A New Approach for Contrast Enhancement Using Sigmoid Function

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Abstract: *The contrast of any image is a very important characteristic by which the image can be judged as good or poor. In this paper, we introduce a simple approach for the process of image contrast enhancement using the sigmoid function in spatial domain. To achieve this simple contrast enhancement, a novel mask based on using the input value together with the sigmoid function formula in an equation that will be used as contrast enhancer. This new contrast enhancer is passing over the target image, operates on its pixels, one by one. The new contrast enhancer is a scaled version of the input that is performed by applying a sigmoid function to the signal itself. The intensity value of each pixel in the output image is computing according to a specific formula. The parameters of the sigmoid function were determined by using three different methods. The effect of gain's value on the contrast enhancement process was studied. The new enhancing approach has been successfully, applied in several gray scale images. We proved that it works efficiently in different dark and bright images adjusting their contrasts. Moreover, the new enhancing approach was effective in dealing with colored images resulting in high-quality outputs. Our proposed algorithm is a simple approach that can be used successfully, in various applications suffering from different image's contrast problems.*

Keywords: *Image processing, contrast enhancement, sigmoid function.*

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1. Introduction

1.1. General Considerations

Image enhancement techniques have been commonly used in various applications where the subjective quality of images is very important. The objective of image enhancement is dependent on the application circumstances. Contrast is an important factor in any individual estimation of image quality. It can be a controlling tool for documenting and presenting information collected during examination. Recently several algorithms for carrying out contrast enhancement have been developed [1, 5, 7, 9].

1.2. Contrast Enhancement

The expression contrast refers to the amount of color or gray scale differentiation that exists between various image features in both analog and digital images. It is the range of brightness present on an image. Images having a higher contrast level usually display a larger degree of color or grayscale difference than those of lower contrast. The contrast variations affect the ultimate form of the image. Contrast enhancement is a process that allows image features to show up more visibly by making best use of the colors presented on the display device [2].

1.3. Common Enhancement Methods

Among the others, there are common methods for contrast enhancement. They fall in two categories, spatial domain, and frequency domain methods [4]. Spatial domain enhancement modifies pixel values based on the values of neighboring pixels. Spatial domain enhancement deals mainly with spatial frequency. Frequency domain methods are based on modifying the Fourier transform of an image [8].

1.3.1. Histogram Equalization

A histogram is a graph that shows how much of the image has a certain intensity 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. This technique is useful for processing images that have little contrast with equal number of pixels to each of the output gray levels.

1.3.2. Linear Stretch Convolution Filtering

Convolution filtering is the process of averaging small sets of pixels across an image that is used to change the spatial frequency characteristics of that image. A convolution kernel is a matrix of numbers that is used to average the value of each pixel with the values of surrounding pixels in an exacting way. The numbers in the matrix serve to weight this average toward particular pixels. High pass filter and low pass filter are general examples of this method. High pass filter attenuates the low spatial frequencies of an image and emphasizes the high spatial frequencies of an image. It is used normally, to enhance details, edges, and lines. Low pass filter attenuates the high spatial frequencies of an image and accentuates the low spatial frequencies of an image. It is usually enhance common image features. Contrast enhancement by point processing is one of the simplest enhancement methods. In this method, the grey level of each pixel in the input image modified to a new value; this modification based on the pixel value and is independent of location or neighboring values. In color images, objects can show differences in color saturation with little or no connection in luminance variation. Several methods have been proposed in the earlier period for color image enhancement [6, 10].

In this paper, we describe a new approach to deal with the images improving their contrast in a simple way. We prepared a mask based on the input parameters with using a non-linear activation function that is the sigmoid function parameters in one formula. By using this mask, passing it over the input target image, it works on that image pixel by pixel then giving its results which is the processed image after adjusting and enhancing its contrast.

1.4. Sigmoid Function

Sigmoid function is a continuous non-linear function. The name, sigmoid derives from the fact that the function is "S" shaped. Statisticians call this function the logistic function. Using f(x) for the input and with g as a gain, the sigmoid function is

$$f(x) = 1/(1 + e^{-g(x)})$$

For better explanation of this function, refer to [3]. Figure 1 illustrates the sigmoid function; it goes up smoothly and kindly.

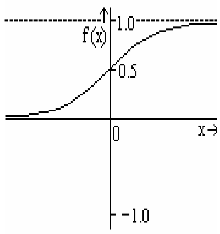


Figure 1. Sigmoid function.

