number of samples in the input image.
- $p(X_k)$ is associated with the histogram of the input image which represents the number of pixels that have a specific intensity X_k.

Based on the probability density function, the cumulative density function is defined as

$$c(x) = \sum_{j=0}^{k} p(X_j)$$

Where,

- $X_k = x$ for k=0,1,…….L-1
- $c\ (X_{L-1})$ =1 by definition.
- HE is a scheme that maps the input image into the entire dynamic range, $(X_0\ ,X_{L-1})$ by using the cumulative density function as a transform function.

A transform function f(x) based on the cumulative density function defined as:

$$f(x) = X_0 + (X_{L-1} - X_0)c(x)$$

Then the output image of the HE,

Y={Y (i, j)}

can be expressed as

$$Y = f(x)$$

$$= f\{(X(i,j) / \forall X(i,j) \in X\}.$$

Based on information theory, entropy of message source will get the maximum value when the message has uniform distribution property.

Problems in Histogram Equalization

1. The Histogram Equalization method does not take the mean brightness of an image into account.
2. The HE method may result in over enhancement and saturation artifacts due to the stretching of the gray levels over the full gray level range.
3. Histogram equalization can be found on the fact that the brightness of an image can be changed after the histogram equalization.
4. Nevertheless, HE is not commonly used in consumer electronics such as TV because it may significantly change the brightness of an input image and cause undesirable artifacts.
5. It can be observed that the mean brightness of the histogram-equalized image is always the middle gray level regardless of the input mean.

Brightness Preserving Bi Histogram Equalization

The Brightness preserving bi histogram equalization firstly decomposes an input image into two sub images based on the mean of the input image. One of the sub image is set of samples less than or equal to the mean whereas the other one is the set of samples greater than the mean. Then the BBHE equalizes the sub images independently based on their respective histograms with the constraint that the samples in the formal set are mapped into the range from the minimum gray level to the input mean and the samples in the latter set are mapped into the range from the mean t the maximum gray level. Means one of the sub images is equalized over the range up to the mean and the other sub image is equalized over the range. From the mean based on the respective histograms .Thus, the resulting equalized sub images are bounded by each other around the input mean, which has an effect of preserving mean brightness.

In this the computation unit counts and store the respective number of occurrences *nnkk* for k=0,1,…..,$L-1$,the Histogram Splitter the splits the number of occurrences as $(n_0, n_1, \ldots, n_m)$ and $(n_m, n_{m+1}, \ldots, n_{L-1})$ respectively and where the mapper outputs *Y(i,j)* as

$$Y(i,j) = \begin{cases} X_0 + (X_m - X_0)C_L(x) \\ X_{m+1} + (X_{L-1} - X_{m+1})C_U(x) \end{cases}$$

Which is based on $f_L(X_L) \cup f_U(X_U)$.The computation of Histogram and the mean typically need to be done during one frame period; thus a frame memory to store the image being processed is neccessary

Contrast Limited Adaptive Histogram Equalization (CLAHE)

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. Consequently, adaptive histogram equalization is considered an image enhancement technique capable of improving an image's local contrast, bringing out more detail in the image. However, it also can produce significant noise. A generalization of adaptive histogram equalization called contrast limited adaptive histogram equalization, also known as CLAHE, was developed to address the problem of noise amplification. CLAHE 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.

Motivation

Image enhancement methods based on improvements of contrast and avoidance of the appearance of unrealistic colors are really useful in applications where an image with more distinguished texture details and perceptually better colors are required. As explained before, these applications include surveillance system based on images or simply better image visualization in mobile phones and PDAs. Although there are a lot of techniques available to perform these tasks, all of them have advantages and drawbacks. HE is a technique commonly used for image contrast enhancement, since it is computationally fast and simple to implement. Our main motivation is to preserve the best features the HE methods have, and introduce some modifications which will overcome the drawbacks associated to them.

Equalization Histogram

A histogram is the estimation of the probability distribution of a particular type of data. An image histogram is a type of histogram which offers a graphical representation of the tonal distribution of the gray values in a digital image. By viewing the image's histogram, we can analyze the frequency of appearance of the different gray levels contained in the image. Histogram Equalization is a technique that generates a gray map which changes the histogram of an image and redistributing all pixels values to be as close as possible to a user –specified desired histogram. HE allows for areas of lower local contrast to gain a higher contrast. Histogram equalization automatically determines a transformation function seeking to produce an output image with a uniform Histogram. Histogram equalization is a method in image processing of contrast adjustment using the image histogram. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. Histogram equalization automatically determines a transformation function seeking to produce an output image with a uniform Histogram.

