Application of Gaussian as Edge Detector for Image Enhancement of Ancient Manuscripts

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Abstract: Binarization is an essential step for the Digitization of Ancient Manuscript images. Degradations in the manuscripts, such as, uneven light, low complexity, smears and high noise densities frequently make thresholding of the manuscript images a troublesome task. The purpose of study is to preserve the information contained in documents in digital form. To improve the accuracy of machine reading for camera-based Manuscript images, a simple and novel approach has been proposed based on Difference of Gaussians: a second order edge detector, followed by modified Niblack’s local thresholding. The proposed strategy has been correlated with existing techniques. The numerical result stating average PSNR value 19.21dB validates that the performance of proposed method is superior to other five well known binarization techniques.

Keywords: Binarization, Difference of Gaussians, global thresholding, Local thresholding, edge detection.

1. INTRODUCTION

The evolution of modern imaging devices for Image enhancement and restoration plays a key part in manuscript document processing related applications, for example text recognition and image retrieval. In many cases the documents are deteriorated because of age, dust or due to ink smudging. The fundamental task is to digitize a manuscript image so that, background and foreground content are unmistakably isolated. In binarization there is a need of segmenting the document into two grayscale levels, which can be performed either locally [4], [6], [9],[10] or globally [1], [7], [8].

In the past a great deal of global thresholding concepts were proposed (e.g. Otsu’s method [2], Illingworth and Kittler’s method [3]). But global thresholding fails to remove noise from highly degraded images because of local degradation, poor illumination and complex background texture. Local thresholding is being utilized in [7] to achieve the goal of extracting a foreground part (text) from background (non text). Local thresholding achieves binarization by considering each and every pixel with neighborhood pixels [4]. Niblack proposed a local thresholding procedure by computing a threshold factor using local statistical parameters namely mean and standard deviation [4].
In this manuscript, we present a concept based on difference of Gaussian followed by modified Niblack’s local thresholding [4] and morphological post processing. Where the difference of Gaussian results in preservation of the edge information and thresholding using modified Niblack’s local algorithm produces binarized image, the final binarized image can be digitized with the help of OCR.

The paper is indexed as: Section 2.1 and 2.2 clarifies the importance of Gaussian Filter and difference of Gaussian also depicts Niblack’s thresholding algorithm. Section 2.3 introduces the proposed algorithm. Section 3 states the results of proposed strategy to access the framework. Section 4 finally concludes the work.

2. METHODOLOGY

2.1 Gaussian Filter and Difference of Gaussians:

As a gray image is a two dimensional object, two dimensional Gaussian functions is defined below.

\[
g(a, b) = \frac{1}{2\pi\sigma^2} e^{-\frac{a^2 + b^2}{2\sigma^2}}
\]

Where \(a\) and \(b\) are the distances from the origin in the horizontal axis and in the vertical axis respectively, and \(\sigma\) represents the standard deviation of the Gaussian distribution [5 6].

In image processing, difference of Gaussians (DoG) is a second order edge detection algorithm which performs the subtraction between two blurred versions of the image with different blur amounts \((\sigma)\). Hence DoG acts as a band pass filter for preserving the edge information in an image. Application of Gaussian functions on an image causes reduction in only high frequency spatial information. Subtracting one image from the other conserves spatial information which falls between the ranges of frequencies conserved in the two blurred images.

2.2 Niblack’s Local Thresholding Algorithm:

Niblack’s thresholding algorithm computes a threshold factor to each pixel by moving a rectangular window over the gray level image [4]. The dimensions of rectangular window can be changed depending upon the complexity of the background. The threshold value is calculated using the local mean and standard deviation of all the pixels in the window and is given by following equations [4]:

\[
T_{\text{Niblack}} = M + K \times SD
\]

\[
T_{\text{Niblack}} = M + K \times \sqrt{\frac{\sum(p_i - m)^2}{NP}}
\]

Here NP is the total pixels present in gray scale image, \(T\) represents the threshold value, \(M\) is the mean of gray levels of pixels and \(k\) is fixed depending upon the noise in the background and is - 0.2.
2.3 Proposed Method:
The proposed method for enhancement and restoration for manuscript images is described in this section. The flow diagram is shown in Fig.1 and each step is explained in detail in sub-sections.