2. Algorithm Implementation

This new enhancement approach is a point process that is performed directly on each pixel of an image, independent of all other pixels in that image to change the dynamic range. In this method, the mask that is applied to the target images is a non-linear activation function which is a sigmoid function multiplied by the input itself and by a factor. We used that factor to determine the most wanted degree of the contrast depending on the degree of darkness or brightness of the original image.

2.1. How the New Contrast Enhancer Works

The mask passed over the image pixel by pixel starting from the image's upper right corner. Each pixel's intensity value in the output image is equal to its intensity value in the original image added to the value of this mask. This formula operates upon the original target image pixel by pixel. The following formula defines the pixels' values of the output image

$$O(i, j) = I(i, j) + I(i, j) * C * (1/1 + e^{-I(i, j)})$$

The above formula describes simple exponential growth dynamics with a linear limiting control that adjusts poor image contrast;

Where:
- $O(i, j)$ is the output image.
- $I(i, j)$ is the unprocessed input image.
- C is a factor.

The value of the C is depending on the objective of the enhancement process, we gave it the value of one, two, or three but it is not limited to these values, the user can select the value of C according to desired contrast that the he needs. The pixel values are within a limited range (0-255) for an 8-bit image. The results usually need to be clipped to the minimum or maximum allowable pixel values so that all highest components turn out to be 255 and the lowest values to 0.

3. Experiments

Since $f(x) = 1/(1+e^{-gx})$, the sigmoid function parameters value limits must be specified before the new approach is applied. In order to compare and chose the best result, we studied several methods for determining the parameters of the function and the effect of its gain value. Some of these methods were based on computing the histogram of the image $H(z)$. The image histogram is a graphical plot of the number of pixels in the image with each of the potential intensity levels

$$H(z) = \iint [I(i, j) = z]\, didj$$

Where:
- $H(z)$ is the histogram.
- $I(i, j)$ is the input image.
- z is the gray level.

- First method was performed by finding the median value of that histogram (the median value is the value which uniformly partitions the population of the histogram), then substituting the x by the computed median value.
- Second method was implemented by calculating the mean value of the image's histogram (the mean value is the average value in the histogram) and replacing the x with that mean value.

- In the third method the x was equivalent to the input signal *I(i, j)*.

By comparing the results from the previously described three methods, we found that there are no significant differences in the resulting images from each of them. Based on the above findings among the obtained results, we decided to use the x= input signal *I(i, j)* in all our formula which sounds very simple and without introducing excess complexity. The new contrast enhancer was implemented with C language. Figure 2 shows the output image when using different values of x. In addition to the above, we tested the sigmoid function with positive and negative gain values. When we used negative gain values, the contrast enhancer had no effect on the input images, as we can see in Figure 3-b the contrast of the input image, did not enhance and the output image became slightly dark.


(a) Original dark image.


(b) The output, x= median value of the input image histogram.


(c) The output, x= mean value of the input image histogram.


(d) The output, x= median value of the input image histogram.

Figure 2. Illustrates the output image with different values of x; (a) the original dark image; (b) the output image when x= the median of input image histogram; (c) the output when x= the mean value of input image histogram; (d) the output image when x= the input.


(a) Original dark image.


(b) The output image when using negative gain.

Figure 3. Illustrates the output when using negative gain; (a) the original dark image; (b) the output image.

4. Results and Discussion

The new approach for contrast enhancement that we describe here is a point process operator. It is based on modifying the appearance of an image by controlling the input pixels values via an equation depending on sigmoid function.

We aimed at adjusting the shadows and highlights in the poor-contrast images as well as increasing the signal-to-noise ratio. Adding to this aim, we planned to make certain features of the image much easily seen by modifying the colors or intensities of that image.

The results obtained varied depending on the processed images. In the determination of sigmoid function parameters, we computed the value of "x" by using many methods. This "x" was replaced by median, mean values of images histograms and by the input (i, j). The results of the three methods showed no significant differences or even were almost similar. Therefore, we can conclude that the value of x does not affect the contrast enhancement process.

Our newly proposed approach for contrast enhancement was tested by applying it on more than 700 different poor contrast images. Some images were dark, others were bright, and some have ill-defined boundaries. In addition, it was applied on gray scaled and colored images.

All grey scale images are 200x200 pixels and 256 grey scale.

Figure 4-a shows a dark input image that has poor dynamic range. Then Figures 4-b, 4-c and 4-d are the processed images where we used different values of *C* as the factor that determines the degree of the desired contrast. In the processed output images, the girl appears normal, pleasing and she looks much more alive. This is an example of the effectiveness of the proposed new contrast enhancer for dealing with the dark grey scale images.

Then we aimed at testing its efficiency for dealing with dark Figure 5 shows the dark image in 5-a to the left adjusted and became clearer after the new proposed contrast enhancer processed it in 5-b to the right.

