International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 14, Number 3 (2021), pp. 219-226

Simplified Digital Historical Manuscript Images Binarization Using Mathematical Morphological Techniques

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Abstract

Historical manuscript documents are very important evidence of our historic. They are valuable ancient document. Ancient book and palm leaf manuscript are one of the historical documents. The contents in the manuscript are about Buddhist doctrine, medicine, astrology and religion. Mostly historical manuscripts are discovered in the damaged or degraded sources. The digital files copying and image enhancement techniques could be used to preserve these valuable resources and knowledge. The simple combined enhancement techniques for historical manuscript images or degraded documents has proposed. The method consists of pre-processing, image enhancement using contrast stretching, noise reduction using median filtering, image segmentation using adaptive thresholding, and post-processing using set of mathematical morphological techniques. A set of historical images, as Thai book and palm leaf manuscript, from both institute repositories, online repositories and standard dataset are tested. The resulting images are then compared and validated with the experts. The results show that the proposed method has improved system performance. The accuracy is 93.02%. The results show more visible, detectable and recognizable character that could be used in the future, in the recognition phase.

Keywords Historical manuscript, Preservation, Image processing

1. INTRODUCTION

The ancient book and palm leaf manuscripts are an ancient document that is valuable in both history and religion. It is recognized as an important and precious cultural heritage for the country. There is content about Dharma that is taught in the Buddhist scriptures. It is early documents in the study of the history of olden society in which shows the culture, civilization and wisdom of the people in the nation. The knowledge consists of many disciplines such as culture, art, Buddhism, medicine, and astrology. Ancient book or Samut Khoi or Samut Thai is a type of folding book manuscript. UNESCO considers that the palm leaf manuscript is a literary heritage that records world history and put the conservation of palm manuscripts as part of the world's memory project [1-5]. Preparation of palm leaves, notes or inscriptions on the palm leaf, which is a natural material, has a delicate algorithm. To write, collect and maintenance, the specialist skill is required. The palm leaf scripture is a material that has deteriorated over time and the environment including temperature, humidity, light, dust and insects. Besides, the lack of knowledge in storage causes many palm leaf manuscripts to be destroyed or damaged without knowingly [6].

Although digital duplication began using a camera the photos obtained from the damaged or deteriorated originals causing the letters in the palm leaf to be blurry and incomplete [7]. The text used in most palm leaves is ancient Thai or Khmer scripts. It is difficult to copy and read to transcribe or analyze text. The exchange of letters is the conversion from one form to another such as converting the Dharma alphabet to the Thai alphabet. The conversion of ancient Thai characters to the current Thai alphabet will make the translation easier. Alphabet exchange will be easier if the letters are digitally printed.

The use of image processing techniques to enhance photo quality will be useful in the study of historical documents. This helps rapidly and correctly share, exchange, and transcribe. It also helps to preserve the national intellectual information. There are many techniques attempts to the character segmentation based on thresholding. Threshold-based methods are used to binarize document images.

Traditional global threshold was proposed by Otsu's [8]. A local adaptive binarization algorithm is used by Niblack [9]. The threshold was calculated based on the local mean and standard deviation. Sauvola and Pietikainen [10] proposed a local threshold method which was an improved algorithm based on Niblack's method. The threshold was determined by the average grayscale and standard deviation. Di Lu et al. [11] used contrast enhancement and a local threshold value on the divided area. O. Surinta and R. Chamchong [12] proposed image segmentation of handwriting from palm leaf manuscripts composed of background elimination by Otsu's algorithm, line segmentation and character segmentation. The accuracy of background elimination is 61%. The combination of normalization and binarization methods was proposed by M. Rajeev, N.V.G. Prasad and R.N. Venkata [13]. Adaptive binarization was used to extract text information. The result could improve the clarity of the text. There were researches using adaptive thresholding to binarized document images [14-15]. Most of these researches cannot handle thin text and a large amount of background noise.

