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Binarization via the Dynamic Histogram and Window Tracking for Degraded Textual Images

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ABSTRACT

In this paper, an image binarization method for separating text from the background of degraded textual images is proposed. This proposed methods are based on combination of Window Tracking Method (WTM) and Dynamic Image Histogram (DIH). The WTM and DIH methods work on an image that has been pre-processed. The WTM method searches for the largest pixel value in a 3 × 3 window up to a maximum of five tracking steps, while the method searches for a definite frequency between the two highest values in the image histogram. We test proposed method on DIBCO dataset and self-collection faded manuscripts. The experimental results show that our proposed method outperforms state of the art methods.

Keywords: Dynamic image histogram, Image smoothness, Reference image, Standard deviation, Window tracking

INTRODUCTION

Adaptive image binarization technique consists of a combination of several techniques. In order to adaptively binarise an image, this study proposes an adaptive image binarization method which combines methods based on an image histogram, tracking window, standard deviation and smoothness of image, and automatic thresholding. The aim of this paper is to binarize old degraded textual images (Yahya, Abdullah, Omar, & Liong, 2010; Kavallieratou, DueireLins, & Palacios, 2010). In this study, an old document is converted into a binary image by applying the Window Tracking Method (WTM) and

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Intensity of Image Histogram (IIH-Met) on the image, and then comparing the average contrast values of the useful areas to obtain the final threshold value for the image. The proposed method is tested on well-established test images from the Document Image Binarization Contest (DIBCO) data sets, as well on faded ancient Islamic, Chinese and Indian manuscripts, where the latter are new images without a reference image for comparing the results. There are various reasons for the degraded quality of the damaged ancient documents (Yahya et al., 2010). In general, the damage could be due to (Kavallieratou, DueireLins, & Palacios, 2010; Stathis, Kavallieratou, & Papamarkos, 2008) uneven lighting; absorption of excess ink, spots, scratches and scribbles, and irregular background variations.

Review of Literature and Scope of Study

Many researchers have investigated the use of threshold value for image processing, namely threshold value method for each pixel of the image (Sauvola & Pietikainen, 2000). Yahya et al., (2010) proposed an adaptive local threshold value based on image histogram features. Abdenour Sehad et al. (2014) estimated texture information based on Gabor filters for ancient degraded documents. First, the dominant slant angle of the document image script was computed using Fourier transform. In addition, (Chen, Sun, Heng, & Xia, 2008) proposed two threshold values to generate a binary image. Chen's method has been an inspiration to the method used in this study. Some researchers have managed to produce binary images using the local threshold values of a dynamic window created by Bataineh, Abdullah and Omar (2011). A non-uniform illumination conditions method was proposed by Wen, Li and Sun (2013). They combined two methods - Curvelet transform and Otsu - to binarise the non-uniform illuminated images.

Su, Lu and Tan (2013) introduced a novel document image binarisation technique using an adaptive image. The adaptive image is a combination of the local image contrast and the local image gradient that is tolerant to text and background variation caused by different types of document degradation contrast. Meanwhile, (Gatos et al., 2006) combined surface background image calculations with the results of the initial image processing, similar to the one used in this study, to produce binary images. The general processing steps in the proposed adaptive binarisation method are shown in Figure 1. Each of the steps are described in this section. The initial processing of the proposed method began with the conversion of the original colour scheme of the image into luminance (*Y*), hue (*I*), and saturation (*Q*). The results were then filtered using a bilateral filter proposed by Tomasi and Manduchi (1998) by changing the pre-computed Gaussian distance weights as below:

$$G(x,y) = e^{-\frac{1}{2}\left(-\frac{d(x,y)}{\sigma_d}\right)^2} \tag{1}$$

$$d(x,y) = d\left(-\left(x - y(w+1, w+1)\right)\right) \tag{2}$$

The half-size of the Gaussian bilateral filter window is defined by *w*.