The new contrast enhancer that we describe in this paper has also been tested for adjusting the brightness of the images whether gray scale or colored images. For colored images, we used RGB and CMYK colored images. The technique was applied to each color component "band" independently and in sequence performing the same operation on each color channel.

Figure 6 shows the original bright image 6-a to the left where you find the blurred image with ill-defined edges and unclear details. Then after using our contrast enhancer, the details of the birds in the image highlighted and the edges are no longer hazy in 6-b.

Then the new sigmoid contrast enhancer also has been tested for adjusting the brightness of colored images. Figure 7 shows the results, where 7-a is the bright original target image and 7-b is the output resulting image after brightness adjustment.

Figure 8 demonstrates that we can control the degree of contrast enhancement of the original bright color image 8-a to get the best level of desired contrast by changing the value of the factor C; where C= 1 in 8-b, C= 2 in 8-c, and C= 3 in 8-d.

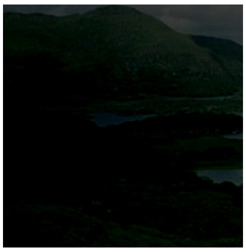
(a) The original image.

(b) The processed image, C= 1.

(c) The processed image, C= 2.

(d) The processed image, C= 3.

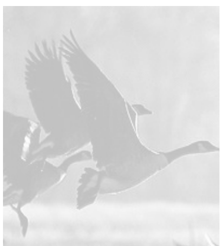
Figure 4. Illustrates the result of applying the proposed contrast enhancement approach on a dark grey scale image; (a) is the original target dark images, (b), (c) and (d) are the processed images where we used different values of C as the factor, which determines the degree of the desired contrast.



(a) The original dark image.

(b) The processed color image.

Figure 5. Illustrates the result of applying the approach on a dark color image; (a) the original dark image; (b) the processed images.



(a) is the original image.

(b) is the obtained image, C= 2.

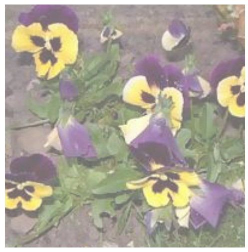
Figure 6. Illustrates the results of applying the proposed contrast enhancing approach on a bright grey scale image; (a) is the original bright image and (b) is the processed image, where C= 2.

(a) The original image.

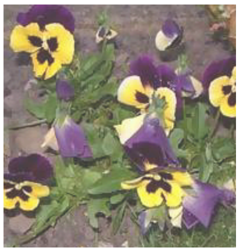
(b) The processed image, C= 2.

Figure 7. illustrates the results of applying the proposed approach on a bright color image; (a) is the original bright image and (b) is the processed image, where, C= 2.

(a) The original color image.



(b) The processed image, C= 1.



(c) The processed image, C= 2.

(d) The processed image, C= 4.

Figure 8. Illustrates the result of applying the approach on a bright color image with adjusting the value of the factor C; where, (a) is the original color image, (b), (c) and (d) are the processed images with using different values of C; C= 2, 3, or 4, respectively.

The resulting images after applying the new proposed contrast enhancer on both dark, bright, grey scale and colored images were satisfactory in the original dark, or bright images, the details are nearly undetectable. However, after applying the proposed enhancer, most of the scene features have become easily discriminated and more interpretable to the human eye. On dealing with bright images that needs to be darkening, it was found that the better value of C is equal to two.

The resulting images from the proposed new contrast enhancer possesses a much higher readability than its original form and prove highly effective in dealing with poor contrast images. It could give high contrast images and the boundaries of each region in the processed images are clearly highlighted. In addition, this approach enhances details in images without increasing the noise present in the smooth areas. From the above results we conclude that by this newly described method we can easily improve the contrast "darkness and the brightness" of the poor images without affecting the details or introducing any amount of noise to the output images. Therefore, the process of image segmentation and classification can be powerfully accomplished from the resulting image.

5. Conclusion

In this paper, we presented a new and quite simple brightness-contrast enhancement method that uses the sigmoid function in order to improve the overall dynamic appearance of an image. The proposed algorithm is fast, easily implemented and is a simple way to adjust an image's tonal range without sacrificing any image details. By using this operator, we can brighten or darken any image, change its dynamic range and make it much clearer to see all of its details. To test the efficiency and effectiveness of the new operator, it was applied on a great number of gray scale images, as well as colored images. Highly satisfactory and good results were obtained. In short, the simplicity of the algorithm and its ability to produce better results than the conventional approaches make it an excellent candidate for practical implementation in real-time and can be successfully used in various applications suffering from different image contrast problems.

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