From the study of related research, it was found that steps for

improving image quality is important and needs to be taken first to reduce the noise of the image and get a clearer clarity of the characters [16-19]. This research, therefore, focuses on experimenting with the steps to improve the effective image quality in order to enhance the results of advanced image processing and using the result in the next character recognition process. Much work has been performed for palm-leaf manuscript enhancement based on a variety of techniques. Most techniques used are complicated, not conducive practical and required large computational power. Most of the images used are also taken from a high spec digital camera with proper light and shooting distance setting. The sample degraded manuscript image is shown in Fig. 1.

While most of the historical manuscripts are discovered in part of rural area in which high spec digital camera is unable to use. Nowadays everyone has a smartphone and it is a very easy and simple way to capture the images. This paper proposed a historical manuscript enhancement technique based on simple combined method on digital images that could both taken from high spec digital camera or smartphone. The combined of adaptive thresholding and mathematic morphological method is proposed. Adaptive thresholding techniques solve the difficulties of low contrast segmentation between the text and background while the mathematical morphological methods solve the problem of thin and disconnected stroke text. The purposed technique is very fast and requires lower computer power. So, the final system can be used for real-time system application even on a poor computer system with any image taken equipment and low image quality. The research also aims to provide clearly binarized historical document images that can increase human readability in which valuable knowledge can be used and proliferate.

The rest of the paper is structured according to the following. In Section 2 Material and method is proposed. In Section 3, the experimental result is reported. The discussion and conclusion are finally presented in Section 4.

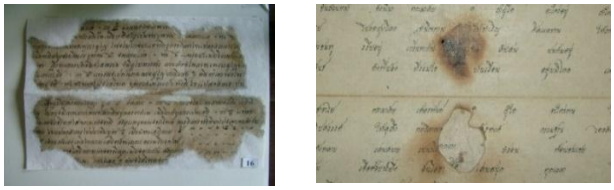


Fig. 1 Degraded palm leaf manuscript images.

2. MATERIAL AND METHODS

Two hundred and twenty historical paper documents are tested. Historical paper documents consisted of Thai book and palm leaf manuscript. The images are collected from two sources. First, 100 digital images are obtained from Tong-tua temple and Chong-lom temple in Thailand. The manuscripts were written in Thai, Balinese, Pali, Sanskrit and Lan Na languages. The images are both taken by a digital camera and smartphone. The remaining is downloaded from online repositories [20-23]. The standard H-DIBCO 2016 and H-DIBCO 2018 dataset are also tested. The historical manuscript imaged used are shown in Fig.3 and Fig.4. The images were stored in JPEC image format files. Since they are ancient scripture, therefore there is damage over time. There are different shooting distances and vary source of light. The color and brightness of the image are uneven and a lot of noises appears.

The experiment is organized as follows: Section 2.1 described a preprocessing step. Section 2.2 explains the contrast enhancement. Section 2.3 explains noise removal. Section 2.4, image binarization using adaptive thresholding is presented. Section 2.5, postprocessing using mathemetic morphological method is proposed. Fig. 2 shows a proposed process diagram of our proposed method.

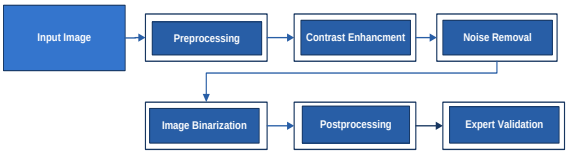
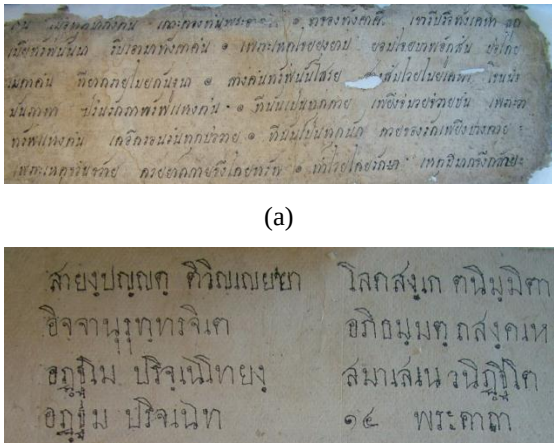


Fig. 2 A proposed process diagram



(a)

(b)

Fig. 3 Historical document images (a) Palm leaf manuscript images from Tong-tua temple. (b) Thai book manuscript images from Chong-lom temple.