Then the image is transformed linearly to become [0 1] using the formula:

$$LI = 0.2(max_1 - min_1) + min_1 + I \tag{3}$$

with LI = the linear image, max_1 = the image maximum value after bilateral filtering, min_1 = the image minimum value image bilateral filtering, and I = images after bilateral filtering. The standard deviation and image smoothness are computed as follows:

$$\sigma = \sqrt{\mu_2}(Z) \text{ and } R = 1 - \frac{1}{1+\sigma^2} \tag{4}$$

where σ is the standard deviation, Z is the variable used to mark the intensity of the global pre-processed image, and R is the image smoothness value.

MATERIALS AND METHODS

Dynamic Histogram

The proposed Intensity of Image Histogram (IIH-Met) algorithm, which is adapted from (Arifin & Asano, 2006), is as follows (refer to Figure 2):

Step 1: Determine all the input values, namely: max_H, max_{H2}, max_{H3}.

Step 2: Create an image histogram to show all the pixel intensity values.

Step 3: Find min_{H2} and min_{H2}, i.e. the minimum pixel value between max_H and max_{H2}, and between max_{H2} and max_{H3}, respectively.

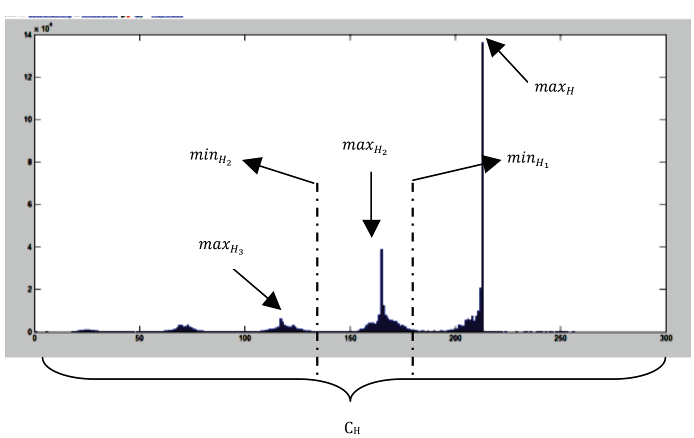

Figure 1. The image histogram of the Intensity of Image Histogram (IIH-Met) shows the three highest peaks in the image, namely max_H, and C_H is the intensity's pixel values on image histogram. which is the highest peak; max_{H2}, the second highest; and max_{H3}, the third highest peak in the image and C_H is the intensity's pixel values on image histogram

Window Tracking Method

The aim of the Window Tracking Method (WTM) is to find the maximum pixel / largest image pixel value within a 3 × 3 window using up to five tracking steps. The proposed Window Tracking Method (WTM /) algorithm is as follows:

Input: Determine the minimum pixel of the whole image and set it as the initial pixel, $P(x,y)$.

Output: max_{WTM}.

Step 1: Determine the window with a 3×3 kernel matrix; t=0, n=0, i=0; max_{WTM} = 0, *lowerlimit* = 99, *upperlimit* = 199;

Step 2: When (ti ≤ 5) or (lowerlimit < max_{WTM} < upperlimit);

Step 3: Find the maximum pixel value, max_{WTM} and its frequencies, n, from the pixels around $P(x, y)$;

Step 4: If $(n < i + 1)$, then $i++$; $t_i = 0$; set the i-th position as the new starting pixel $P(x, y)$;

Step 5: t_i++ ;

The constraints for this second method are that the smallest pixel value must be 99 and the largest value must not exceed 199 within the 3 × 3 window, otherwise the tracking will stop at that step even though the five steps are not yet completed as shown in Step 2 above. The upper and lower limits were set empirically based on tests on many data sets which show that values beyond that range will cause the resulting image to become blurred.

