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Role of Global Contrast in Global-Local Contrast Enhancement

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Abstract: For most of the low contrast images, applying the local contrast enhancement along with global contrast enhancement is much better than that of global contrast enhancement only or local contrast enhancement only. Such Global-Local contrast enhancement methods improve the quality of low contrast images in global contrast as well as local contrast whereas global contrast enhancement methods improve the quality of an image in global contrast only and local contrast enhancement methods improve the quality of an image in local contrast only. However, among the Global-Local contrast enhancement methods, the global contrast enhancement method plays a great role for the enhancement.

Keywords: Global, Local, Global-Local, Contrast, Global Role

I. INTRODUCTION

When we observe the factors of good quality images, we cannot neglect the contrast factor too. For an image, the contrast factor may or may not be proper when the image is collected. If the contrast factor of an image is not proper, the quality of the image can be improved, however, by using global contrast enhancement, local contrast enhancement or both of global and local contrast enhancements (global-local contrast enhancement). Global information of the image are more defined using global contrast enhancement, the local details are more cleared using local contrast enhancement, and both global and local characteristics of the image are more detailed using global-local contrast enhancement, as compared to the original image.

The speed and the simplicity of the enhancement are generally better in global enhancement methods [1]-[12] as compared to the local contrast enhancement methods. However, from the point of view of the quality of the image, global contrast enhancement methods are generally much less in defining the local details of the image as compared to local contrast enhancement methods. However, the global contrast enhancement methods are more suitable for those images which are poor in global contrast only. Linear contrast stretching and histogram equalization etc. are some of the widely used global contrast enhancement methods.

Although the global contrast enhancement methods are fast and simple, only the global enhancement methods are not enough for most of the images, because the image characteristics differ considerably from one region to another region in the same image. For the local details of the different regions of the image, the local contrast enhancement methods are also necessary.

In different images in different fields like medical images, real-time images, surveillance-application images and many others, several local contrast enhancement methods are employed by different persons. One of the local contrast enhancement methods used by Dorst [13] is an adaptation technique of histogram stretching method over a neighbourhood around the candidate pixel for local contrast stretching. Then, it was followed by several enhancement techniques [14]-[28] of histogram equalization based on adapting the same over a sub-region of the image. A local contrast stretching method in which local statistics of a predefined neighbourhood are used in modifying the gray level of a pixel was suggested by Lee [29], [30]. Narendra and Fitch [31] designed a method by using the amplification factor too to be a function of the pixel based on the local gray level statistics over the same neighbourhood in which contrast gain is inversely proportional to Local Standard Deviation (LSD). From the observation of Dah-Chung [32], image enhancement with contrast gain which is constant or inversely proportional to the LSD produces either artifacts or noise over enhancement due to the use of too large contrast gains in regions with high and low activities and developed a new method in which gain is a non-linear function of LSD. Schutte [33] introduced another method that a multi-window extension of the technique using LSD was utilized and how the window sizes should be chosen was shown. Sascha [34] implemented an improved multi-window real-time high frequency enhancement scheme based on LSD in which gain is a non-linear function of the detail energy. However, some of the enhancement methods which are using LSD's suffer from divide by zero condition when LSD's of some pixels are having the value zero. This divide by zero condition can be overcome [35] by modifying the LSD's, changing with a very small negligible value.

Although the local contrast enhancement methods are necessary in the enhancement of different images in different fields, neither only the global contrast enhancement method nor only the local contrast enhancement method is sufficient for some images which are poor in both of global contrast and local contrast. For those images which are poor in global contrast as well as in local contrast, the quality of the images can be improved by using the global-local contrast enhancement technique [36] which can improve the global contrast as well as the local contrast of the original images. However, the global-local contrast enhancement technique can be improved by using a better global contrast enhancement method for the combination with the same local contrast enhancement method.

