STUDY OF IMAGE ENHANCEMENT TECHNIQUES

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Abstract-- Image enhancement has an important role in image processing applications. The principal objective of image enhancement is to process a given image so that the result is more suitable than the original image for a specific application. The enhancement doesn't increase the inherent information content of the data, but it increases the dynamic range of the chosen features so that they can be detected easily. The enhancement techniques make the identification of key features easier by removing noise and other artefacts in an image. These techniques provide a multitude of choices for improving the visual quality of images. One of the most common defects of photographic or digital images is poor contrast resulting from a reduced, and perhaps nonlinear, image amplitude range. Contrast enhancement is an important factor for image enhancement. Histogram equalization is a very effective approach to contrast enhancement. This paper presents the evaluation of some popular image enhancement techniques using Histogram modification framework.

Index Terms-- Image Enhancement, Histogram Equalization, Local Histogram Equalization, Contrast Enhancement, Contrast stretching

I. Introduction

Digital images are always affected by noise, blurring, incorrect color balance and poor contrast. Most of digital images that can be produced through scanners, digital cameras, video cameras, Charged Coupled Devices (CCD cameras) and web-cam can be easily affected by these problems. This will lead to low quality images. Image enhancement is one of the most important issues in low-level image processing. It will be used to minimize the effects of these degradations. Its purpose is to improve the quality of low contrast images, i.e., to enlarge the intensity difference among objects and background. It accentuates or sharpens image features such as edges, boundaries, or contrast to make a graphic display more helpful for display and analysis. This can be done by using a number of image enhancement techniques. In the image enhancement process, an image is taken as input and enhancement algorithm is applied on it. After that enhanced image is taken as output as shown in figure.
Image enhancement problem can be formulated as: given an input image of low quality and the output image of high quality for certain applications. Contrast stretching and Histogram Equalization are commonly used techniques for image enhancement in the field of removal of noise, contrast enhancement, and edge enhancement. Among these contrast enhancement is a popular image enhancement method. The main goal of contrast enhancement is to distribute the pixel values uniformly in the available dynamic range of gray levels and to result with an output image with linear cumulative histogram [1].

II. IMAGE ENHANCEMENT METHODS

A. Histogram Equalization

Histogram-based techniques are one of the most important image processing techniques that are used for enhancement tasks. It can give us a general overview of an image such as gray scale, gray level distribution and its density, the average luminance of an image, image contrast, and so on [3]. Histogram is defined as the statistical probability distribution of each gray level in a digital image. Histogram Equalization (HE) is a very popular technique for contrast enhancement of images[4]. Contrast of images is determined by its dynamic range, which is defined as the ratio between the brightest and the darkest pixel intensities. The histogram provides information for the contrast and overall intensity distribution of an image.

The traditional HE technique is described below:
Let \( X = \{X(i, j)\} \) denotes a digital image, where \( X(i, j) \) denotes the gray level of a pixel at \( (i, j) \). The total number of pixels in the image is \( N \) and the image intensity is digitized into \( L \) levels as \( \{X_0, X_1, \ldots, X_{L-1}\} \). So, it is obvious that \( X(i, j) \in \{X_0, X_1, \ldots, X_{L-1}\} \ \forall(i, j) \). If \( n_k \) denotes the total number of pixels with gray level \( X_k \) in the image, then the Probability Density Function (PDF) of \( X_k \) is given as:

\[
p(X_k) = \frac{n_k}{N}, \quad K=0,1,\ldots,L-1
\]

The plot between \( p(X_k) \) and \( X_k \) is defined as the histogram of an image. The Cumulative Density Function (CDF) based on the images PDF is defined as:

\[
C(X_k) = \sum_{i=0}^{k} P(X_i)
\]

where \( k=0,1,\ldots,L-1 \) and it is known that \( C(X_{L-1})=1 \). The transformation function of HE is defined as:

\[
f(X_k) = X_0 + (X_{L-1} - X_0) \times C(X_k), \quad k = 0,1,\ldots,L-1
\]

Thus, HE flattens the histogram of an image resulting in a significant change in the brightness. There are various histogram equalization techniques with their own advantages and disadvantages. Some disadvantage includes change in the brightness of image after HE is applied. Generally, we can classify these methods in two principle categories – global and local histogram equalization [5].
Global Histogram Equalization (GHE)

It uses the histogram information of the entire input image in its transformation function. Global HE methods improve the image quality by extending dynamic range of intensity using the histogram of the whole image. HE is an ideal example of this approach that is widely used for contrast enhancement [2].

For a discrete gray scale image \( I(x,y) \) is constituted form the dynamic range of the gray scale values in the range form \([0, L_e - 1]\) levels. \( n_x \) be the number of occurrences of gray level \( x \). Then the function \( P_l(x) \) is defined as,

\[
P_l(x) = \frac{n_x}{n}
\]

where \( 0 \leq x \leq L_e - 1 \)

The function \( P_l(x) \) is the probability of occurrence of a pixel of level \( x \) in the input image i.e., Probability Density Function. Let the total no of gray levels in the image. Typically gray levels are 256 i.e., 0 to 255. \( n \) is the total no of pixels in the image.

