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Evaluation of local thresholding techniques in Palm-leaf Manuscript images

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Abstract— Digital image processing is the usage of computer algorithms for the analysis and manipulation of images. This work emphasis local thresholding technique for the segmentation of characters in palm leaf manuscript images. The preprocessing stage comprises of filtering and image enhancement. The filtering of noise was done by decision based median filter and contrast local adaptive histogram equalization was applied for enhancement. For segmentation, Otsu global thresholding and local thresholding techniques like Niblack, Sauvola and Bernsen algorithms were evaluated. The Sauvola local thresholding generates more efficient results than the global thresholding and other local thresholding techniques. The computational complexity of Sauvola thresholding is considerably low and the performance of thresholding techniques was evaluated by entropy measure. The Sauvola thresholding resultant image has low entropy value when compared with other thresholding techniques. The algorithms were developed in Matlab 2010a and evaluated on the real-time images acquired by canon SX600HS camera.

Keywords— Palm leaf manuscript; Decision-based median filter; CLAHE; thresholding; Shannon entropy.

I. INTRODUCTION

The role of image processing is vital in many fields that include remote sensing, medical, archaeology, and military. The images obtained from the acquisition system are subjected to computer-aided algorithms for detailed analysis. Old manuscript documents are often subjected to background damages such as varying contrast, smudges, dirty uneven background and even ink through text. The image processing gains its role in archaeology for restoration; segmentation and pattern recognition of old palm leaf manuscript, documents and stone carvings images.

II. RELATED WORK

Romen Singh et.al describes a local adaptive thresholding technique based on integral sum image concept for document images [1]. The pixel level pre-processing technique comprising of Quadratic Integral Ratio (QIR) and OTSU algorithms were proposed for an Optical Character Recognition system for brahmi script images [2]. QIR algorithm is a two-stage thresholding algorithm that uses the histogram to find the threshold value. In QIR algorithm, the image is divided into 3 sub-images i.e.; foreground, background and a fuzzy sub-image (whose pixels may be part of either foreground or background) and it outperform Otsu thresholding result [2].

Ntogas Nikolaos et.al proposed binarization techniques for six different classes of document images based on their quality [3]. For pre-processing, Mean, Median and Weiner filters in the spatial domain and Gaussian and Butterworth filters in the frequency domain options have been proposed [3]. The Binarization was done by OTSU such as local thresholding techniques and finally, a post-processing stage for the output refinement based on erosion and dilation was also used for discriminating the text from the background [3].

Saxena developed an effective binarization method for removing stains from severely degraded and stained manuscript images, where the text is unclear [4]. The proposed technique divides the image into windows of size ranging from 3 x 3 to 15 x 15 and determines a local threshold value for each window by finding the mean and

standard deviation of gray values in the image. The window size is determined by a trade-off between the size of the image and processing time; smaller the window size, more will be the processing time. It is particularly suitable for segmentation of document images with dark and complex backgrounds.

Sitti Rachmawati Yahya et.al has put forward methods to enhance old manuscript images with a degraded background as follows; binarization / thresholding method, a hybrid of binarization/ thresholding technique and non-threshold based methods [5]. The hybrid method was found to be efficient for damaged images, and it comprises of pre-processing by low-pass Wiener filter, thresholding by Niblack algorithm, a post-processing stage to improve the quality of text regions and preserve the stroke connectivity [5].

Rajiv Medithi et.al proposed a segmentation technique based on combined binarization and normalization for digital photographic images of palm leaf manuscripts [6]. The base color of the palm script manuscripts was first identified and color bleaching transform was applied so that the background color gets washed off. The bleached image was then subjected to two-stage local adaptive normalization algorithm. After normalization, the images were subjected to adaptive binarization in order to extract useful text information from low-quality document images. PP Rege proposed an enhancement technique for extracting useful text information from the low-quality document and palm leaf manuscript images [8]. Ntirogiannis et al proposed a combination of global and local adaptive binarization method to efficiently detect faint characters in handwritten document images [9]. Youlian Zhu et.al discusses local and global histogram equalization algorithms [10]. The local histogram equalization enhances local details of the image and it may be further divided into three types: overlapping sub-block, non-overlapping sub-block, and partially overlapping sub-block. The non-overlapping sub-block method is very rarely used because of its obvious square effects; the overlapping sub-block method is also not used in practice because of its low processing speed; the partially overlapping sub-block method can speed up the calculation, but it is relatively complex. Compared to local histogram equalization algorithm, the global algorithm has certain advantages in processing speed, but the enhancement region of interest is poor. Kong et al performed a comparative analysis of histogram equalization and its variations for digital images [11]. The proposed research work analyses global and local thresholding techniques for palm leaf manuscript images. This work highlights the application of image processing for archaeological applications. The Sauvola local thresholding was found to yield efficient segmentation results for palm leaf manuscript images.