This paper is organized as follows: Section II briefly reviews some enhancement methods. Section III describes two global-local enhancement methods which differ only in the global enhancement methods. Section IV shows experimental results and discussion. And Section V is for conclusion.

II. REVIEW ON SOME METHODS

Some enhancement methods are reviewed briefly in this section.

One of the global contrast enhancement methods, controlled with single user defined parameter, is Semi-Automatic Global Contrast Enhancement (SAGCE) [12]. This method can be expressed as

$$f_x(i,j) = (1 + C_g) * [x(i,j) - g_{mean}] + 0.5 \tag{1}$$

where, $x(i,j)$ is the pixel value at location (i,j) of the original input image, C_g is the global contrast gain control, g_{mean} is the global mean of the pixel values of the whole image and the threshold too and $f_x(i,j)$ is the enhanced value of the pixel $x(i,j)$.

With this method, global mean of the pixel values of the original image is always brought into the value 0.5 automatically in the output image and the contrast gain can be controlled by using only C_g. This method is user friendly so that when C_g is increased, the gain in the global contrast is increased, when C_g is more increased, the output image will have more gain in the global contrast and the upper and lower range of intensity are adjusted uniformly with the reference of g_{mean}. This method is very convenient to the user to combine with other local contrast enhancement methods because this method has very less number of user defined parameters i.e. single user defined parameter.

Next is also one of the global contrast enhancement methods. In this method, the enhancement is controlled by two user defined parameters. As a simple implementation, this method [4] can be expressed as

$$F_x(i,j) = m \cdot x(i,j) - n \tag{2}$$

where, $F_x(i,j)$ is the enhanced output pixel of the image, $x(i,j)$ is the pixel value at location (i,j) of the original input image, m is a global multiplier and n is a real value such that $m>0$, $n>=0$.

When the appropriate values of m and n are already known for the enhancement of the input image, this method is the fastest one [4]. If the values of m and n are to be guessed, it may try for many times for the proper values of m and n. For determining the appropriate values of m and n, the histogram of the relevant image is very helpful. By choosing different values of m and n, the user can get various options. The user can fine tune the enhancement of an image with more number of user defined parameters. However, the user's convenience may be less in choosing the desired combination from different combinations of m and n.

Next is one of local contrast enhancement methods using LSD in which divide by zero condition can be overcome [35]. In this method, the enhanced output image can be described as

$$f(i,j) = x(i,j) + \frac{C}{\sigma(i,j)+s} \cdot \left[x(i,j) - m(i,j) \right] \tag{3}$$

where, $x(i,j)$ is the gray scale value of a pixel in an image, $f(i,j)$ is the enhanced value of $x(i,j)$, $m(i,j)$ is the local mean, $\sigma(i,j)$ is the LSD, C is for local contrast control, and s is a very small and negligible quantity greater than zero.

The removal of divide by zero, with this method, doesn't affect the quality of the enhancement. It retains the same local contrast enhancement quality except the removal of divide by zero condition.

The method in equation (1) as well as the method in equation (2) can combine with the method in equation (3) to provide different global-local contrast enhancement methods. If different global-local contrast enhancement methods are implemented, the results produced by the methods can be observed very easily.

III. GLOBAL- LOCAL CONTRAST ENHANCEMENT (GLCE) METHODS

Using equations (1) and (3), a global-local contrast enhancement method [35] can be implemented and again using equations (2) and (3), another global-local contrast enhancement method can also be implemented. However, the two methods differ only in global contrast enhancement method although they are utilizing the same local contrast enhancement method.

The first GLCE method can be implemented as follows.