Now, Cumulative Density Function (CDF) is calculated based on PDF.

\[
Cdf(X) = \sum_{x=0}^{m} P_l(x) = \sum_{x=0}^{m} \frac{n_x}{n}
\]

Where \( m=0, 1, 2..., L_e - 1 \)

CDF needs to be found to do intensity mapping i.e., to get an equalized histogram. Therefore,

\[
Cdf(X) = q_m
\]

where \( 0 \leq q_m \leq 1 \)

Here \( q_m \) can easily be mapped to dynamic range \([0, L_e-1]\)

multiplying it with \((0, L_e-1)\). It stretches the dynamic range of gray levels by using the cumulative density function (CDF) of the image. This mapping is Histogram Linearization or Global Histogram Equalization. Though this global approach is suitable for overall enhancement, it fails to preserve the local brightness features of the input image[7]. Normally in an image, the high frequency gray levels dominate the low frequency gray levels. In this situation, GHE remaps the gray levels in such a way that the contrast stretching becomes limited in some dominating gray levels having larger image histogram components and causes significant contrast loss for other small ones.

HE is simple and effective in enhancing the low contrast image only if (a) it contains single object or (b) no apparent contrast change between object and background. Since the above conditions cannot be always met, the global methods have both over-enhancement and under-enhancement problem. To overcome the above drawbacks, various modifications have been developed[9]. Local histogram equalization (LHE) [2] tries to eliminate such problems.

Local Histogram Equalization (LHE)

While GHE takes into account the global information and cannot adopt to local light condition, Local Histogram Equalization (LHE) performs block-overlapped histogram equalization [8]. These methods use the histogram and the statistics obtained from the neighbourhood pixels of an image for equalization.
They usually divide the original image into several non-overlapped sub-blocks and perform HE operation on the individual sub-blocks. It uses a small window that slides through every pixel of the image sequentially. The block of pixels that is masked by the window is considered for HE. Then, the gray level mapping for enhancement is done only for the center pixel of that window. Thus, it makes use of the local information remarkably. The resultant image is produced by merging the sub-blocks using the bilinear interpolation method. The major drawback of these methods is the introduction of discontinuity, called blocking effect which occurs near the boundaries of the sub-blocks. Though LHE cannot adapt well to partial light information [6], still it over-enhances some portions depending on its mask size. However, LHE requires high computational cost and sometimes causes over-enhancement in some portions of the image. Moreover, this technique has the problem of enhancing the noises in the input image along with the image features[7]. To get rid of the high computational cost, another approach is to apply non-overlapping block based HE. Nonetheless, most of the time, these methods produce undesirable checkerboard effects on enhanced images. Often the quality of an image is more often linked to its contrast and brightness levels enhancing these parameters will certainly give us the best result.

Fig. 3. Flow-chart of Local Histogram Equalization

3. Adaptive Histogram Equalization (AHE)

Adaptive histogram equalization (AHE) 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. It is therefore suitable for improving the local contrast and enhancing the definitions of edges in each region of an image. It does the transformation of each pixel using a transformation function derived from a neighboring region. The transformation function is proportional to the Cumulative Density Function of the pixel values. AHE improves the local contrast of an image but this method increases the noise level in relatively homogeneous regions of an image.

B. Contrast stretching

The commonly used techniques for image enhancement are removal of noise, edge
enhancement and contrast enhancement. Out of these contrast enhancement is a popular one. Contrast enhancement is one of the most important techniques for image enhancement [10]. In this technique, contrast of an image is improved to make the image better for human vision. The term contrast, as observed in digital images, is the separation of dark and bright areas present in the image. Contrast stretching is used to increase the dynamic range of the gray levels in the image. For example, in an 8-bit system the image display can show a maximum of 256 gray levels. If the number of gray levels in the recorded image spread over a lesser range, the images can be enhanced by expanding the number of gray levels to a wider range. This process is called contrast stretching. The resulting image displays enhanced contrast between the features of interests.[10]

III. EXPERIMENTAL RESULTS

In our experiments, the range of the gray-level values of the images is [0, 255]. The Cameraman image has been enhanced by the proposed approaches. The results demonstrate that the proposed approaches can enhance image effectively.

Fig. 4 and 5 show the original image along with simulation results from HE.

Fig. 5 Histogram of original image and equalized image

Fig. 6 and 7 show the original image along with simulation results from LHE.

Fig. 6 Before local histogram equalization  After local histogram equalization

Fig. 7 Histogram of before and after local histogram equalization

Fig. 8 and 9 show the original image along with simulation results from LHE.
Fig. 8 Original image     Histogram of Original image

Fig. 9 After adaptive histogram equalization and it’s histogram

Fig. 10 shows the original image along with simulation results from Contrast stretching.

Fig.10 contrast stretching

IV. CONCLUSION

The paper mainly deals with processing an image as well as enhancing it. To achieve the target we grab the pixel information from the input image, then using that pixel information we process and/or enhance it based on the algorithms. The processing of the image is done by modifying the pixel data in relative context while enhancing the image is done based on enhancement algorithms. we can easily observe that HE has increased the overall brightness of the image. It has not enhanced the contrast that much. Moreover, it has produced washed out effects in some portion of the image.

LHE has also increased the average brightness of the image, but it has not given a better view. Moreover, it creates some artifacts in the black regions and it has destroyed the center.

V. REFERENCES

