Journal of Theoretical and Applied Information Technology
15th November 2017. Vol.95. No 21

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

USING AN ANT COLONY OPTIMIZATION ALGORITHM FOR IMAGE EDGE DETECTION AS A THRESHOLD SEGMENTATION FOR OCR SYSTEM

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ABSTRACT

Binarization or thresholding is one problem that have to solve in pattern recognition methods and applications. Moreover, it has a very important influence on the sequent steps in computer vision applications such as, Optical Character Recognition (OCR), image segmentation, and tracking objects. Ant colony optimization (ACO) is a population-based metaheuristic which use to solve optimizations problems in diverse fields, such as traffic congestion and control, structural optimization, manufacturing, and genomics are presented. In this work, a combination of ant colony, edge detection, and thresholding methods are combine in order to use in OCR system. The algorithm which is used the DIBCO 2009 in printed and a handwritten image was tested. This method has a compare with Kittler and Illingworth's Minimum Error Thresholding, potential difference, max entropy, Pirahansiah's method and Otsu.

Keywords: *Ant colony optimization (ACO), Peak Signal-to-Noise Ratio (PSNR), single thresholding, image processing, image segmentation, optical character recognition, computer vision, Deep Learning.*

1. INTRODUCTION

Thresholding, edge detection, and ant colony are the methods which used in many computer vision applications such as video stabilization [1], camera calibration [2], segmentation [3], binarization [4], Simultaneous Localization and Mapping (SLAM) [5], feature extraction [6], stereo vision [7], License plate recognition system [8-12].

One of the essential stages of pre-processing in any applications of computer vision is thresholding [3, 4, 8-12]. Thresholding can be used as a method to separate the foreground from the background of an image or in OCR systems [13] can be used as a separate character from images. This paper compares several thresholding methods: Otsu [14], Kittler and Illingworth [15], potential difference[16], max entropy[17], multilevel threshold[18], Pirahansiah's method [3, 4] and the unprecedented method aimed in this paper which used ant colony on edge detection for thresholding is a compare with 6 before proposed method.

In [13] a nonparametric and unsupervised method of automatic threshold selection for picture segmentation is presented. An optimal threshold is selected by the discriminant criterion, namely, so as to maximize the separability of the resultant classes in gray levels. The procedure is very simple, utilizing only the zeroth- and the first-order cumulative moments of the gray-level histogram.

In [14] a computationally efficient solution to the problem of minimum error thresholding is derived under the assumption of object and pixel grey level values being normally distributed. The method is applicable in multithreshold selection.

The ant colony optimization (ACO) for edge detection proposed by Jing et al. [19] and the source code of their method is based on MATLAB which is available free.

The paper is organized as follows. In Sections 2, 3 a brief introduction are provided to present the fundamental concepts of ACO and thresholding.

Result and discussion are presented in Section 4. Finally, Section 5 concludes this paper.

2. STATE OF THE ART

Thresholding is a type of image segmentation, where change the pixels of an image to make the image simpler to recognize. There are many applications, which use thresholding in computer vision algorithms as a first step. For example, in camera calibration algorithms first step is to use threshold for the calibration pattern in order to find corner points to perform calibration [2]. In robot localization, SLAM methods require threshold value to find interesting point and landmark properly [5]. In addition, threshold use for image segmentation [13]. in the object and character recognition system [6].

Using ant colony optimization for find proper value of threshold have been studied [20-24] however; lack of using ACO based thresholding for OCR system.

2.1 THRESHOLDING

The thresholding methods can be divided into three main categories which are single, multilevel and multi thresholding [3, 4]. Kittler and Illingworth's Minimum Entropy Threshold (MET) [14], potential difference [15] and Pirahansiah's method [3, 4] are examples of single thresholding methods. Multilevel threshold methods, such as that of [17], separate object based on gray values. Multi-threshold [11] techniques choose a selection of threshold values based on certain behaviors such as number objects inside the image after threshold. We discuss some state-of-the-art methods in the following subsections.

2.1.1 Single Threshold Method

The usage of the single thresholding means one threshold value, t, change the image to black and white. The thresholding process is a very important step through the segmentation phase. It is also a very significant part of image processing and pattern recognition. Thresholding is carried out for distinctive reasons, for example to increase the computational fast or to reduce the storage space. The segmentation accuracy can be maximized by an appropriately chosen threshold value. The single threshold condition is given as:

$$f'(i,j)\begin{cases}1 & iff(i,j) > threshold \\ 0 & iff(i,j) \leq threshod\end{cases} \quad (5)$$

Different approaches are used to automatically determine the threshold value. Methods such as local entropy, Kittler and Illingworth's MET [14], and potential difference [15] often use a gray level co-occurrence matrix as the population set to determine the appropriate threshold value.