Applying equation (3) on the output values given by equation (6.1),

$$f(i,j) = f_x(i,j) + \frac{C}{\sigma(i,j)+s} \cdot \left[f_x(i,j) - m(i,j) \right] \tag{4}$$

where, $f_x(i, j)$ is the globally enhanced output value of the original pixel value $x(i, j)$ at location (i, j) of the original input image using equation (1), $m(i, j)$ is the local mean at (i, j) among the neighbourhood values of $f_x(i, j)$, $\sigma(i, j)$ is the LSD at (i, j) among the neighbourhood values of $f_x(i, j)$, C is the local contrast gain control, s is very small and negligible quantity greater than zero and $f(i, j)$ is the enhanced output value produced by GLCE.

Here, in this first method, GLCE is controlled with the two user defined parameters at different stages. In the first stage, C_g controls the global contrast so that the increase in C_g gives more global contrast in the output. And in the second stage, C controls the local contrast in such a manner that the increase in C enhances the input image with more local contrast. However, the contrast controls of C_g and C should be done with certain combinations of the values of C_g and C because when the values of C_g and C are increased too large, some information may be lost or may not be defined properly in the output image.

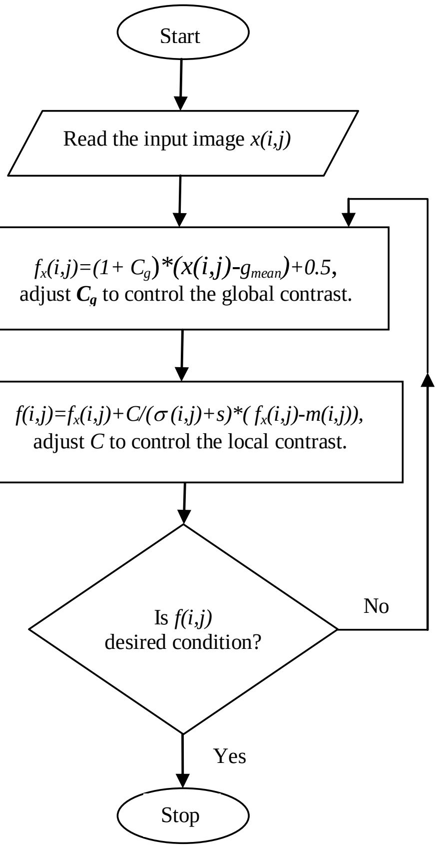


Fig.1 Flowchart for the first GLCE method

The whole procedure for implementing the above GLCE method can be summarized as

1. Read the input image
2. Apply SAGCE to the input image as in equation (1) and adjust $\boldsymbol{C_g}$ to control global contrast.
3. Apply the equation (4) to the output from step 2 and adjust ***C*** to control local contrast to get the final output.
4. Check the output from step 3. If it is not the desired condition, take the input image again and repeat from step 2.
5. Get the final output image.

The flowchart of the GLCE is shown in fig. 1.

And the second GLCE method can be implemented as follows.

Applying equation (3) on the output values given by equation (2) as

$$f(i,j) = F_x(i,j) + \frac{C}{\sigma(i,j)+s} \cdot \left[F_x(i,j) - m(i,j)\right] \qquad (5)$$

where, $\boldsymbol{F_x(i, j)}$ is the globally enhanced output value of the original pixel value ***x(i, j)*** at location ***(i, j)*** of the original input image using equation (2), ***m(i, j)*** is the local mean at ***(i, j)*** among the neighbourhood values of $\boldsymbol{F_x(i, j)}$, ***σ(i, j)*** is the LSD at ***(i, j)*** among the neighbourhood values of $\boldsymbol{F_x(i, j)}$, ***C*** is the local contrast gain control, ***s*** is a very small and negligible quantity greater than zero and ***f(i, j)*** is the enhanced output value produced by GLCE.

Here, in this second method, GLCE is controlled with the three user defined parameters at different stages. In the first stage, ***m*** and ***n*** control the global contrast in a more adjustable manner. And in the second stage, ***C*** controls the local contrast in such a manner that the increase in ***C*** enhances the input image with more local contrast. However, the contrast controls of ***m, n*** and ***C*** should be done with certain combinations of the values of ***m, n*** and ***C*** because when the values of ***m, n*** and ***C*** are increased too large, some information may be lost or may not be defined properly in the output image.