2.3.1 Difference in Gaussians:
The difference of Gaussian edge detector eliminates high frequency details that generally include random noise removal. It reduces noise in the image by blurring and also preserves the edge information in the image. DoG also removes the low frequency background blotches. Finally the resultant image is normalized to $[0, 1]$. Equation for DoG is:

$$\Gamma(x, y) = I \ast (g_{\sigma_1} - g_{\sigma_2})$$ (4)

The output image after application of DoG is denoted by $\Gamma(x, y)$. $I$ is the input gray scale image, $g_{\sigma_1}$ and $g_{\sigma_1}$ are Gaussian functions, provided $2 > 1$.

2.3.2 Modified Niblack’s Local Thresholding Algorithm:
In the proposed method threshold value is calculated using variance instead of standard deviation and the constant $k$ is chosen in the range 0.15 to 0.30. Hence modified equation for calculation of threshold is:

$$T_{\text{Niblack}} = M + K \ast \text{Var}$$ (5)

2.3.3 Post Processing:
In the last step, the binarized image is applied with morphological operation to sharpen the text details in the image.

Fig. 1
3. EXPERIMENTAL RESULTS

The proposed method is evaluated on a set of 80 images including DIBCO-2009 [11] standard data set. Table 1 shows comparison of PSNR value of proposed technique with the existing binarization methods. Figure 4 and 5 shows that the proposed strategy is superior to contemporary Global and Local thresholding methods. Experimental results show that most of the documents are satisfactorily denoised. Figure 2 and 3 shows output and intermediate stages of the proposed method.

![Figure 2](image1.png)

(a) Input Image, (b) output after application of DoG (c) Result of applying modified Niblack thresholding on fig 2(b), (d) Final resultant image of proposed method

![Figure 3](image2.png)

(a) Input Image, (b) output after application of DoG (c) Result of applying modified Niblack thresholding on fig 2(b), (d) Final resultant image of proposed method

![Figure 4](image3.png)

(a) Its salutary effect in of bilious affection, which it is liable to months...It appears (b) Its salutary effect in of bilious affection, which it is liable to months...It appears (c) Its salutary effect in of bilious affection, which it is liable to months...It appears (d) Its salutary effect in of bilious affection, which it is liable to months...It appears
Figure 4: Result of proposed binarization method in comparison with some well known methods of fig 3a. (a) Bernsen’s method, (b) Niblack’s method, (c) Nick’s method, (d) Otsu’s method, (e) Sauvola’s method and (f) proposed method.

Figure 5: Result of proposed method in comparison with some well known methods. (a) Input image (b) Bernsen’s method, (c) Niblack’s method, (d) Nick’s method, (e) Otsu’s method, (f) Sauvola’s method and (g) proposed method.
The performance is validated by calculating Peak Signal Noise Ratio (PSNR) and Mean Square Error (MSE). The mathematical formula for MSE and PSNR are:

\[
MSE = \frac{1}{MN} \sum \sum (k(x, y) - g(x, y))^2
\]

\[
PSNR = 10 \log \left( \frac{m_xi * m_xi}{MSE} \right) \text{dB}
\]

Where \(k(x, y)\), \(g(x, y)\) and \(m_xi\) are the output image, input image and maximum intensity of the pixels in image respectively. In table 1 the PSNR value of proposed method (performed on DIBCO 2009 data set) is compared with some standard binarization methods. The numerical results stating average PSNR value 19.21dB validates that the execution of proposed strategy is better than other five binarization methods.

| Method        | PSNR(dB) |
|---------------|----------|
| OTSU [2]      | 15.89    |
| NIBLACK’S [4] | 10.89    |
| SAUVOLA [9]   | 9.39     |
| BERSEN [10]   | 15.01    |
| NICK [12]     | 18.98    |
| Proposed Method | 19.21   |

4. CONCLUSION

In this paper, hybrid technique by linking the difference of Gaussian and modified Niblack’s local thresholding method has been proposed to improve the legibility of manuscript images for better binarization. Results state that the proposed method is producing a binarized image in which background noise is eliminated and the texture information is enhanced. The performance is validated using MSE and PSNR values. Figure 4 and 5 also validates the superiority of proposed method over well known methods. However the method fails to produce better binarization if the manuscript images having very low contrast between text and the non text portion. Hence addressing the ancient manuscripts with the above said problem will be taken up as future work.

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