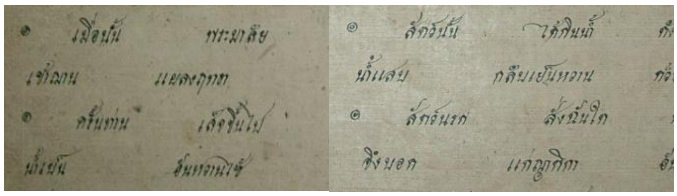
Fig. 4 Palm leaf manuscript images from repository database.

2.1 Pre-processing

In the preprocessing step, the original images are prepared and resized. The original image is divided into two equal parts. For example, an original digital image file size of 1280 x 960 pixels at 24 bits per pixel is divided into two parts that are the same size of 640 x 960 pixels as shown in Fig. 5 and Fig. 6. The division into sub-images is suitable for images where different values for each part of the image are different. There are uneven

lighting conditions throughout the image. Image segmentation makes each part more consistent in lighting conditions. As a result, the processing accuracy is improved. Furthermore, splitting images into smaller pieces reduces the size of the data, allowing for faster processing. Even though the smaller size of the image improves the accuracy but too many divisions will take a large computer calculation, therefore only 2 sub-images are used. The original Red, Green and Blue (RGB) image are transformed to Hue, Saturation and Intensity (HSI) image. HSI color mode is suitable for the segmentation cause the intensity component is separated in which the intensity mode shows the clearest character over the background. The shade correction algorithm is applied to remove slow background variation.

Fig. 5 Original image of 1280x960 pixels size.



(a) (b)

Fig. 6 Two sub-image of 640x960 pixels size (a) left side, and (b) right side.

2.2 Contrast Enhancement

Due to the extremely high fuzzy and unclear images taken in this experiment, the image contrast enhancement process is performed before reducing the noise so as not to reduce the significant details [24-25]. To remove slow background variation, shade correction algorithm is applied. The contrast enhancement of the image is a procedure for emphasizing the object of interest. Studying experiment by adjusting the light intensity by using the image in intensity mode by comparing 4 techniques, namely Histogram Equalization, Contrast Limited Adaptive Histogram Equalization (CLAHE), Gray-Level Transformation and Piecewise – Linear Transformations function or Contrast Stretching. The detail of each method is described.

2.2.1 Histogram Equalization (HE)

Histogram equalization increases local contrast by spreading out the intensity histogram [26]. HE defines a gray level transformation function automatically, which generates a uniform histogram output image. The global cumulative histogram is used as a gray-level transformation function, as in (1).

$$s_k = T(r_k) = \sum_{j=0}^{k} p_r(r_j) \tag{1}$$

where r is input gray levels, s is output gray levels and p is probability function

2.2.2 Contrast Limited Adaptive Histogram Equalization (CLAHE)

Contrast limited adaptive histogram equalization overcome the limitations of histogram equalization in which global threshold is applied by performing local contrast enhancement [26]. It used for improving the local contrast according to pixel's neighbor and enhancing the edge in the small region of an image. A histogram is divided into predefined regions. The intensity is then adjusted and uniformly distribute into gray image. CLAHE consists of performing histogram equalization of the image's non-overlapping sub-areas, using interpolation to resolve inconsistencies between borders.

2.2.3 Power-Law Transformation

Power-law or gamma transformation or gamma correction is an intensity transformation based on gamma values [27-28]. Transformation curves are obtained by varying the gamma (γ) as in (2). If γ <1, the input image is map into a brighter output image. Similarly, for γ >1, the opposite result is obtained.

$$s = cr^{\gamma} \tag{2}$$

where s and r are the output and input pixel values, respectively and c and γ are the positive constants.