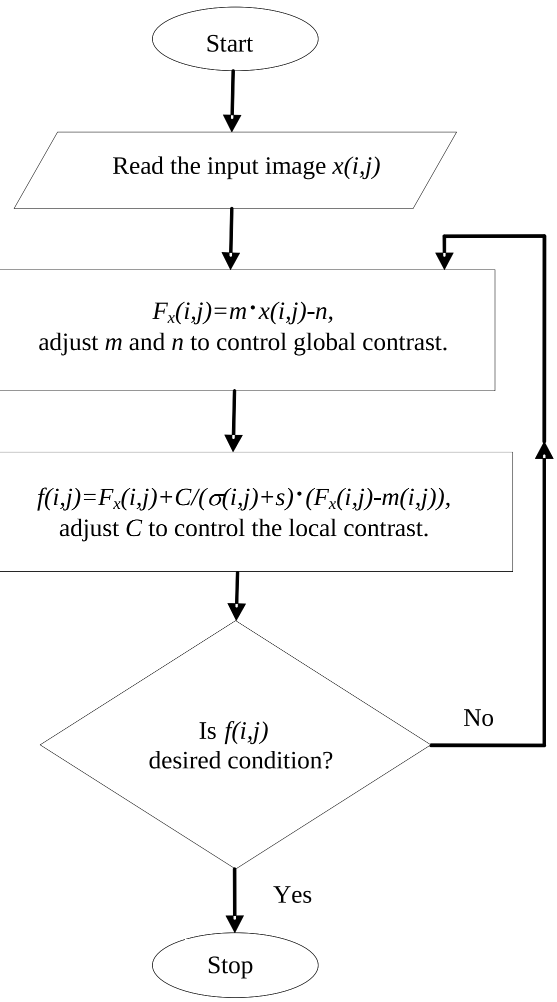


Fig. 2 Flowchart for the second GLCE method.

The second GLCE method i.e. the method of equation (5) is more adjustable in enhancement than that of the first GLCE method i.e. the method of equation (4).

The whole procedure for implementing the above GLCE method can be summarized as

1. Read the input image
2. Apply the method of equation (2) to the input image and adjust ***m*** and ***n*** to control global contrast.
3. Apply the equation (5) to the output from step 2 and adjust ***C*** to control local contrast to get the final output.

4. Check the output from step 3. If it is not the desired condition, take the input image again and repeat from step 2.

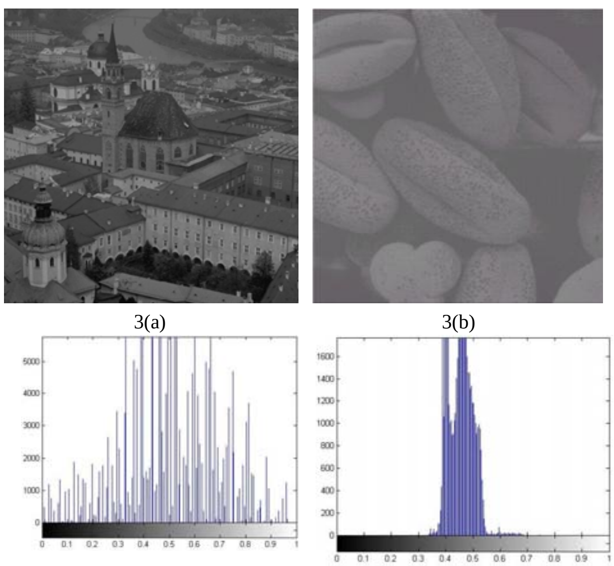
5. Get the final output image.

The flowchart of the GLCE is shown in fig. 2.

IV. Experimental Results And Discussion

The two GLCE methods have been tested on various test images using MATLAB 7.13.0.564 and the observation of the results has been taken up.