Automatic Threshold Value Method 1. After performing the IIH-Met, the Automatic Threshold Value Method 1 (*ATV-Met 1*) was then performed following the results obtained from the *IIH-Met*, i.e. the min_H value. The proposed Automatic Threshold Value (*ATV-Met 1*) algorithm is as follows:

Input:
- Maximum intensity values max_{H2} and max_{H3} ,
- Minimum intensity value of pixel minH, pixel value max_{WTM},
- Standard deviation of image, $\sigma = \sqrt{\mu^2(Z)}$,
- Image smoothness, $R = 1 - \frac{1}{1+\sigma^2}$

Output: Threshold value man_H .

Step 1: Determine all the input values, i.e.: max_{H3}, max_{WTM}, σ, R.

Step 2: Do $\delta = max_{H3} - max_{WTM}$;

$S_1 = max_{H3} = min_H$;

$S_2 = min\mathrm{H} - \delta$;

$S_3 = S_2 + \mathrm{Si}$;

$S_4 = S_3 - \sigma$;

Step 3: If $R \geq 0.9990$, then

If $\sigma \leq 50$

$S_4 < 100$, value = S_3

Step 4: If $R < 0.9990$, then

If $\sigma \leq 50$

$max_{WTM} < 190$, threshold = min_H;

$max_{WTM} \geq 190$, threshold = $max_{WTM} - (3\sigma/2)$

If $\sigma \leq 50$ and

max_{WTM} <190, threshold = min_H;

$max_{WTM} \geq 190$, threshold = $max_{WTM} - (3\sigma/2)$

Step 5: Assign the final threshold value to man_H .

ATV-Met1 produces the output man_H, which is a temporary threshold value in the proposed method. It will be an input to the next level of processing.

Automatic Threshold Value Method 2. *ATV-Met 2* method is the last step in the proposed method. The result of *ATV-Met 2* method is the final threshold value in order to generate the binary image. The proposed Automatic Threshold Value (*ATV-Met 2*) algorithm is as follows:

Input: Determine the threshold value man_H , the pixel value max_{H2} the pixel value max_{WTM}, and the minimum intensity of the pixel value

Output: Threshold value of ATV-Met 2 man_{Hend}

Step 1: When the value of $max_H \leq 225$, find the smallest value for man_{Hend} from among the three values of max_{WTM}, min_H, and man_H , but with the condition that $man_{Hend} \geq 90$.

Step 2: When $man_{Hend} \leq 90$ is not obtained in the first step, then find the pixel value min_H by altering the placing of max_{H2} and max_{H3} .

Step 3: Then repeat steps 1 and 2.

Step 4: When the value of $man_H >$ 225, then obtain the larger value for man_{Hend} from among the three values of man_H, max_{WTM} and min_H.

But also with the condition that $man_{Hend} \geq 90$.

Step 5: When $man_{Hend} \leq 90$ is not obtained in the first step, then find the pixel value min_H by fixing the placing of max_{H2} and max_{H3}.

Step 6: Then repeat step 1 and step 2.

Figure 2 below shows an example of DIBCO image histogram after applying our proposed method:

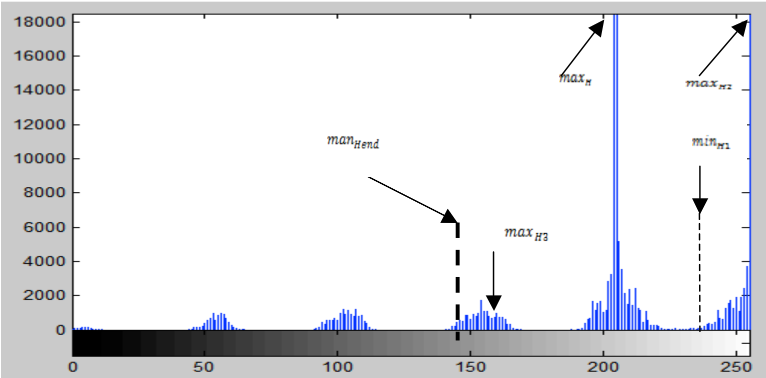

Figure 2. The image histogram for image pre-processing result. The final threshold value (man_{Hend}) is 147

So, for this example, the first threshold value process which involved max_{H2},,max_{WTM} and min_H is T = 147. The values for the various parameters of the dataset are as shown in Table 1.