2.2.4 Piecewise-Linear Transformation

Contrast stretching is the simplest piecewise linear function. It is a process that increases the dynamic range of the image. The image is enhanced by stretching the range of intensity values. A piecewise linear function is used to transform the gray levels in the range {0,1,…,L-1}, as in (3). To perform the stretching, the upper and lower pixel value limits are specified.

$$s = (r-c)\left(\frac{b-a}{d-c}\right)+a \tag{3}$$

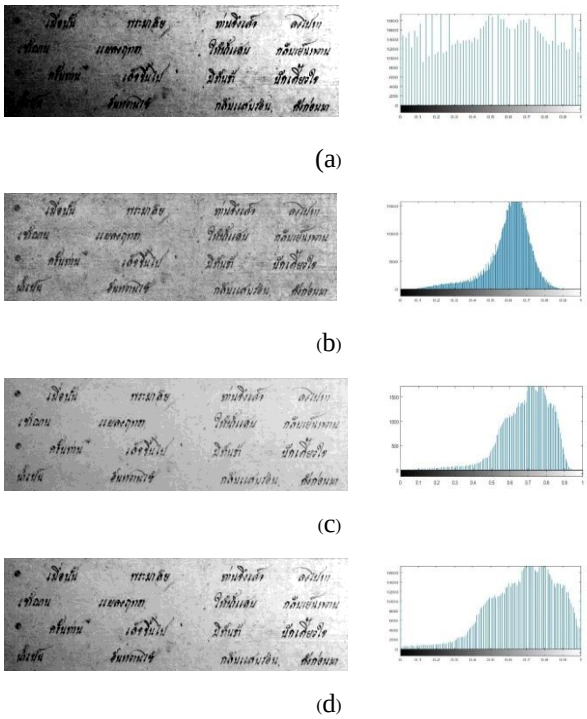
where a and b is the lower and the upper limit values, c and d is the existing lowest and highest pixel values.

From the results, as shown in Fig. 7, it was found that HE and CLAHE method not only made the characters sharper but also makes the background and noise clearer as well. The artifacts are generated. While the method of power-law transformation and contrast stretching show clearer characters with a smoother background. But the results of the power-law transformation method, some fainted characters are blended to be the background. The contrast stretching shows the most powerful method for contrast enhancement.

2.3 Noise Removal

From the process of increasing the contrast of the image, the result increases the clarity of the characters, unfortunately, the noises are also increased. The median filtering and averaging filtering are considered. As noised appears is the salt-and-pepper pattern in which median filtering could better remove the noise more effectively than averaging filtering method. The median filtering operation not only removes the impulsive noise but also preserves the sharp edges. The median filter replaces a pixel value by the median of the neighborhood gray levels, as in (4). A median filter of 3x3 is then added. A noise removal results are shown in Fig. 8.

$$\hat{f}(x,y) = \underset{(s,t\in S_{xy})}{\text{median}}\{g(s,t)\} \tag{4}$$



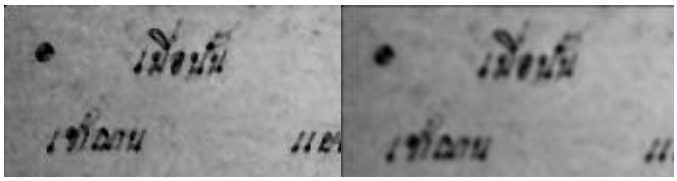
(a)

(b)

(c)

(d)

Fig. 7 Contrast enhancement results and its histogram by (a) Histrogram Equalization (b) Contrast Limited Adaptive Histogram Equalization (c) Power-Law (Gamma) Transformation (d) Contrast stretching



(a) (b)

Fig. 8 Noise removal results by (a) median filtering (b) averaging filter

2.4 Image binarization using adaptive thresholding

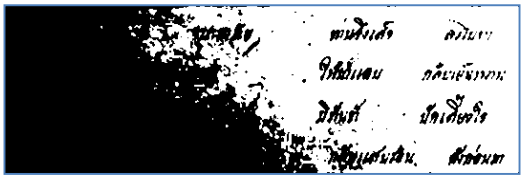
Thresholding is the simplest method of segmentation by detects a valley in the histogram [29]. The foreground image is segmented by setting pixels whose intensity values are above the threshold and the background image is segmented by the remaining pixels. There are three types of thresholding namely: global, local and adaptive. The global thresholding used a single threshold while the local thresholding used local properties of some image regions. Both global and local thresholding are difficult to segment object in non-uniform illumination environment. To cope with non-uniform illumination is to partition the image into sub-images and use a different threshold to each sub-image.

