Normalization of Contrast in Document Images using Generalized Fuzzy Operator with Least Square Method

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Abstract

The visual effect of non-uniform contrast and brightness surrounds in the image is a very common problem in the applications of photocopying, IC manufacture and medicine. In using the digital/CCD camera to capture documents and photos based on non-uniform illumination condition, the poor image will be seen. The poor image can result in achieving the inaccurate reading from the optical character recognition (OCR) system. This paper present a new approach to normalize the local contrast in documentation based on the least square method and also enhance the object of interest using generalized fuzzy operator (GFO). Two typical examples are used for evaluating the method.

1. Introduction

Documents and photos digitization using digital/CCD camera based on non-uniform illumination background (non-uniform contrast/brightness) can result in image degradation which would cause pattern recognition systems to make unacceptable errors. This kind of errors can be represented as the background noise in the image. Another application relates to this problem is in IC manufacturing. IC recognition machine cannot read the IC model number or serial number significantly so that it is difficult to sort the suitable IC in the running bell line. Pervious studies [1-4] have proposed using the noise equalization, thresholding, adaptive noise suppression and feature-based classification methods. However, the performance of these methods is insufficient. In recent, for the analysis of Mammography study, Veldkamp *et al.* [5] has proposed that noise level should be depended on the standard error of feature values. Background noise can be removed by using the standard deviation of local contrast in re-scaling local contrast features. The latter approach is related to this work but the concept in the noise is not the same. Basically, on the one hand, the object of the image is light source dependent. Hence, the background noise comes from a higher intensity of the illumination. On the other hand, the noise depends on the light reflection rate of the object. By then, we define the image based on this concept: (1) The image can be separated into three regions in which each are depends on each other. (2) The objects and background are in the lowest light reflection rate. The first region is based on the highest intensity illumination source but in the lowest contrast region of image, all information in this region is lost. The second is the normal region in which the noise is not much occupied into this region. The last is the degraded image region. Characters in this region are displayed fuzzily. Three regions are matches with each other in contrast/brightness based on the adaptive GFO with the Least Square method. The method in local contrast normalization [6-7] is included in the generalized fuzzy set that will be presented in the next section. Finally, the Generalized Fuzzy Operator is introduced to enhance the object that needed.

2. Definitions of the new approach

2.1 Least Square Method using in Normalized Local Contrast

Contrast is the received difference in luminance between objects and background. According to Weber's law [8], the contrast C_i is defined as

$$C_i = \frac{|B_o - B_b|}{B_b} \quad (1)$$

Where B_o is the brightness stimuli of the object and B_b is the object background. The contrast can be normalized by

$$C_i' = \frac{(C_i - \mu_{c_i}(x,y))}{\sigma_{c_i}(x,y)} \quad (2)$$

where C_i denotes the normalized local contrast at the area i of the image, μ_{c_i} represents the mean of the local contrast, and σ_{c_i} is the smoothing function (filter function). Now, we redefine the smoothing function σ_{c_i} based on the pixel histogram of the selected regions.

Let S_i, $i = 0, 1, \ldots, k$ is the pixel sequence of the normal contrast/brightness regions, and S_j, $j = 0, 1, \ldots, k$ is the pixel sequence of the abnormal contrast/brightness regions (included over-brightness or low-contrast). The contrast/brightness error is defined by the difference between the normal sequence S_i and the abnormal sequence S_j:

$$\varepsilon_k = S_i - S_j = S_i + \sum_{j=1}^{p} \mathring{a}_j S_{k-j} \quad (3)$$

where $\mathring{a}_j$ denotes the pixel estimated value that is the difference between normal and abnormal regions. Then, the Least Square method [11] denotes the estimated parameters by minimizing the squared error,

$$\underset{a_i}{Min}\, E\{\varepsilon_k^2\} = \underset{a_j}{Min}\, E\left\{\left(S_i + \sum_{j=1}^{p} \mathring{a}_j S_{k-j}\right)^2\right\} \quad (4)$$

and we differentiate the $E\{\varepsilon_k^2\}$ with respect to a_1 and a_2 shown in equation 5.

$$\frac{\partial E\{\varepsilon_k^2\}}{\partial \mathring{a}_j} = 0 \quad (5)$$

where $j = 1, 2$.