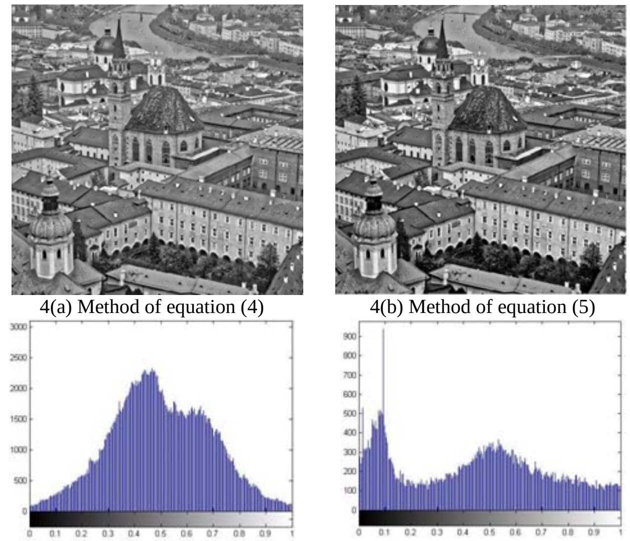
Fig. 3 shows two sample images and their histograms. Fig. 3(a) and Fig. 3(b) are two sample images with having different low contrast values and Fig. 3(c) and Fig. 3(d) are the corresponding histograms respectively. The image in Fig. 3(b) is having very low contrast values that it has very narrow range of intensity values in the histogram of the image as shown in Fig. 3(d) and the image is poor in global contrast as well as in local contrast.



3(c) 3(d)

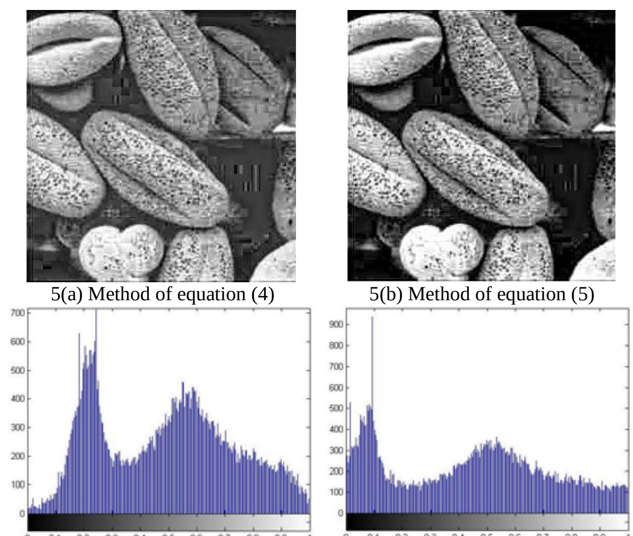
Fig. 3 Two sample images and histograms

The enhanced output images of fig. 3(a), processed with the two GLCE methods i.e. method of equation (4) and method of equation (5), are shown in fig. 4. The image in fig. 4(a) is the enhanced output image processed with the method of equation (4) with C_g=0.08 and C=0.12. The image in fig. 4(b) is the enhanced output image processed with the method of equation (5) with m=1.45, n=0 and C=0.12. Here, the qualities of both the output images are much improved from the original image so that the local contrast as well as the global contrast are improved in a reasonable amount. However, the objects in the enhanced output image using the method of equation (5) are more pronounced than that of the method of equation (4). Here, for both of the methods, the value of local contrast control C is 0.12, i.e. no change in local contrast for both of the methods. The only change is in global contrast. For the method of equation (5), m=1.45, n=0 are the global contrast control values, and for the method of equation (4), C_g=0.08 is the global contrast control value. However, the method of equation (4) is more user-friendly in choosing the desired value of C_g than that of the method of equation (5) in choosing the values of m and n. Here, the method of (4) is semi-automatic in nature and the method of equation (5) is controlled manually by two user-defined parameters m and n during their global enhancement stages. The histograms of the images of fig. 4(a) and fig. 4(b) are shown in fig. 4(c) and fig. 4(d) respectively.