2.1.2 Pirahansiah's Single Threshold Method

One of the latest threshold algorithm which is based on single threshold method is proposed by Pirahansiah [3, 4]. The pseudo code of the algorithm is presented below as Algorithm 1.

Algorithm 1. Pirahansiah's Threshold Algorithm.

Input: column gray scale images, img.
Output: The selected threshold values, t.

```
For (0<t<256) where (t = t +5) then find PSNRt of imgt
by compare with the original image
If ( (mean value/k1<  PSNRt<  mean value/k2))
then threshold=t
end for
```

2.1.3 Multilevel Threshold

In multilevel thresholding, more than one threshold value is used to change the image to a gray-scale image. Arora et al. [17] proposed a multilevel threshold method that identifies threshold values globally based on a gray scale distribution. A recursive algorithm is applied to determine a sequence of threshold values based on the mean and standard deviation at each step. The multilevel algorithm is described in Algorithm 2.

Algorithm 2. The Multilevel Thresholding Algorithm[17]

1: While increasing PSNR>0.1 is true do
2 : r = [a, b]. (in the first step a = 0 and b = 255)
3 : Find the mean and standard deviation for all of the pixels in the image range r
4 : t1 = mean–k1* standard deviation; (k1 is a random number)
5 : t2 = mean+k2* standard deviation; (k2 is a random number)
6 : The mean value of range (a, t1] is set as the threshold value of the partial range.
7 : The mean value of range [t2, b) is set as the threshold value of the partial range.
8 : a = t1+1
9 : b = t2-1
10 : end while
11 : t1 = mean
12 : t2 = mean+1
13 : repeat step 6
14 : Obtain new image with multilevel thresholding

2.1.4 Multi-Threshold

Multi-threshold is another approach that applies multiple threshold values [11]. This method uses a series of threshold values and computes the total number of blobs or objects

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

in an image for each threshold. The peak threshold values are those with the highest total number of blobs as compared to their threshold neighbors. The Heuristic threshold algorithm is described in Algorithm 3.

Algorithm 3. The Multi Threshold Algorithm [11]
1: Start.
2: Obtain the histogram distribution.
3: Calculate the total number of gray-scale pixels according to three levels.
4: For (0<t<256) step 10 is true do
5: Obtain the total number of objects, num_t, in the source image when the threshold value t is used.
6: end for
7: Search for and select the peak values from num (1 … 255).
8: Choose the selected threshold values if the number of objects is maximum.
9: Execute the character segmentation module.

2.2. ANT COLONY OPTIMIZATION (ACO)

Ant Colony Optimization Initially proposed by Marco Dorigo in 1992 in his PhD thesis. Ant colony optimization algorithms have been applied to many combinatorial optimization problems. Jing et al. [19] proposed the ant colony optimization (ACO) for edge detection and the source code of their method is based on MATLAB which is available free. In this research we use this approach. pseudo-code of ACO can be written as:

```
procedure ACO_MetaHeuristic
   while(not_termination)
      generateSolutions()
      daemonActions()
      pheromoneUpdate()
   end while
end procedure
```

The steps of ACO based on the paper [19] consisted of several steps as follows:
1) Randomly initial all ant position and pheromone matrix.

2) For moving ant use the Equation 1

$$s = \begin{cases} \arg\left(\max_{j \in N_i^k}\left[(\tau_{ij})^{\alpha}.(\eta_{ij})^{\beta}\right]\right), & while\ q \le q_0 \\ S, & else \end{cases} \quad (1)$$

Where q (0<q<1) is a random number and q0 is a number between 0 and 1. For the moving and choosing next move base on probability distribution can use Equation 2.

$$p_{ij} = \frac{(\tau_{ij})^{\alpha}.(\eta_{ij})^{\beta}}{\sum_{j \in N_i^k}(\tau_{ij})^{\alpha}.(\eta_{ij})^{\beta}}, if\ j \in N_i^k \quad (2)$$

Where the notations of α and β are control parameters determined the relative influence of the pheromone and the visibility respectively.
3) For the update of movement use Equation 3 and 4 as below.

$$\tau_{ij} = (1-\rho).\tau_{ij} + \sum_{k=1}^{m}\Delta\tau_{ij}^{k} \quad (3)$$

$$\Delta\tau_{ij}^{k} = \begin{cases} \frac{Q}{L_k}, & if\ ant\ k\ passed\ link\ (i,j) \\ 0, & else \end{cases} \quad (4)$$

Where ρ ($0 < \rho < 1$) denotes the pheromone evaluation ratio. Q is constant, m ant number, L_k length of tour by ant k.