The error values estimated from the equation 5 can be used as the smoothing function to normalize the local contrast in the degraded image. Thus,

$$\sigma_{c_1} = a_1 \text{ and } \sigma_{c_2} = a_2$$

2.2 Generalized Fuzzy Operator (GFO)

According to the previous studies using GFO [9-10], we have the definition of the GFO,

$$GFO[\mu_s(x)] = \begin{cases} \sqrt[\beta]{1 - [1 + \mu_s(x)]^\beta}, & -1 \le \mu_s < 0 \\ [\mu_s(x)]^\beta, & 0 \le \mu_s < \gamma \\ \sqrt[\beta]{1 - \alpha[1 - \mu_s(x)]^\beta}, & \gamma \le \mu_s(x) \le 1 \end{cases} \quad (6)$$

Where $x \in R$, and $\mu_s(x) \in [-1,1]$ is called the Generalized Membership Function of Generalized fuzzy set ς in the region $\Re$. Then, We use a Sine function to map the original image $X(i,j)$ into a fuzzy set $P_k(i,j)$:

$$P_k(i,j) = \sin\left\{\frac{\pi}{2}\left(1 - \frac{X_k(i,j) - X_{\min}}{D}\right)\right\} \quad (7)$$

where $\frac{X_{\max} - X_{\min}}{2} \le D$ and $k = 1, 2, \ldots, 5$.

Then, $P_k \in [-1,1]$ is mapped to the new fuzzy set P' as shown in the following equation. Let $k = 1$,

$$P'(i,j) = \begin{cases} a \times \left\{\frac{P(i,j) - P_{k+4}}{\sigma_{c_1}}\right\}, & P_k < P(i,j) < P_{k+1} \\ a \times \left\{\frac{P(i,j) - P_{k+4}}{\sigma_{c_2}}\right\}, & P_{k+2} < P(i,j) < P_{k+3} \\ [P(i,j)]^2 & others \end{cases} \quad (8)$$

By using $\beta = 2$ and $a = 1$, the newer image $X'(i,j)$ is

$$X'(i,j) = X_{\min} + D\left\{1 - \left[\frac{\sin^{-1}(P(i,j))}{\frac{\pi}{2}}\right]\right\} \quad (9)$$

The local contrast can be normalized by the equation 8 based on the smoothing function σ_{c_1} and

σ_{c_2}. For the object enhancement, it can be determined by the third term of the equation 8.

3. Results and Discussions

We implement our method in a Pentium II PC. The algorithm is programmed in the MATLAB. There are two kinds of image which have been selected in evaluating our method. Figure 1a shows a printed page image captured from the book. It is captured by the CCD color camera (JVC TK-C1380) based on the non-uniform illumination background. The characters shown in the image is out of focus since the printed paper is made as a projection error when the book is opening. The light source is hold in the right side so that the contrast is low and the brightness is high. Characters in the right side of the image were lost. Also, the illumination was performed on the left side of the image. Hence, the background of the printed paper is in non-uniformed. Figure 1b shows the result of using our method which processed in the same image. The non-uniform background of the whole image is remapped into the same gray level, and the characters in the left page can be enhanced. However, the characters in the right page are lost in the remapped image since the degraded characters are difficult to be reconstructed. Figure 2a is the second example to show the profile of the Intel 486 CPU in which the serial number printed in the surface of the CPU to show the lowest contrast between serial number and the background. Figure 2b is the result in using our method to enhance the serial number in this kind of images. Greater contrast between the serial number and the background of the CPU can be performed.