Table 1
The parameters computed for one of the DIBCO 2009 dataset

Variable	Value	Variable	Value
max_M	204	min_M	228
max_{M2}	255	o	48.0103
max_{M3}	154	R	0.9996
max_{WTM}	196		

Figure 3 describes the workflow of the proposed binary image processing. Starting from the initial processing into grayscale image then it calculates the standard deviation and the smoothness of the image. Next it determines the highest peak of the image histogram. Later, it gets area between the highest peak of the range of the first with the second highest peak (min_{H1}) in range area of *a* between the second peak and the first with the third highest peak min_{H2} / Image histogram of range area of *b*. Make each part *a* and *b* for the next processes: it finds the minimum value in the range (min_{H1}) / *a* and min_{H2} / *b*; do the WTM method; ATV-Met 1; After that, it compares the values of WTM, ATV-Met 1, and the value range on the *a* or *b* to find the minimum value of the three values consequently. Then it compares the result with the value a among b and take the smallest value. The ATV-Met 2 Method is done to obtain a threshold value which is certain to generate a binary image of the perfect.

RESULTS AND DISCUSSION

The datasets were tested using the proposed method and the other state of art by Bilal (Bataineh et al., 2011), Minimax (Ray & Saha, 2007) and Niblack (Niblack, 1985). The datasets that were tested comprised faded ancient manuscripts, namely DIBCO 2009, DIBCO 2010 and DIBCO 2011 and ancient Islamic, Chinese and Indian manuscripts. Altogether, the were 46 images. The DIBCO 2009-2010 datasets were evaluated against the groundtruth image, while the others, which are the ancient Islamic, Chinese and Indian manuscripts, were evaluated using Mean Absolute Error (MAE) and Negative Rate Metric (NRM) evaluation methods. All the DIBCO image datasets were tested using the F-measure and Jaccard Coefficient evaluation methods.

The evaluation results in Table 2 for the DIBCO dataset show that the proposed method is more accurate. This is indicated by the F-measure and Jaccard Coefficient evaluation results, which were much higher compared with the results obtained by the other methods except for the F-measure of the Bilal's method. However, the F-measure is very close to this study's proposed method and Bilal's method, and is also better in terms of the Jaccard coefficient. An analysis of the results across the test images showed the proposed method is the most accurate among all the printed DIBCO images.

Table 3 shows the values obtained by the proposed method are better for the other ancient manuscripts. The smaller MAE values obtained using this method across all the data sets except for India1_1 indicates it is more accurate. The overall smaller NRM values in Table 4 means the images are also more accurate using the proposed method.

On the subjective visual evaluation side, Figure 4 shows samples of the resulting image binarization results. The results for each of the methods using a sample of three images from the DIBCO and ancient manuscripts datasets are presented in row form, one row per method. Row 1 shows the results using the proposed method, followed by Bilal's in Row 2, Minimax's