Adaptive thresholding is designed to resolve the limitation of traditional global thresholding by using a different threshold at each position of the pixels in the image. Adaptive thresholding used a different threshold value according to the brightness/darkness of the image. The local mean intensity (first-order statistics) in the neighborhood of each pixel is used as a threshold value. To extract characters from the non-uniform background image, adaptive thresholding is then applied. The adaptive threshold value depends on the coordinates *x* and *y* as shown in (5).

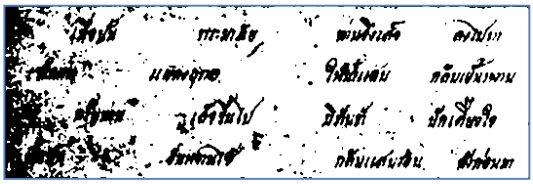
$$T = T[x, y, p(x,y), f(x,y)] \tag{5}$$

where $f(x,y)$ is the gray level of point (x,y), and $p(x,y)$ represents some local property of the point, e.g., the average gray level of a neighborhood centered on (x,y).

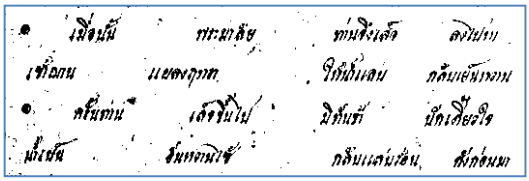
The results, as shown in Fig. 9, show that character could extract from the background, but the resulting image still found several non-character objects detected. And the lines of some characters are very thin. Therefore, the next step presents an increase in the line stroke and eliminates non-character objects.



(a)



(b)



(c)

Fig. 9 Text and background segmentation by (a) Local thresholding, (b) Global thresholding, and (c) Adaptive thresholding.

2.5 Post-processing using Mathematic Morphological

In this step, non-character objects that are smaller than characters and objects of similar size to the alphabet, but not characters are removed. The strokes of the character are also increased using mathematic morphology method. Dilation and erosion method are used.

2.5.1 Dilation

Dilation expands the boundary of characters in an image. Dilation is applied to enlarge the character, repair breaks and intrusions. The broken characters are then joined. It does also thicken the object. The dilation of A by B is shown in (6).

$$A \oplus B = \left\{ z \mid [\,(\hat{B})_z \cap A\,] \subseteq A \right\} \tag{6}$$

$\hat{B}$ is the reflection of B about its origin, and z denotes the amount of shifting of B.

2.5.2 Erosion

Erosion contracts the boundary of objects in an image. Erosion thins the objects, spit apart joined objects and strip away extrusions. The object with smaller size than the structuring elements will be removed. The erosion of A by B is shown in (7).