4) Make decision

3. PROPOSED METHOD

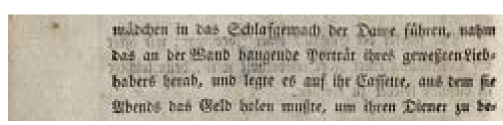
In the same spirit as Otsu [14], Kittler and Illingworth [15], potential difference [16], max entropy [17], multilevel threshold [18], Pirahansiah's method [3, 4], the algorithm which is used the DIBCO 2009 in printed and a handwritten image was tested. This method has a compare with Kittler and Illingworth's Minimum Error Thresholding, potential difference, max entropy, Pirahansiah's method and Otsu. The proposed method use ACO based threshold method to enhance performing thresholding on images which is sutiable for OCR systems.

3.1 RESULTS AND DISCUSSION

The comparison was done by using DIBCO benchmark. The DIBCO dataset contains several images which are divided into two main categories "handwritten" and "printed". The Otsu [14], Kittler and Illingworth [15], potential difference[16], max entropy[17], Pirahansiah's method [10] and the unprecedented method aimed in this paper which used ant colony on edge detection for thresholding are using for comparison. The comparison is done by using PSNR which explained in [3, 4].

3.2 Experiment Results

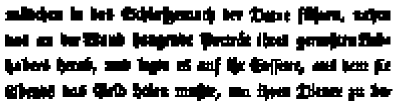
The Figure 1 shows proposed method results of the printed images from DIBCO benchmark dataset.


mädchen in das Schlafgemach der Dame führen, nahm
das an der Wand hängende Porträt ihres gewesenen Lieb-
habers herab, und legte es auf ihr Caffette, aus dem sie
Abends das Geld holen mußte, um ihren Diener zu be-

(a) P01. Original image from DIBCO

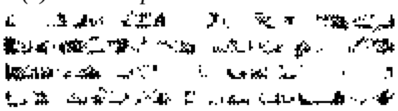
Journal of Theoretical and Applied Information Technology
15th November 2017. Vol.95. No 21

