Penerbit Akademia Baru

Journal of Advanced Research in Computing and Applications

Journal homepage: www.akademiabaru.com/arca.html
ISSN: 2462-1927

A proposed optimum threshold level for document image binarization

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ARTICLE INFO

Article history:
Received 15 May 2017
Received in revised form 14 June 2017
Accepted 21 June 2017
Available online 8 Aug 2017

Keywords:
Nick, document, binarization, optimum, modified, threshold

ABSTRACT

Today, document binarization is very important especially for text analysis. In background degradation, it's complicated to determine the optimum threshold. The inappropriate threshold value will be effected on the segmentation result, such as produced artefact and black noise. In this study, a modified algorithm of the Nick method in order to obtain the optimum threshold value was presented. The aim of this work is to improve the performance of Nick method and achieved a better binarization result compared to the other existing binarization methods. The results of the numerical simulation indicate that the proposed method obtained highest in terms of F-measure (71.399) and the PSNR (14.662) compared to the Otsu method, Niblack method, Bernsen method, and Nick method. Conclusion, the proposed method capable and effective to deal with the low contrast and black noise problem.

1. Introduction

Document image processing is a subject of research for more than three decades due to increased demand for archiving and preserving documents in large quantities worldwide in digital format. However, there are many challenges addressed in handwritten document image binarization, such as faint characters, bleed-through and large background ink stains [1–4]. Document image binarization is the process that segments the document image into the text and background by removing any existing degradations [1], [4]. According to Bataineh *et al*. [5], the binarization of document images is to extract the text from the images, remove the noise and reduce the size of the images in memory. This is done by removing non-useful information to increase the visibility of the useful information in the image. Now, many document image binarization methods have been proposed in the literature [6–9]. However, selecting the most optimum threshold for binarization is a difficult task due to the presence of a variety of degradations in document images [10-11].

In 2004, a new method using digital image binarization performs on the low quality document was studied by Gatos *et al*. [12]. This technique involved five stages of processing; (1) applied a low

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pass Wiener filter as a pre-processing step and to remove a noise, (2) estimate of the foreground area based on Niblack method, (3) obtained a background surface using interpolating neighbouring, (4) threshold a superimposed image between background surface result with the original image and (5) improve the result by applied connectivity step. In another study, Sezgin and Sankur [13] gave a comprehensive study of popular binarization approaches such as measurement space clustering, spatial correlation and local gray-level surface, histogram shape, and object attributes. Bieniecki and Grabowski [14] performed experimental investigations on Bernsen approach between multi-pass algorithms of the global and local threshold for proper pixel neighborhood window size that fits the size of image objects.

The above finding is consistent with the study by Chen and Leedham [15] which compared the effect of local and global binarization techniques. Finally, they suggest a new method using a local feature thresholding decompose algorithm or document sub-regions using quad-tree decomposition. Interestingly, Kitadai and Saito [16] proposed a binarization discriminant analysis to extract characters from badly blurred or missing ink. Kavallieratou [17] and Kavallieratou and Antonopoulou [18] presented a binarization method of document images and photos. The method uses the fact that the pixels that compose the text in a document do not exceed the 10% of its size. In 2007, Badekas et al. published two papers in which they proposed a new binarization method; (1) based on the Kohonen adaptive neural network in order to solve the degraded and low contrast document image [19]. (2) Based on a colour reduction technique to segment the text on colour document images [20].

Local binarization algorithms have good performance in extracting text from degraded document images. We briefly review three related local binarization algorithms which will be evaluated and compared with our binarization method. Otsu Method [21] obtained the threshold value is automatically obtained based on the global variance and between-class variance. In the non-uniform image, Otsu assumes the image contains two areas: dark and bright in order to purpose final algorithm. A Niblack's method was proposed by Niblack [22]. The main purpose is to set the threshold value based on local standard deviation and local mean. The default windowing size [23] and standard k value is 15 x 15 and - 0.2. This method does not work correctly if the image suffers from non-uniform illumination. The Bernsen method [24] is based on the estimation of a local threshold value for each pixel. This value is assigned as the local threshold value only if the difference between the lowest and the highest grey level value is bigger than a threshold (k). Otherwise, it is assumed that the window region contains pixels of one class (foreground or background). The default windowing size (w) is 3-by-3 and k is 15 [24].

In this paper, a new binarization method based on the modification threshold was discussed. The proposed method inspired from Nick method. The objective of the proposed method is to improve and increase the result performance of document binarization compared to other methods. A few image quality assessment such as f-measure, Peak Signal Noise Ratio (PSNR), NRM (Negative Rate Metric), MPM (Misclassification Penalty Metric) was performed in order to compare the effectiveness of every method. The rest of this paper is organized as follows: Section 2 describes our methodology for degraded document image binarization. Experimental results and comparison with other binarization algorithms are shown in Section 3. Finally, Section 4 explained the conclusion of this work.