$$A \Theta B = \left\{ z \mid (B)_z \subseteq A \right\} \tag{7}$$

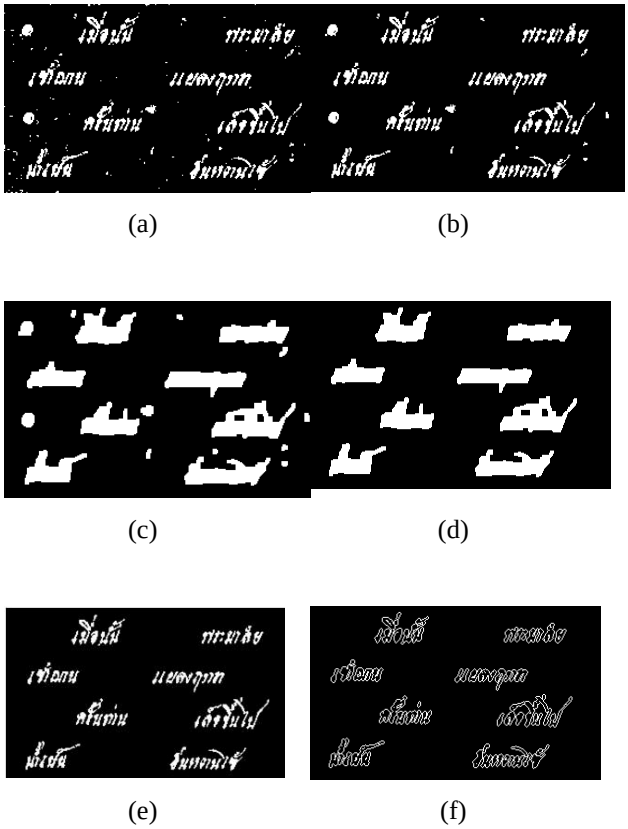
The images are first inverted. The objects which are smaller than character and edges around the image are removed using erosion operator. The result showed in Fig. 4 (a) and Fig.4 (b). The characters are then dilated so the words are adjacent to a large area. A binary dilation operation is applied with a 3x3 diamond-shaped structuring element. To ensure that the character in each word is connected, the enclosed area was also flood-filled. The resulting image is shown in Fig 4(c). The very small objects are considered to remove as shown in Fig. 4 (d). To get the character, the intersection image between the original image and image after removing non-character is operated. The dilation operation is then applied again to increase the text stroke to improve readable clarity. Finally, erosion operation is applied to shrink text size to the original size. The size of the structuring elements used for the dilation and erosion operation are varied and tested in order to access the best performance. Too large structuring element size leads to a too thickness stoke in which hard to read while too small structuring element size will cannot connect the line. The results are shown in Fig. 10.

3. RESULTS

The results of the experiment are validated with image processing experts and palm leaf manuscript experts. The performance is evaluated both in a qualitative and quantitative method. The qualitative evaluation was measured by the vision test with the readability by the expert. Visual inspection is done by the experts. Clarity and readability are considered. Visual evaluation is categorized as recognized or unrecognized words. In quantitative evaluation; the resulting extractions are compared with expert ground-truth images.

DIBCO 2009 [30] has a benchmark for the evaluation measurements which are F-mean, the peak signal-to-noise ratio (PSNR) and negative rate metric (NRM) for measuring binarization efficiency. The value of the F-mean represents the precision of the binary image. MSE and PSNR are used to measure the similarity of the binarized image and ground truth image. A higher PSNR value shows a higher similarity of the two images. These quantities values are computed using (8) through (13).

$$F-mean = \frac{2 \times recall \times precision}{recall + precision} \tag{8}$$



(a) (b)

(c) (d)

(e) (f)

Fig. 10 Post-processing result images (a) inverted images, (b) small object removal image, (c) dilated image, (d) non-character object removal image, (e) stroke emphasized image, and (f) edge contour image.

where

$$recall = \frac{TP}{FN + TP} \tag{9}$$

$$precision = \frac{TP}{TP + FP} \tag{10}$$

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \tag{11}$$

R is the maximum fluctuation in the input image data type

$$MSE = \frac{\sum_{x,y}^{M,N}\left(I_1(x,y) - I_2(x,y)\right)^2}{M \times N} \tag{12}$$

where M and *N* are the number of rows and columns in the input images.

$$NRM = \frac{\frac{FN}{FN + TP} + \frac{FP}{FP + TN}}{2} \tag{13}$$

where *TP* (True Positive) is a number of text pixels that are correctly classified, *FP* (False Positive) is a number of non-text pixels that wrongly classified as text, *TN* (True Negative) is a number on non-text pixels that are correctly classified, and *FN* (False Negative) is a number of text pixels that are wrongly classified.

The proposed method is compared with three standard methods: global thresholding method by Otsu, local thresholding method by Sauvola and Pietikainen and local thresholding method on partition area by D.Lu. The proposed method has a higher F-mean of 93.02%, higher PSNR of 15.97%, and lower NRM of 6.25%, respectively. By the visual evaluation, the proposed method also shows the best visual recognition. The qualitative and quantitative performance is shown in Table 1 and Table 2, respectively.