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

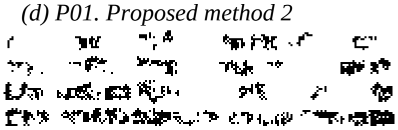


(b) P01. Ground truth image from DIBCO

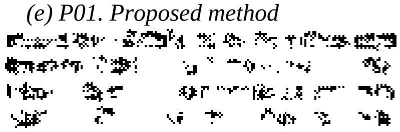
(c) P01. Proposed method 1



(d) P01. Proposed method 2

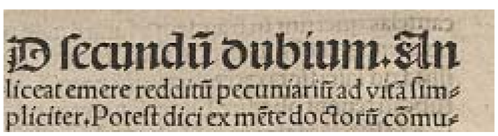


(e) P01. Proposed method



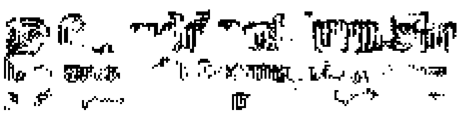
3

(f) P01. Proposed method 4

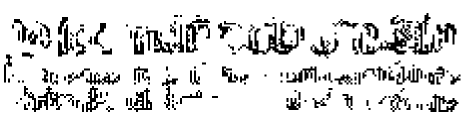


(a) P02. Original image from DIBCO

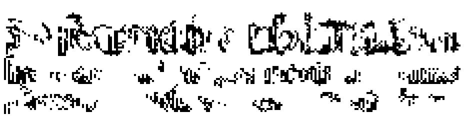
(b) P02. Ground truth image from DIBCO



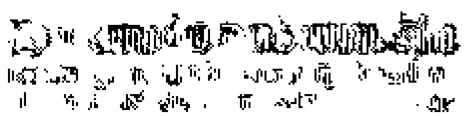
(c) P02. Proposed method 1



(d) P02. Proposed method 2



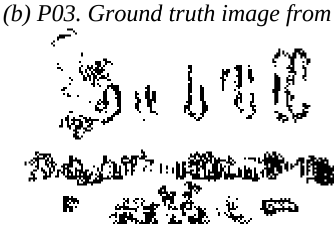
(e) P02. Proposed method 3



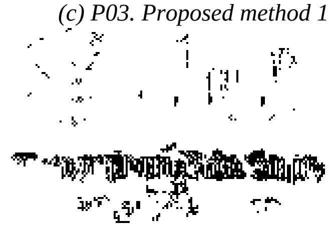
(f) P02. Proposed method 4

(a) P03. Original image from DIBCO

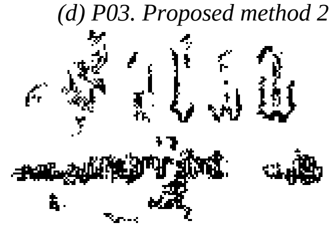
(b) P03. Ground truth image from DIBCO



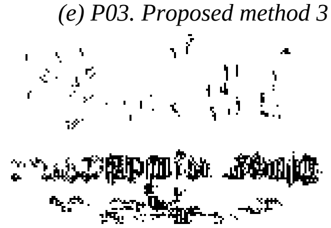
(c) P03. Proposed method 1



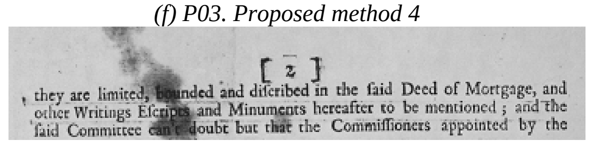
(d) P03. Proposed method 2



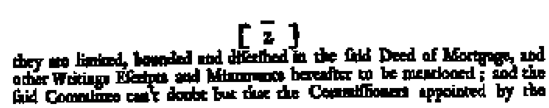
(e) P03. Proposed method 3



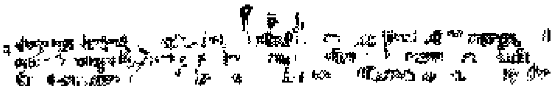
(f) P03. Proposed method 4



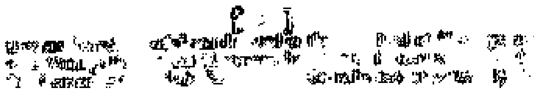
(a) P04. Original image from DIBCO



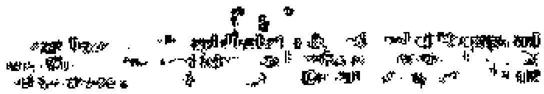
(b) P04. Ground truth image from DIBCO



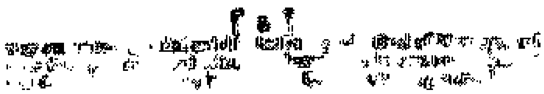
(c) P04. Proposed method 1



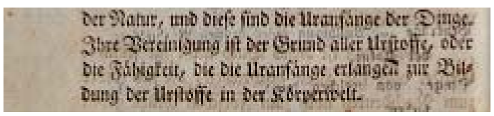
(d) P04. Proposed method 2



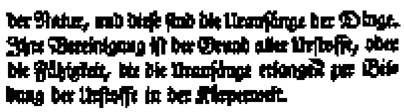
(e) P04. Proposed method 3



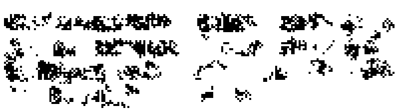
(f) P04. Proposed method 4



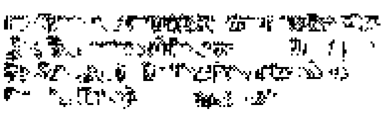
(a) P05. Original image from DIBCO



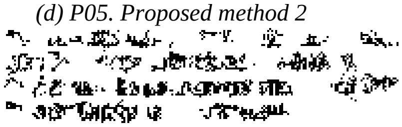
(b) P05. Ground truth image from DIBCO



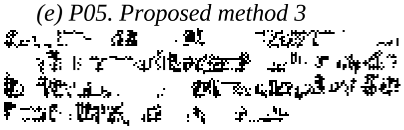
(c) P05. Proposed method 1



(d) P05. Proposed method 2



(e) P05. Proposed method 3



(f) P05. Proposed method 4

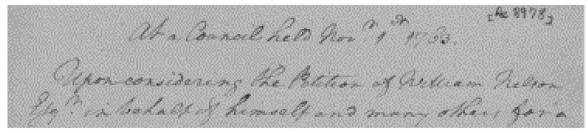
Figure 1: The printed dataset of DIBCO benchmark. (a) is original images, (b) ground truth, (c) to (f) proposed method.

Table 1 shows the result of each proposed method based on PSNR.