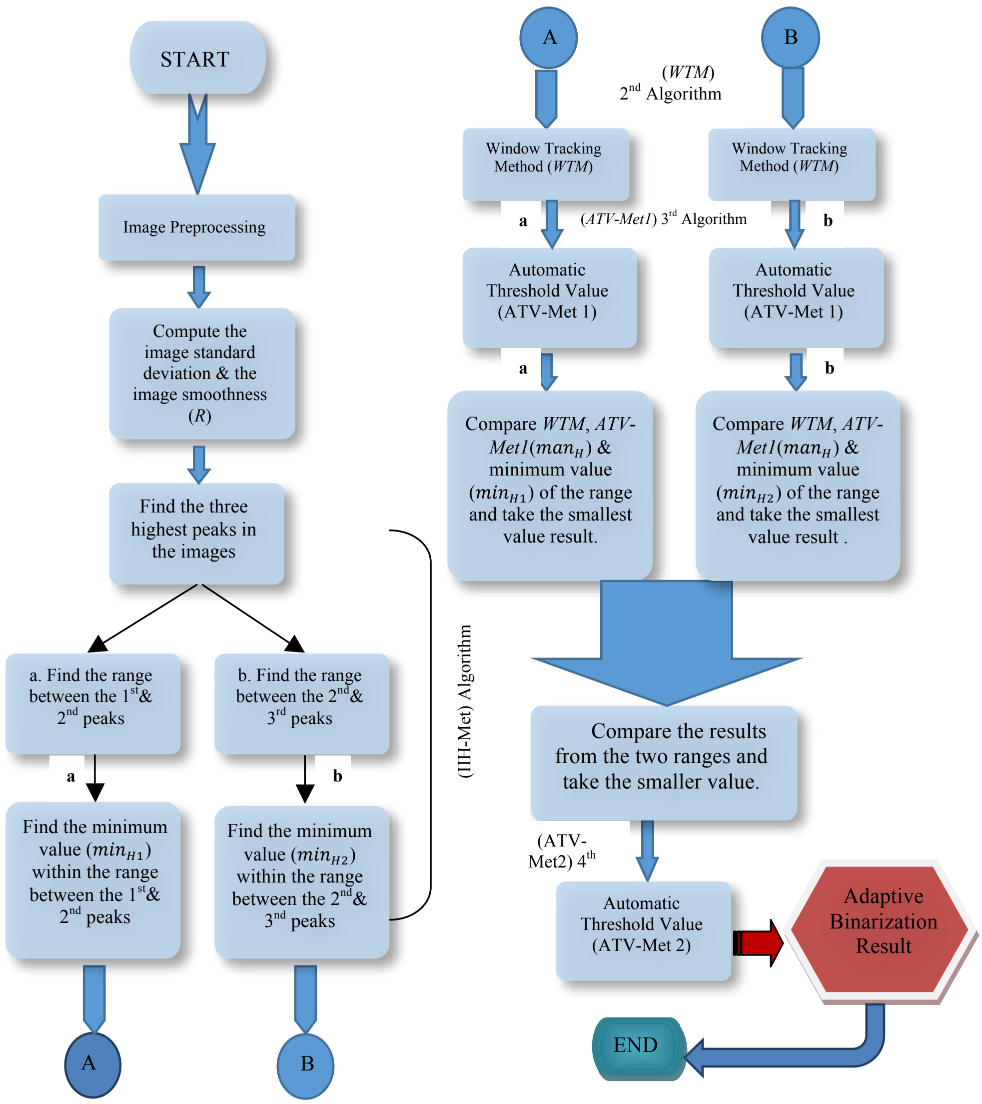

Figure 3. The general flowchart of the processing steps in the proposed adaptive binarization method

in Row 3, and Niblack's in Row 4. For those three images, the proposed method shows sharper and cleaner results. The improvement is very obvious especially on the third image, on the right hand side of the Chinese characters.

Table 2
F-measure and Jaccard Coefficient evaluation methods for all the DIBCO(DIBCO 2009, 2010, 2011) datasets (datasets based on groundtruth image)

	Proposed Method	Bilal's method	Minimax's method	Niblack's method
F-Measure Jaccard	81.535	83.897	81.037	38.430
Coefficient	0.789	0.725	0.690	0.239

Table 3
MAE evaluation method for ancient manuscripts datasets (datasets without ground truth image)

