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An Adaptive Approach for Image Contrast Enhancement using Local Correlation

Sarah M. Baqer
Faculty of Computer Science & Mathematics,
University of Kufa, Najaf, Iraq.

Zahir M. Hussain[1]
Professor, School of Engineering,
Edith Cowan University, Joondalup, Australia.

Abstract

In this work an adaptive approach for contrast enhancement has been presented. We modify a fixed-parameter enhancement method based on power transform to an adaptive technique based on maximum correlation between image pixels. Experimental results of the proposed approach show better details for the enhanced output image using the proposed correlative approach as compared to the fixed-parameter approach.

AMS subject classification: 11B68, 11S40, 11S80.
Keywords: Image enhancement, image correlation, covariance, adaptive contrast.

1. Introduction

Image enhancement refer to the process of enhancing the appearance of image or subset of images for better contrast, or modifying the attributes of a given image to make it more suitable for specific task and observer. Contrast enhancement is a consequential issue in image processing for both computer vision and human.

Contrast enhancement improve the perception of objects in the scene by enhancing the brightness difference between objects and their background. Contrast is the difference in visual properties that make an object distinguishable from other objects and the background [1].

[1]Corresponding author.

The human visual system is more sensitive to contrast than absolute luminance [2], so the information may be lost in the area of the image that are uniformly dark or bright. When image has very low or too high contrast it cannot be said that the quality of a given image is good. The difficulty is how the contrast of a given image can be improved to represent all the information in the image. Different local and global contrast enhancement techniques can be used to enhance the quality of low contrast image. Histogram equalization and linear contrast stretching are two widely used techniques for global contrast enhancement [3]. Despite these methods are generally simple and fast in processing speed but these techniques cannot adapt to local brightness features of the input image and in many cases can amplify the noise and produce worse results than the original image due to many pixels falling inside the same gray level range. In most cases, for the same image, the image characteristics differ to a great extent from one region to another. This is one of the basic reasons of the need for local contrast enhancement that can enhance overall contrast more effectively. Several local contrast enhancement methods are employed in various images in the different fields, like real time images, medical image, surveillance application and many others.

Many enhancement techniques [4], [5] of histogram equalization based on adapting the same over a sub-region of the image has been suggested. In [6], instead of applying the usual histogram equalization which works on the whole image, the authors applied a new algorithm called CLAHE (contrast limited adaptive histogram equalization) to enhance the contrast of small tiles and to combine the neighboring tiles in an image by using bilinear interpolation. In [7], [8], Lee suggested a local contrast enhancement and noise filtering method by using local statistics of predefined neighborhood to modify the gray level of pixels.

Despite the fact that these methods make good use of local information, the computational cost goes very high and they may enhance noise effects in the image as well. In this work, a more robust and accurate adaptive contrast enhancement approach will be presented.

2. Fixed-parameter contrast enhancement using power transform

In [9] the Author presented and applied a linear stretch method for contrast enhancement. Here we apply a non-linear stretch which shows higher contrast between pixel values and gives better details for image X as follows:

$$f(x) = \frac{1}{[1 + (\frac{b}{x})^p]} \tag{2.1}$$

where is $x \in X$ is a pixel in X, p is a contrast parameter, where larger p gives stronger contrast; x is the image, and b is a threshold. This non-linear transform pushes pixels whose values are above b to values above 0.5 by an amount proportional to their values, while it pushes lower pixels to lower values.

In this work the above power transform enhancement technique will be modified based on correlation rather than a straightforward choice (like average) to define a new adaptive contrast enhancement approach.

3. Covariance as a correlative measure

Covariance produces a measure of strength of relation between two or more sets of random variables. In various applications such as pattern recognition tasks, there are more than one features that should be tested for independence of one another, in other word, to decide whether there exists a relationship between each pair of these features. To understand this relationship the covariance is computed [10].