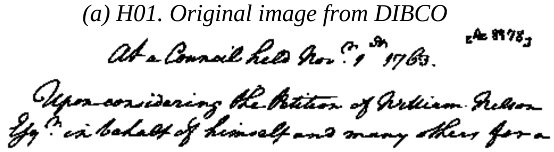
Table 1. The result of each proposed method based on PSNR

		PSNR			
Methods		1	2	3	4
Images					
P01		6.6701	6.6135	6.4767	6.3915
P02		5.4008	5.6267	5.5604	5.5133
P03		7.0038	6.5976	6.89	6.6289
P04		7.6099	7.6533	7.6781	7.5529
P05		5.7077	5.4939	5.7731	5.6181
Average		6.47846	6.397	6.47566	6.34094

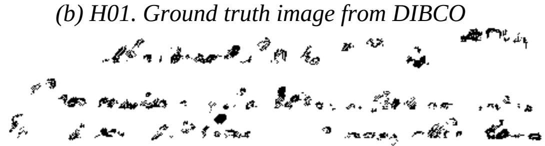
Figure 2 shows proposed method results of the handwritten images from DIBCO benchmark dataset.



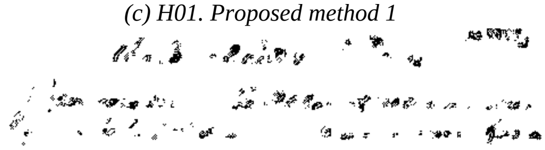
(a) H01. Original image from DIBCO



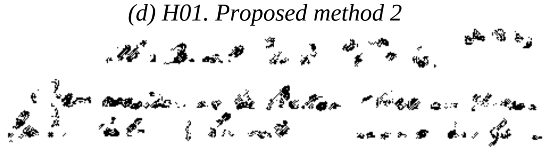
(b) H01. Ground truth image from DIBCO



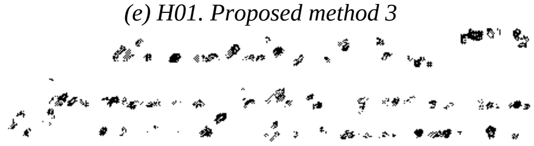
(c) H01. Proposed method 1



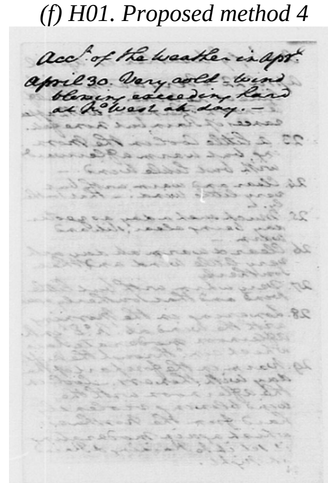
(d) H01. Proposed method 2



(e) H01. Proposed method 3

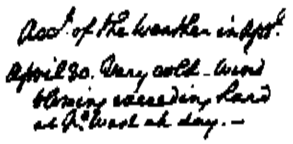


(f) H01. Proposed method 4



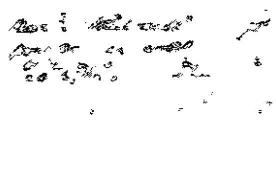
(a) H02. Original image from DIBCO

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195