4(c) Histogram of fig. 4(a) 4(d) Histogram of fig. 4(b)

Fig. 4 Enhanced output images of fig. 3(a) and histograms



5(c) Histogram of fig. 5(a) 5(d) Histogram of fig. 5(b)

Fig. 5 Enhanced output images of fig. 3(b) and histograms

Again, the enhanced output images of fig. 3(b), processed with the two GLCE methods i.e. the method of equation (4) and the method of equation (5), are shown in fig. 5. The image in fig. 5(a) is the enhanced output image processed with the method of equation (4) with C_g=4.0 and C=0.08. Fig. 5(b) is the enhanced output image processed with the method of equation (5) with m=6.76, n=2.61 and C=0.08. Here also, the qualities of both the output images are much improved from the original image so that the local contrast as well as the global contrast are improved in a reasonable amount. However, the objects in the enhanced output image using the method of equation (5) are more pronounced and cleared than that of the method of equation (4). Here, for both of the methods, the value of the local contrast control C is 0.08, i.e. no change in local contrast for both of the methods. The only change is in global contrast. For the method of equation (5), m=6.76, n=2.61 are the global contrast control value, and for the method of equation (4), C_g=0.08 is the global contrast control value. However, here also, the method of equation (4) is more user-friendly in choosing the desired value of C_g than that of the method of equation (5) in choosing the values of m and n because the method of (4) is semi-automatic in nature and the method of equation (5) is controlled manually by two user-defined parameters m and n during their global enhancement stages. The histograms of the images of fig. 5(a) and fig. 5(b) are shown in fig. 5(c) and fig. 5(d) respectively.

Table1 Comparative Statements of the two GLCE methods.

Method of equation (4)	***Method of equation (5)***
More user-friendly	Somewhat less in user-friendly
Much more improved in quality from the original image.	The quality is more improved than that of the method of equation (4)
Semi-automatic nature in global contrast control	More manual nature in global contrast control
Single user-defined parameter, C_g is used in global enhancement stage.	Two user-defined parameters, m and n are used in global enhancement stage.
Single user-defined parameter, C is used in local contrast enhancement stage	Single user-defined parameter, C is used in local contrast enhancement stage
Two user-defined parameters are used in the method and this method is more in user-convenience.	Three user-defined parameters are used in the method, and this method provides more options to choose.

By the observations of the enhanced output images, it is found that the images produced by the method of equation (5) are more improved in quality and more adjustable in global enhancement than that of the method of equation (4). However, the method of equation (4) is more convenient to find the final desired output image than that of the method of equation (5) because the global enhancement is controlled with a single user defined parameter C_g and semi-automatic in nature, whereas in the case of the method of equation (5), the global enhancement is controlled with two user-defined parameters m and n. In both of the methods, the same local contrast control C which is a single user-defined parameter is used to adjust the local contrast. In the experiment above, the same value of C is applied for both of the methods for each of sample image. Here, one method is better in quality and another is better in user's convenience. This is nothing but the results from the role of global contrast enhancement in global-local contrast enhancement. The distinctive features of the two GLCE methods are shown in comparative statements given in Table 1.

V. CONCLUSION

Global-local contrast enhancement methods are very efficient methods for improving the quality of low contrast images. However, if the global enhancement method which is used in global-local contrast enhancement method is replaced with another global enhancement method, something will be changed in the global-local enhancement. The new method may be more convenient to find the desired output image or may be having the better quality in the enhanced output image. A better enhancement method is justified as per the requirement of the enhancement condition depending upon the convenience or the better quality if the method reaches the reasonable enhancement quality. So, global enhancement method plays a great role in global-local contrast enhancement.

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