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The probability density function (X_k).

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Where

• k = 0, 1 …L −1.
• n_k represents the number of times that the level X_k appears in the input image X.
• n is the total number of samples in the input image.
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Based on information theory, entropy of message source will get the maximum value.

Methods for histogram equalization

There are a number of different types of histogram equalization algorithms, such as cumulative histogram equalization, normalized cumulative histogram equalization, and localized equalization. Here is a list of different histogram equalization methods:

• Histogram expansion
• Local area histogram equalization (LAHE)
• Cumulative histogram equalization
• Brightness Preserving Bi Histogram Equalization
• Contrast Limited Adaptive Histogram Equalization (CLAHE)

These methods were studied and compared in order to determine which one offers the best equalization and is also best suited to DSP implementation.

Cumulative histogram equalization

In this section the general approach for cumulative histogram equalization is described. Here are the steps for implementing this algorithm.

1. Define the window for the image.
2. Find the number of rows and columns to be padded with zero.
3. Padding the image with zero on all side.
4. Find the middle element in the window.
5. Compute the cumulative distribution function for the values in the window
6. Calculate the new values through the general histogram equalization formula.
7. Assign new values for each gray value in the image.

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2. The HE method may result in excess of enhancement and saturation artifacts due to the stretching of the gray levels over the full gray level range.
3. Histogram equalization can be initiate on the fact that the intensity of an image can be changed after the histogram equalization. s
4. However, HE is not commonly used in consumer electronics such as TV because it may drastically change the intensity of an input image and cause adverse artifacts.
5. It can be observed that the mean intensity of the histogram-equalized image is always the middle gray level despite the consequences of the input mean.

Matlab implementation

The cumulative histogram equalization was implemented and tested using MATLAB version 7.6. For an image with 256 gray levels like the one in Figure 5, the first step is to generate the image's histogram.

Figure 5. Example image

Getting histogram

```
for grey_level = 0:1:255
images_histogram (grey_level + 1) = 0;
for i = 1:1:size_c
for j = 1:1:size_r
        if array_1(j,i) == grey_level images_histogram
        (grey_level + 1) = images_histogram
        (grey_level + 1) +1;
       end
    end
  end
end
```

Where,
size_c and *size_r* are the number of columns and number of rows respectively,
array_1 is the matrix that contains the image data.

The plot of this histogram is shown in Figure 6.

After this, we need to calculate the cumulative distribution function which is defined as

$$cdf(x) = \sum_{j=1}^{x} h(j)$$

Where x is a gray value and h is the image's histogram.
The cumulative distribution function for each gray tone is calculated by the code shown here.

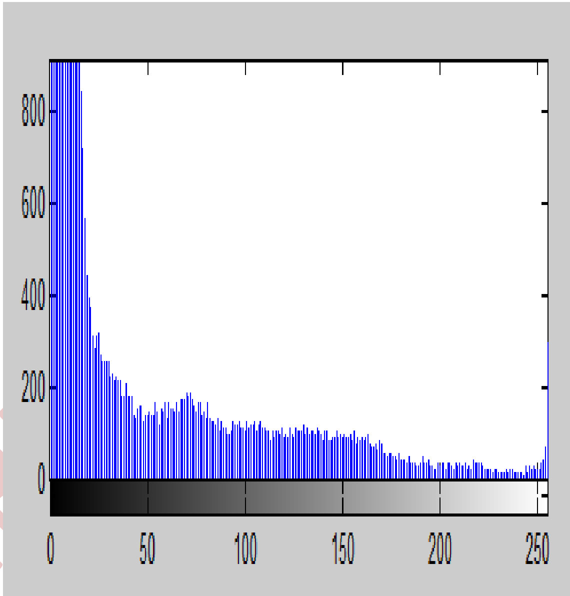

Figure 6. Histogram of example image

Cumulative distribution function (cdf)

```
for grey_level = 1:1:256
cdf (grey_level) = 0;
for i = 1:1:grey_level
cdf (grey_level) = cdf (grey_level) + images_ histogram (i);
     ends
end
```

And here is the plot of the cumulative histogram (figure 7).

Now, the general histogram equalization formula is

$$eh(i) = round\left(\frac{cdf\,(1) - cdf_{min}}{M \times N - cdf_{min}} * (L-1)\right)$$

Where,

cdf_{min} is the minimum value of the cumulative distribution function.

$M \times N$ are the image's number of columns and rows.

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L is the number of gray levels used (in most cases 256).