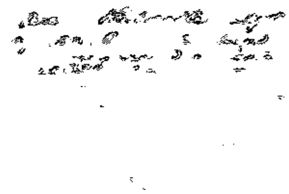
(b) H02. Ground truth image from DIBCO

(c) H02. Proposed method 1

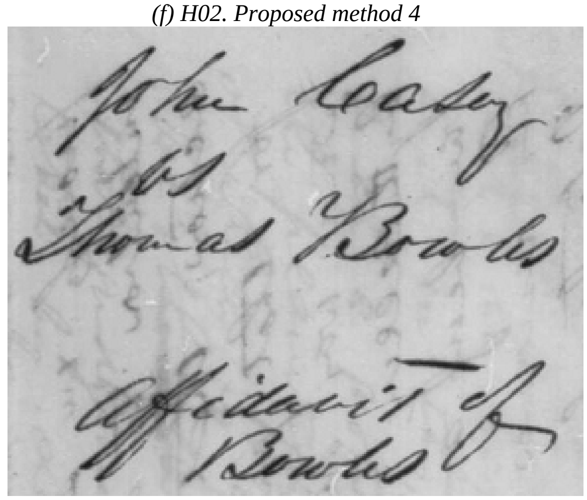


(d) H02. Proposed method 2

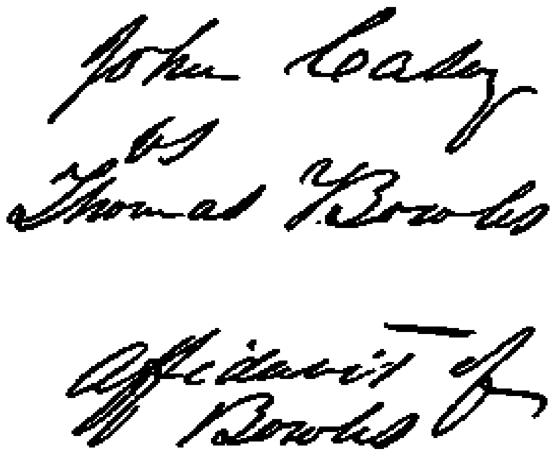
(e) H02. Proposed method 3



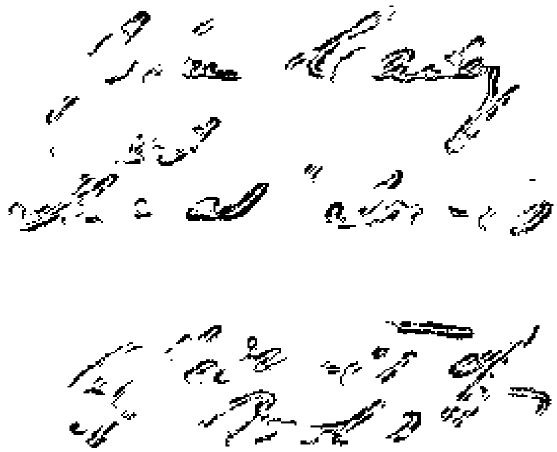
(f) H02. Proposed method 4



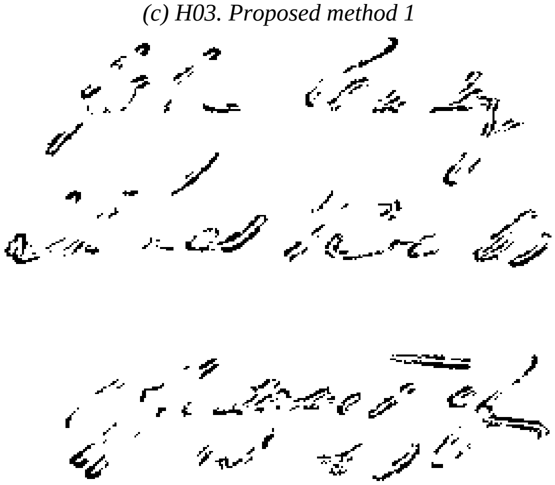
(a) H03. Original image from DIBCO



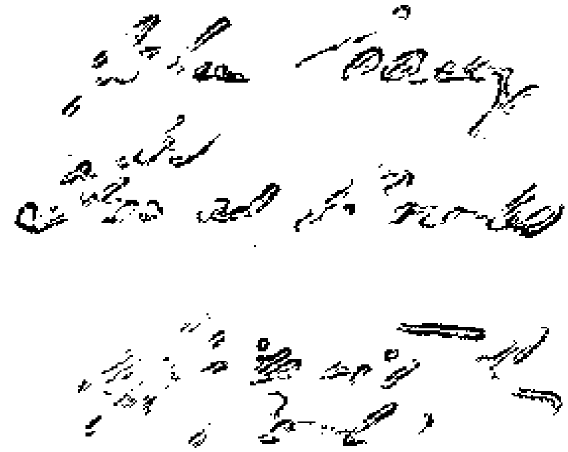
(b) H03. Ground truth image from DIBCO



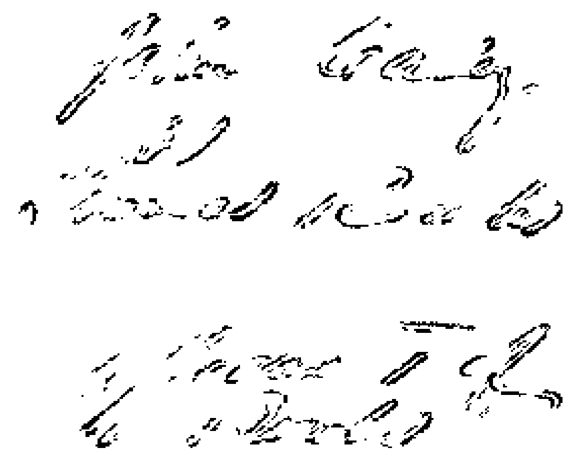
(c) H03. Proposed method 1



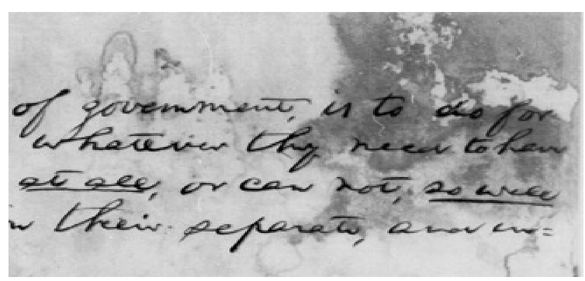
(d) H03. Proposed method 2

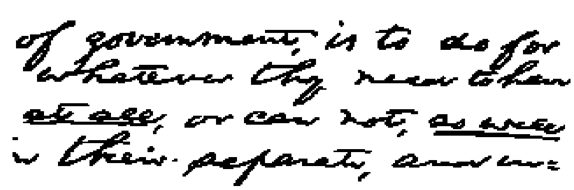


(e) H03. Proposed method 3



(f) H03. Proposed method 4





(a) H04. Original image from DIBCO
(b) H04. Ground truth image from DIBCO

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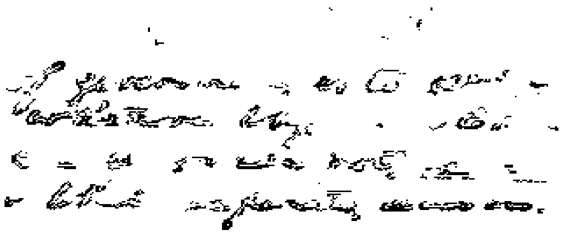
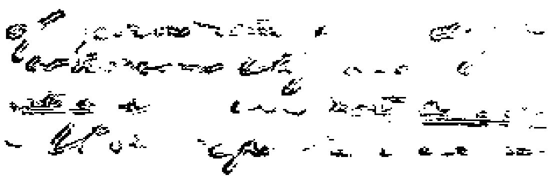
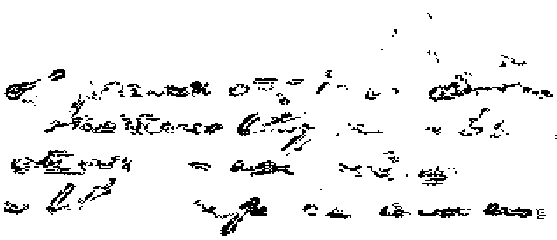