2. Methodology

The proposed method was inspired by Nick method [25] by modification the algorithm in order to determine the optimum threshold level. Nick method satisfied to improve the Niblack method (black noise) and Sauvola method (low contrast) by shifting the thresholding value downward.

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However, Nick method still fails when the contrast is too small or the text is in thin pen stroke text. In the proposed method, we want to overcome the problems and weaknesses of the Nick method. Besides, the proposed method is generally capable of dealing with all binarization challenges with high performance and is particularly effective in solving the problems of the low contrast between the foreground and background and thin pen stroke text. The Nick algorithm as follows;

$$T(x,y)=m+k\sqrt{\sigma+m^2} \tag{1}$$

where, *m* is the mean value, σ is the variance and *k* was set as the default value (- 0.2). Based on the Equation 1, the main part to find the threshold value is $k\sqrt{\sigma+m^2}$, where the variance and mean is the combination to find the optimum threshold. However, in low contrast and small document text condition, the minimum threshold value should be considered. In this research, we suggest modifying the mean value (*m*) to the minimum value in order to solve the smaller gap of the intensity images. The small value capable of representing the small and thin pen stroke text. The proposed algorithm as follows;

$$T(x,y)=m+k\sqrt{\sigma+\min(x,y)^2} \tag{2}$$

A combination of minimum intensity and variance successful to solve the low contrast and thin text on degrade document image. Despite, a small modification of proposed algorithm but the effect of the resulting performance is very big. The comparison result between original Nick method and proposed method are presented in figure 1. As shown in figure 1, the proposed method successful in improving and increasing the result in term of eliminating the black noise and detect the small text in the low contrast region.

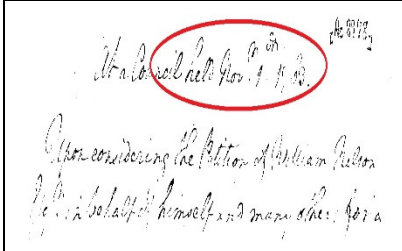
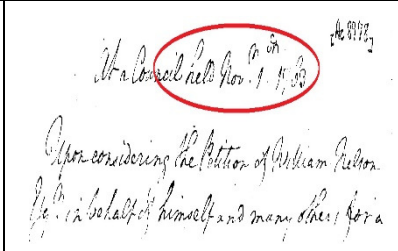
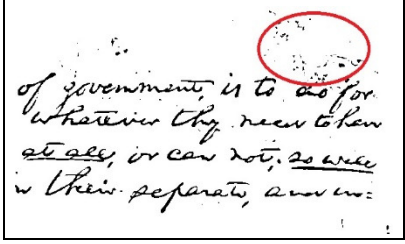
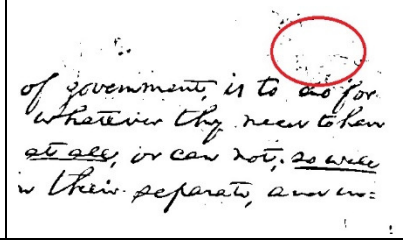
Nick method	Proposed method	Explanation
		In the red circle show the improvement of detection on low contrast region. Nick show loss result details, however the proposed method overcome this problem.
		In the red circle, the proposed method show the reduction of black noise after implemented the proposed algorithm compared using the Nick algorithm.

Fig. 1. Comparison between Nick method and the proposed method

3. Result

The proposed binarization algorithm experimented on the online dataset adopted by the Document Image Binarization Contest 'DIBCO 2009' organized by the International Conference on

Document Analysis and Recognition 'ICDAR 2009' [26]. All images consist non-uniform intensity and its performance was compared with four well-known document image binarization algorithms such as Otsu method, Niblack method, Bernsen method and Nick method. According to observation, the proposed method more successful compared to all algorithms that are tested. Example results are shown in figure 2 and figure 3.

Fig. 2. Comparison of resulting images; (a) original, (b) Otsu method, (c) Niblack method, (d) Bernsen method, (e) Nick method, and (f) Proposed method