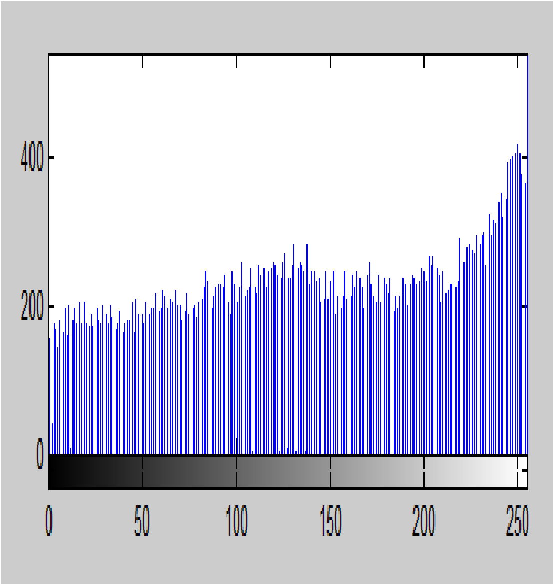

Figure 7. Cumulative histogram of example image

This formula is implemented in this code:
for i = 1:1:256
*h (i) = ((cdf(i)-1)/((size_r * size_c)-1)) * 255;*
ends

Applying this to the image in Figure 5, we obtain the next new image and its corresponding histogram and cumulative histograms.

Figure 8. Example image after applying algorithm

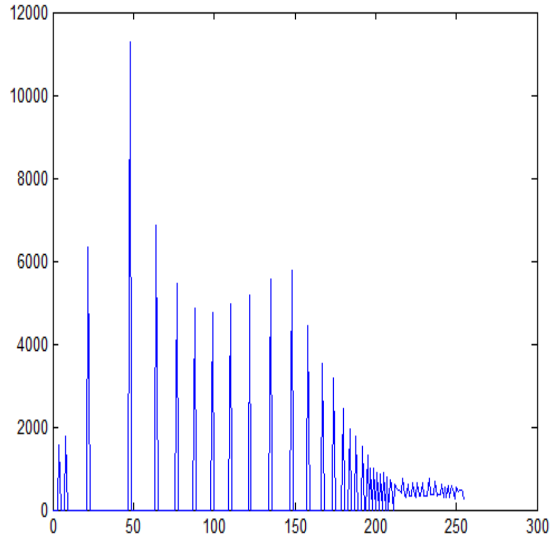

Figure 9. New equalized histogram

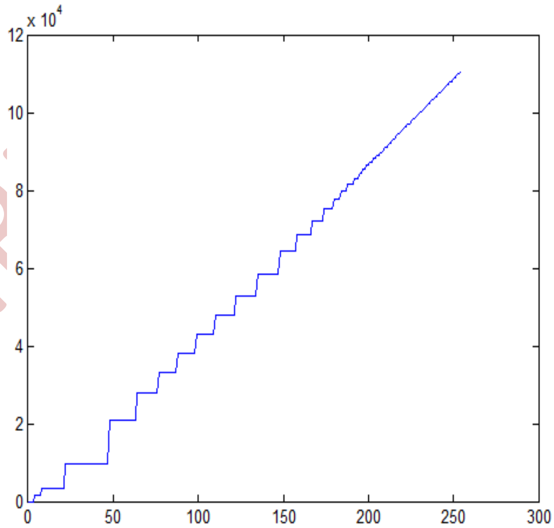

Figure 10. Equalized cumulative histogram

Result and discussions

Peak signal-to-noise ratio, often abbreviated PSNR, is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. The PSNR is most commonly used as a measure of quality of reconstruction of lossy compression codecs (e.g., for image compression). The signal in this case is the original data, and the noise is the error introduced by compression higher PSNR would normally indicate that the reconstruction is of higher quality.

$$\text{PSNR} = 10log\frac{255^2}{mse}$$

Where,
mse is the mean square error between the original image (i.e. s) and the enhanced image (i.e.$\hat{s}$) with size M×N:

$$\text{mse} = \frac{1}{MN}\sum_{i=1}^{m}\sum_{j=1}^{n}[\ s(i,j) - \hat{s}(i,j)^2]$$

Table 1: MSE and PSNR results for various

	HE	AHE	BBHE	CHE
PSNR	28.4446	31.0509	31.4223	31.5206
MSE	4334.29	297.303	1227.13	1223.15

HPT
HE- Histogram Processing.
AHE- Adaptive Histogram Equalization.
BBHE- Brightness Preserving Bi- Histogram Equalization.
CHE- cumulative histogram equalization

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