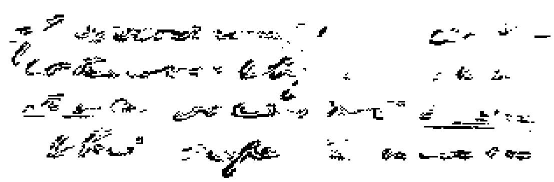
(c) H04. Proposed method 1



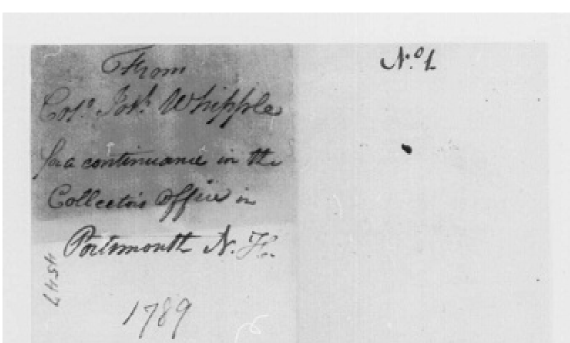
(d) H04. Proposed method 2



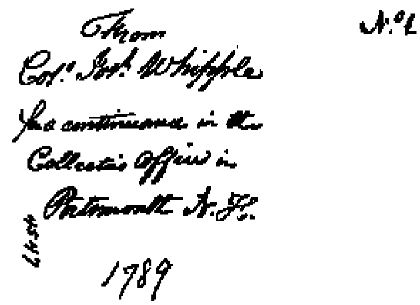
(e) H04. Proposed method 3



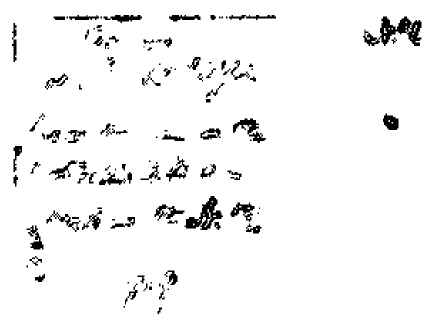
(f) H04. Proposed method 4



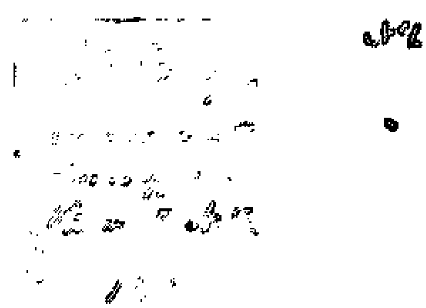
(a) H05. Original image from DIBCO



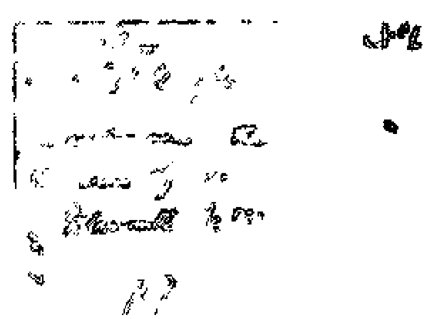
(b) H05. Ground truth image from DIBCO



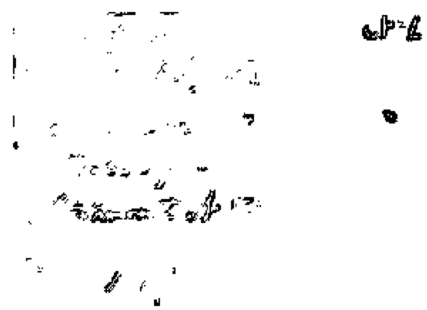
(c) H05. Proposed method 1



(d) H05. Proposed method 2



(e) H05. Proposed method 3



(f) H05. Proposed method 4

Table 2 shows the result of each proposed method based on PSNR for the handwritten images.

TABLE 2. The result of each proposed method based on PSNR

	PSNR			
Methods	A	B	C	D
Images				
H01	9.5516	9.5508	9.7037	9.4849
H02	15.1372	15.4791	15.0854	15.5681
H03	9.3283	9.3051	9.3528	9.2715
H04	9.9124	9.8011	9.6884	9.7458
H05	12.0292	12.0834	12.0076	12.0858
Average	11.1917	11.2439	11.1676	11.2312

3.3 Comparison Results

For the comparison of PSNR result Table 3 and Figure 3 show overall results.