Table 1. Qualitative evaluation results.

	Recognized	**Unrecognized**
Proposed	213	7
Di Lu	200	20
Sauvola	130	90
Otsu	30	190

Table 2. Quantitative evaluation results.

	F-mean (%)	**PSNR**	**NRM**
Proposed	93.02	15.97	6.25
Di Lu	82.75	15.86	9.49
Sauvola	59.17	11.67	25.50
Otsu	48.45	6.55	36.12

4. DISCUSSION AND CONCLUSION

The palm leaf manuscript images and Thai book are an ancient document that is damaged according to storage conditions and time, and still has a lot of dust or stains. This research presents the use of image processing techniques to enhance the quality of historical manuscript images. Character segmentation is an important process for character recognition. To get a high segmentation accuracy rate, the image has to be binarized to separate between text and background. The original images are divided into two parts to reduce uneven lighting problems. As

well as reducing the size of the data resulting in faster processing. The intensity color mode is used. Then the contrast stretching is used to enhance the contrast of the image. The median filtering is used to remove noise. To binarized the image, adaptive thresholding is applied. And finally, mathematic morphological is used to emphasis text stoke and remove non-character objects. The results show that the algorithms proposed could correctly extract characters up to 93%.

From the research, it is found that the original digital image obtained from the process of shooting there is no proper lighting or the physical documents are much damaged. The color of the palm leaf background and the color of the characters are blurry or dull with time, which is a huge problem in the process of separating characters with the background. The method proposed could clearer the original image before extracting the characters in ancient documents that faded with time or written with different handwriting and hand weights. It could improve the faded stripes to be visible.

As shown in Fig. 11, images that cannot completely separate characters from the background are caused by the original photos having very uneven lighting or the color of the text is very close to the color of the background. Then the letters are considered as a background or noises. When looking at the original image, we found that that missing character appears at the tail of character, letters or consonants that are thin. In the case that there is ink marks or dirt in the same area as the letters, ink marks will be considered to be in characters and make it impossible to read. There are some incorrect text detections which are caused by the large artifacts and some faint texts are missing. The performance of the algorithm can be improved if these problems are coped.

(a) (b)

Fig. 11 Unrecognized result images (a) Original images, (b) result images.

In each step, the parameter setting is very important. To preserve the valued palm-leaf manuscript, in the courtyard that does not have modern cameras or lighting equipment, taking images with a simple method is one way of conservation in the folk style. The use of character separation and background adjustment techniques according to the specific intensity of the images presented in this research can distinguish characters and backgrounds in images with uneven lighting. This extracted character can be used to read for transcription or text analysis more conveniently. To promote the conservation of the palm leaf manuscript and transfer of Eastern wisdom to be extensively used in the long-term, facilitating the study of eastern wisdom in digital form also helps preserve national data and documents. This system intends to preserve a very valuable document and extend the knowledge which hard to accesses by the ordinary people. And the results also make subsequent tasks such as image analysis and image recognition more effective.

In future work, we plan to expand the data set and explore text recognition. Separating groups of characters into single characters could be done. In the use of palm leaf manuscript handwriting, in which the gestures and the weight of each person's hand are also different. In addition, the character of the Thai character with streaks that have a lot of tail flicks keeps the characters next to each other very difficult to separate. The use of handwriting recognition techniques for automatic translation is a big future step. The difficulty of character recognition on the palm leaf scripture is that the letters used are varied according to age and area such as Khmer script, Lao alphabet, Lanna alphabet, ancient Thai script. Making computers able to recognize these characters will add value to the conservation of ancient scriptures. Also, using image recovery techniques together will help to restore the damaged image more complete.

Acknowledgments

We would like to thank to temples, organizations and Burapha library center for the images used in this project, and we thank experts for providing ground truth data and great advice. This research is supported by the Burapha University.

Conflict of interest

There is no conflict of interest.

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