The covariance matrix C_G for a real matrix G is calculated as follows:

$$\mathbf{C}_G = [C_G(i, j)] = [\mathbf{cov}(G_i, G_j)] = [\mathcal{E}\{(G_i - \mu_i)(G_j - \mu_j)\}] \tag{3.2}$$

where G_i is the i^{th} column of G, $\mathcal{E}\{\cdot\}$ is the mathematical expectation functional, and $\mu_i = \mathcal{E}\{G_i\}$.

In this work we calculate the total covariance for regions of the reference image whose columns represent random variables to find maximum correlation for every sub-region by taking an adaptive window that maximizes the total covariance defined for a region G by Equation (3.3) below:

$$S_G = \sum_{i,j} C_G(i, j) \tag{3.3}$$

Now we make the factor b in Equation (2.1) a linear function of the average of the local region whose center is $x \in X$, enclosed by the locally-optimal window W of size $w \times w$ whose covariance is S_W as given in Equation (3.4) below:

$$b = K\overline{W} + A \tag{3.4}$$

where $\overline{W}$ = average of window region W; K, A are constants.

4. An adaptive approach

At each pixel $x \in X$, an adaptive window is considered; starting with 3×3 size around the examination point (pixel) x. Then the covariance of this area is calculated. The next step the window size is expanded around the examination point. If the new correlation (represented by total covariance) is larger, then the new window is considered as it represents a new area with more pixels relevant to the examination point, where this window will show correlative characteristics better than the previous smaller window. However, if the new correlation is weaker than that presented by the previous window, that is, finding points with less relation to the previous area, then the search stops, giving the optimal window size surrounding the pixel $x \in X$. Hence, the window size is optimized based on the maximum correlation. The optimal window is then used to enhance the image contrast locally.

The adaptive approach is given by the following algorithm.

Algorithm:
Input: X is the reference image, w_0 and w_m are minimum and maximum window sizes; p, K, and A are constants.
Output: Y which is the enhanced output image.
Step 1: Convert image value into double type.
Step 2: For each pixel $x(i, j)$ in image X do:
Step 2.1: Initialize window length: $w = w_0$.
Step 2.2: Crop $w \times w$ region W.
Step 2.3: Initialize: $S_0 =$ total covariance of W.
Step 2.4: For $w = w_0$ to w_m do:
Step 2.4.1: Crop w×w region W.
Step 2.4.2: Find total covariance of W.
Step 2.4.3: If $S < S_0$, stop (optimal window).
Step 2.4.4: $S_0 = S$
Step 2.4.5: Go to Step 2.4 for a new window.
Step 2.5: Set $b = K * \text{mean}(W) + A$.
Step 2.6: Compute the enhanced pixel $y(i, j)$:

$$y(i, j) = \frac{1}{\left[1 + \left(\frac{b}{x(i,j)}\right)^p\right]}$$

End of Algorithm

5. Results and discussion

The proposed method has been tested on different images using MATLAB. We took $K = 0.5$ and $A = 0.1$, $p = 2$. Landscape and geometrical images has been chosen as represented by MATLAB images cameraman.tif and tire.tif. Results are compared with the fixed-parameter power transform enhancement method, using the contrast parameter $b = 0.3$. The results in Figures 1 and 2 show that enhanced image using the proposed adaptive approach give rise to perceptually better details than the fixed-parameter power transform approach.

6. Conclusions

An adaptive approach for contrast enhancement has been proposed and tested for different gray scale images. The proposed approach optimizes local windowing based on the maximum correlation between image pixels within the window. Experimental results show that the proposed approach gives more details for the enhanced image as compared to

Figure 1: Performance of the proposed adaptive contrast enhancement versus fixed-parameter enhancement using power transform for the MATLAB landscape image cameraman.tif.

Figure 2: Performance of the proposed adaptive contrast enhancement versus fixed-parameter enhancement using power transform for the MATLAB geometric image tire.tif.

fixed-parameter approach. Based on the fact that contrast is the difference between visual properties that makes objects distinguishable from other objects and their background, it can be concluded that the proposed enhancement method outperforms fixed-parameter approach.

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