The normalization of contrast in document image using our algorithm is based on the fuzzy sets P_k. The conditions of fuzzy set are related to the histogram of selection region. Normally, on the one hand, the lowest contrast region is selected as the fuzzy sets P_1 and P_2. On the other hand, the normal contrast region is chosen as P_3, and the highest contrast region has been chosen as P_4 and P_5. The normalization of contrast is processed in these fuzzy sets within the GFO to obtain the new fuzzy set P'. With the smoothing function σ_{ci}, it is used to remove the background noise. The enhancement of the object is obtained by the term of $[P(i,j)]^2$ within the new fuzzy set P'. The words printed in the page and the serial number printed in the Intel 486 CPU are enhanced by using $[P(i,j)]^2$. Figure 1c and 1d show the histograms of the original document image and the resultant image using our method representatively. It shows that the pixel value of the image shifted from the range of 150 and 255 to below 100. However, the background of the image is remapped into around 220. It determines that the background noise is fundamentally removed, and the background gray scale is transformed to uniformity. The words are enhanced in the gray scale lower than 100. It can be separated with the background significantly. Figure 2c and 2d are the histograms of the original 486 CPU image and the resultant image using our method representatively. The lowest contrast image can result in the gray scale of the serial number with the background located from 110 to 255. However, the serial number and the background are significantly separated to the gray scale below 30 and around 230. Hence, the serial number can be enhanced.

4. Conclusion

The proposed Generalized Fuzzy Operator with Least Square algorithm is a simple, effective and efficient method for contrast/brightness normalization and pattern enhancement. We have presented that it is very useful in applying to the documentation analysis, IC manufacturer and also the work in pattern recognition.

5. References

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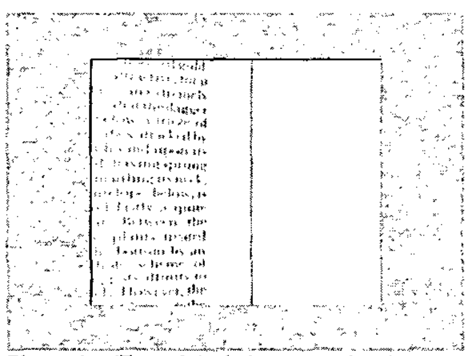


Figure 1a. The original documentation image with lower contrast and over-brightness.

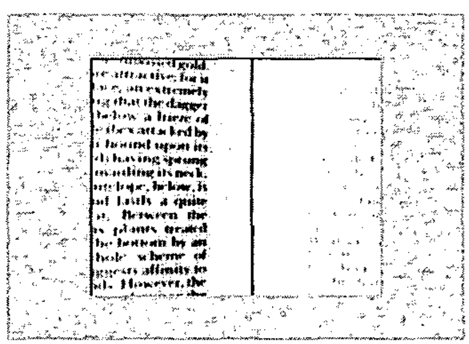
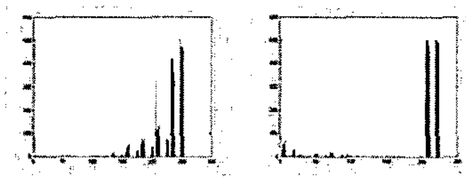


Figure 1b. The result of Figure 1a uses our method. The words have been enhanced and the background is smoothing.



1c 1d

Figure 1c. The histogram of the original documentation image, the gray scale of the image is located in high level. Figure 1d is the histogram of the resultant image, the background of this image is maintained in high gray level but the words is shifted to lower gray level.

Figure 2a. The original image of the Intel 486 CPU with the lowest contrast between the serial number and the background.

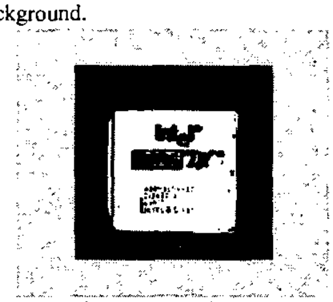
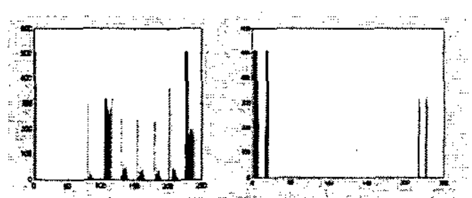


Figure 2b. The resultant image of Figure 2a uses our method. The serial number has been enhanced.



2c 2d

Figure 2c is the histogram of original image for the Intel 486 CPU, and Figure 2d shows that the gray scale is separated into two individual range of scales.