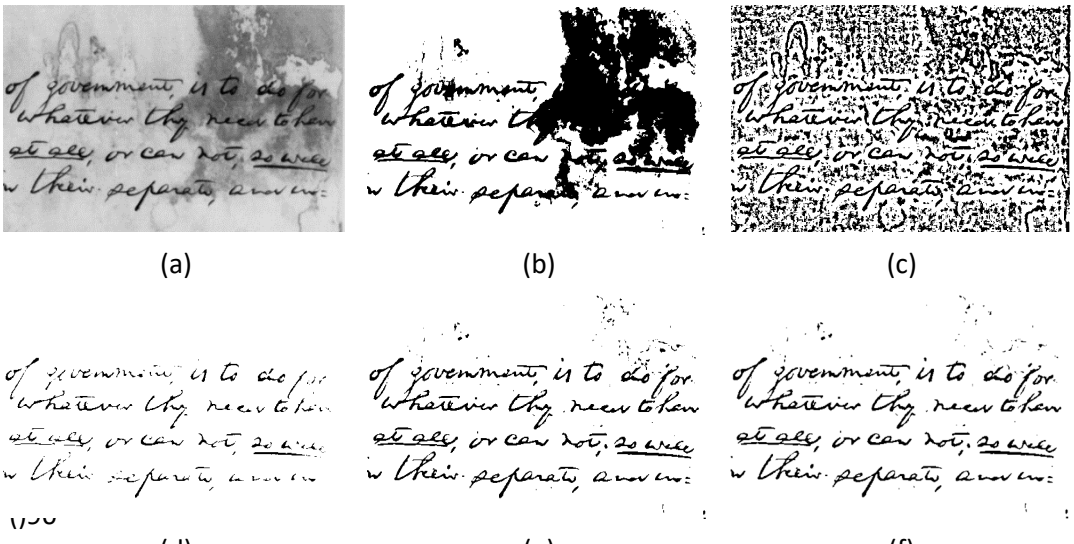


Fig. 3. Comparison of resulting images; (a) original, (b) Otsu method, (c) Niblack method, (d) Bernsen method, (e) Nick method, and (f) Proposed method

We briefly explain the reasons that other binarization algorithms fail to binarize badly illuminated document. Otsu method [21] failed to binarize these images properly because the gray level of foreground and background is not separable. Niblack method [22] is very sensitive to the predetermined parameters and introduces some parts of the regions inside the sliding window as text, so in the regions far from the text, some part of the background are labeled as text. In most of the cases Bernsen method [24] outperforms the two predecessors, however, there are occasions when the characters disappear or break if intensity variations are very small or there is some noise patch with a very sharp intensity variation from the rest of the image. Besides, the Nick method [25] perform good result compared to the Otsu method, Niblack method, and Bernsen method. Based on figure 2 and figure 3, the Nick method successful in solving the problem of binarization such as noise from Niblack method and able to identify the text in some cases where Sauvola's method failed. However, Nick method still fails when the contrast is too small or the text is in thin pen stroke text. Thus, the proposed method was the outcome the Nick method by using a modification of Nick algorithm. In figure 2 and 3, the result of proposed method shows improvement in term of noise/artefact and low contrast details.

In order to prove successful of proposed method binarization, a few familiar evaluation technique was calculated such as F-measure, Peak Signal to Noise Ratio (PSNR), Negative Rate Metric (NRM), and Misclassification Penalty Metric (MPM). All the equation details can be referred to [5], [27], [28]. The highest of F-measure and PSNR show the good of binarization. Opposite to F-Measure and PSNR, the binarization quality is better for lower NRM and MPM. Table 1 presents the comparison evaluation result for four types of binarization methods with the proposed method. Based on Table 1, the average F-measure is 71.399% for the proposed method, compared to 69.478%, 39.930%, 47.161% and 69.556%, respectively, for Otsu's method, Niblack's method, Bernsen's method, and the Nick method. Besides, the proposed method also achieved the best performance in terms of PSNR (14.662), followed by the Otsu method and Nick method. However, based on NRM and MPM, the proposed method slightly lower (NRM = 0.162 and MPM = 2.388) compared to the Otsu method and Bernsen method. The Otsu method produced lowest NRM caused it's very sensitive to intensity image and automatically present a smaller pixel- wise mismatches between the ground truths. While the MPM calculation focuses on to identify the boundary. The Bernsen method shows the effectiveness in order to detect the boundary compared to other methods.

Table 1
The comparison of binarization methods in term of F-measure, PSNR, NRM, and MPM

	F-measure	PSNR	NRM	MPM
Otsu	69.478	14.403	**0.0934**	13.806
Niblack	36.930	5.8028	0.218	179.334
Bernsen	47.161	12.646	0.328	**1.732**
Nick	69.556	14.245	0.175	2.681
Proposed Method	**71.399**	**14.662**	0.162	2.388

4. Conclusion

The proposed method was inspired by the Nick method. A modification of Nick algorithm was introduced in order to solve the small and low contrast on the document image. The proposed method experimented on DIBCO dataset and the result performance was compared with four popular binarization methods such as Otsu, Niblack, Bernsen and Nick methods. In this research, we can conclude that no algorithm works well for all types of images but some work better than others

for particular types of images suggesting that improved performance can be obtained by selecting the optimum threshold. The finding after the extensive experiment is the proposed binarization algorithm demonstrates superior performance against four well-known binarization algorithms on a set of degraded document images.

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