	Proposed Method	Bilal's method	Minimax's method	Niblack's method
China1	92.9129	160.6823	64.5580	87.8951
Antique Mamluk Quran Leaf_1	78.7947	215.9083	121.3304	175.1374
Antique Ethiopia Quran1	82.9649	91.2928	90.7710	96.1570
Antique Mamluk Quran Folio	98.9968	117.4874	118.7456	114.4217
China2	89.3762	91.8647	91.5320	100.3649
India1_1	117.3151	116.9226	114.6637	111.7038
MS-ADD-01116-000-00003_1	63.5878	65.7867	66.0477	102.1288
MS-ADD-01131-000-00007-Edit_1	71.0384	73.0718	72.1345	85.8962
MS-ADD-01136-000-00003-Edit_1	71.0162	80.9557	81.4980	103.0168
India2	66.5490	68.6167	67.6953	81.0267
Average	83.2552	108.2589	88.8976	105.7748

Table 4
NRM evaluation method for ancient manuscripts dataset (dataset without ground truth image)

	Proposed Method	Bilal's method	Minimax's method	Niblack's method
China1	10.918	27.277	24.672	19.077
Antique Mamluk Quran Leaf_1	5.436	13.710	15.012	17.040
Antique Etiopia Quran1	6.879	26.696	27.799	24.056
Antique Mamluk Quran Folio	31.762	41.914	43.093	41.010
China2	11.552	15.022	12.651	14.467
India1_1	43.098	40.991	40.935	28.057
MS-ADD-01116-000-00003_1	12.664	14.940	10.615	28.692
MS-ADD-01131-000-00007-Edit_1	3.829	5.882	6.735	11.716
MS-ADD-01136-000-00003-Edit_1	8.551	27.087	25.543	34.026
India2	23.027	16.343	16.486	20.952
Average	15.772	22.986	22.354	23.909

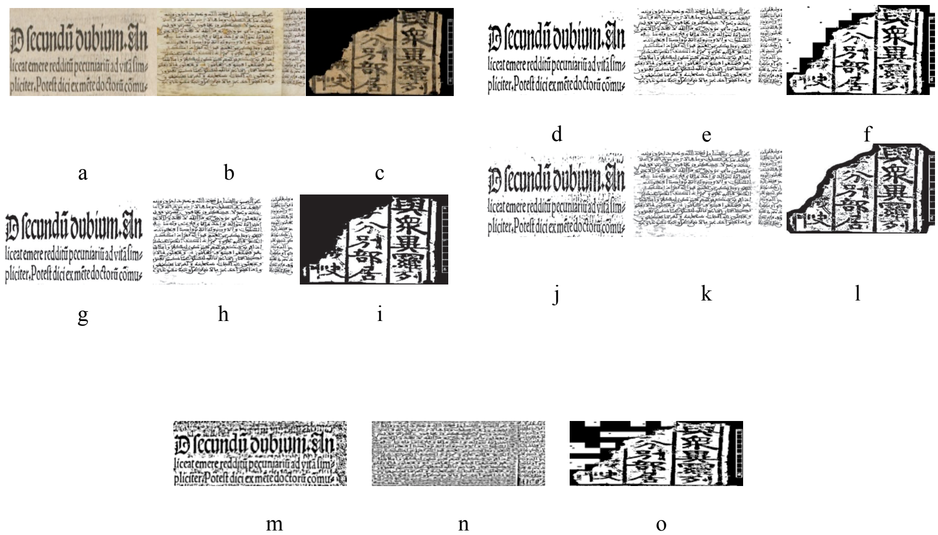

Figure 4. Three sample images of the datasets in the top row (a, b, c), and the respective image binarization results in the following rows by using (i) the proposed methods in the 1st row (d, e, f); (ii) Bilal's method in 2nd row (g, h, i); (iii) Minimax's method in the 3rd row (j, k, l); and (iv) Niblack's method in the last row (m, n, o).

CONCLUSION

In this study, an adaptive image binarization method which combines methods based on an image histogram, tracking window, standard deviation and smoothness of images, and automatic thresholding was proposed. The results obtained using DIBCO datasets and faded ancient Islamic, Chinese and Indian manuscripts show that the proposed method is more accurate. The results demonstrate the potential of the proposed method for binarizing degraded textual images.

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