TABLE 3. Comparison of thresholding methods using PSNR value

Methods	Otsu	Kittler and Illingworth	potential difference	max entropy	Pirahansiah's method	Ant method
Printed	8.548	8.800	8.580	8.880	9.050	6.423015
Handwritten	6.425	7.022	6.094	6.802	6.162	11.20861

Results are depicted.

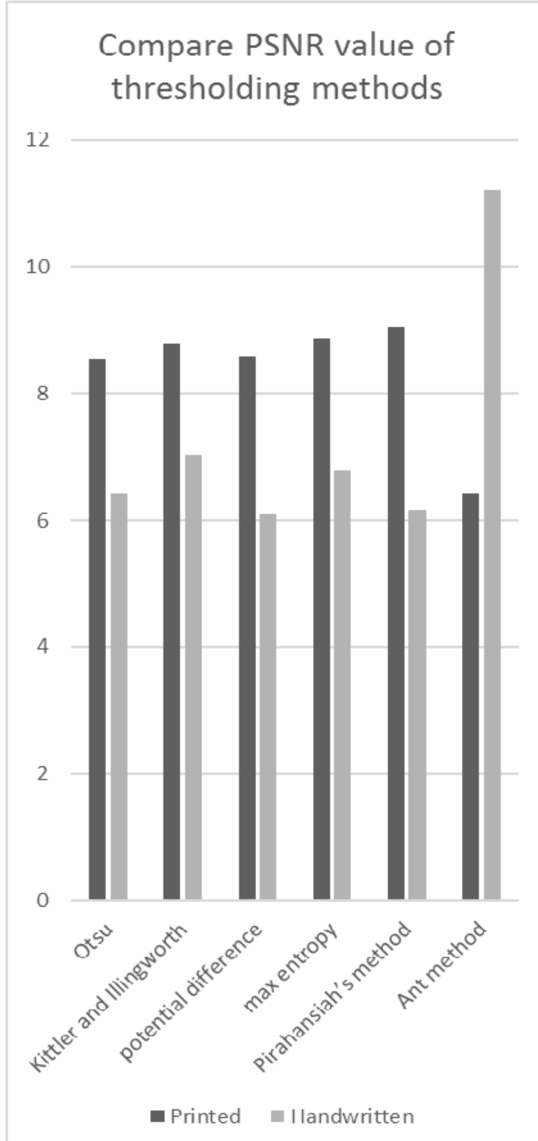


Figure 3: Comparison of thresholding methods.

4. CONCLUSION

ACO algorithm has been used for edge detection of noisy images. We present combination of ant colony, edge detection, and thresholding methods in order to use in OCR system. In this paper, the algorithm which is used the DIBCO 2009 in printed and a handwritten image was tested. As we seen in Table 3 and Figure 3, handwritten of ant method is more effective. The result shows that ACO_Threshold perform better on printed images.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

5. ACKNOWLEDGEMENT

We thank to “anonymous” reviewers for their so-called insights. We are also immensely grateful to for their comments on an earlier version of the manuscript.

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