III. METHODOLOGY

MATERIALS AND METHODS

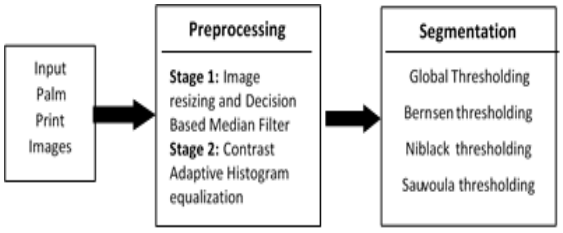


Figure 1. Block diagram of proposed methodology

Preprocessing

The input images were preprocessed by the decision-based median filter. The decision based median filter alters the noisy pixels only, unlike the conventional median filter that alters both noisy and non-noisy pixels [12][13]. The partial differential equation based filtering approach was found to be efficient for image restoration [14][15]. The classical histogram equalization uses the same transformation derived from image histogram to transform pixels [16]. After filtering, the input images are subjected to Contrast Local Adaptive Histogram Equalization (CLAHE); where the histogram equalization is done on small regions of the image termed as tiles rather than applying to the entire image. The resultant enhanced regions are combined by bilinear interpolation.

Segmentation Techniques for Palm Leaf Manuscript Images

Thresholding is a classical algorithm deployed for segmentation of images. The thresholding can be categorized into global thresholding and local thresholding. The Otsu thresholding is a widely used global thresholding in many applications. This research work uses Otsu thresholding and various local thresholding techniques on palm leaf manuscript images.

Global Thresholding

In global thresholding method, a single threshold value is used and then each pixel is assigned to the foreground or the background based on the comparison between that pixel's gray level and the global threshold value. Global thresholding methods are very fast and give good results for typical scanned documents with uniform contrast distribution of background and foreground. However, the major drawback of this technique is that it cannot differentiate those pixels which share the same gray level but do not belong to the same group. It also performs

unsatisfactorily for poor quality images that have low contrast and non-uniform illumination. Hence, the global thresholding is inappropriate for complex documents, especially for degraded document images.

Local Thresholding

In degraded document images, where considerable background noise or variation in contrast and illumination exists. In the case of anon-uniformly scanned page with marginal noise at the page borders, there exist many pixels that cannot be easily classified as foreground or background. In local thresholding, a threshold $T(x,y)$ is calculated for each pixel based on local statistical characteristics. The local thresholding algorithms used in this work are Niblack's, Sauvola's and Bernsen's Technique.

In the above said local thresholding methods, the threshold is calculated based on the parameters such as local mean $m(x,y)$ and standard deviation $\delta\,(x,y)$ within a window of size $w \times w$. Sauvola's method is an improvement on the Niblack's method, especially for stained and badly illuminated documents.

In Niblack's method, the local threshold value $T_N(x,y)$ at (x,y) is calculated within a window size of $w \times w$ as

$$T_N(x,y) = m_a(x,y) + K\,\delta(x,y) \qquad (1)$$

Where K is the bias value (default value -0.2), $m_a(x,y)$ and $\delta(x,y)$ is the local mean and standard deviation of the local window *w* x *w*. The threshold value depends on the local mean $m_a(x,y)$and the standard deviation $\delta(x,y)$.

In Sauvola's technique, the threshold $T\,(x,y)$ is determined using the mean $m(x,y)$ and standard deviation $\delta\,(x,y)$ of the pixels within a window of size $w \times w$ as:

$$T_S(x,y) = m_a(x.y)\left[1 + K\left(\frac{\delta(X,Y)}{R} - 1\right)\right] \qquad (2)$$

Where R is the maximum value of standard deviation, K is a bias that takes positive values in the range [0.2, 0.5].

In Bernsen's technique, the threshold is calculated based on local neighborhood. The threshold at each pixel is the mean of lowest and highest gray level pixels in the neighborhood as shown below:

$$T_B(x.y) = \frac{I_{max} + I_{min}}{2} \qquad (3)$$

The threshold is assigned based on local contrast value

$$T(x,y) = \begin{cases} \dfrac{I_{max} + I_{min}}{2}, & if\ I_{max} - I_{min} > L \\ GT, & if\ I_{max} - I_{min} < L \end{cases} \qquad (4)$$

Where 'L' is a contrast threshold value. This technique is fast; however, it does not work well with varying gray level intensities of the background.

IV. RESULTS AND DISCUSSION

The algorithms are developed in Matlab 2010a with the following system specifications: Intel Core i3 processor, 64-bit operating system, 4 GB RAM. Prior to segmentation, the input images were preprocessed by the decision based median filter. After preprocessing, the adaptive histogram equalization is applied to the image enhancement. The images were acquired by Canon SX600HS digital camera and the flash light was turned off during the acquisition process since light could act as a noise and degrade the quality of the image. Prior to segmentation, preprocessing stage comprises of decision based median filter and CLAHE. The tuning of parameters plays a vital role in the execution of algorithms.

The local thresholding techniques have two tunable parameters; neighborhood window dimension (W) and contrast threshold (K). The default value of window size is 3×3 and can be changed based on the application. The computation time of algorithms for input images are plotted in Table 1.The T1 to T6 represents the test data and the computation time is measured in seconds.

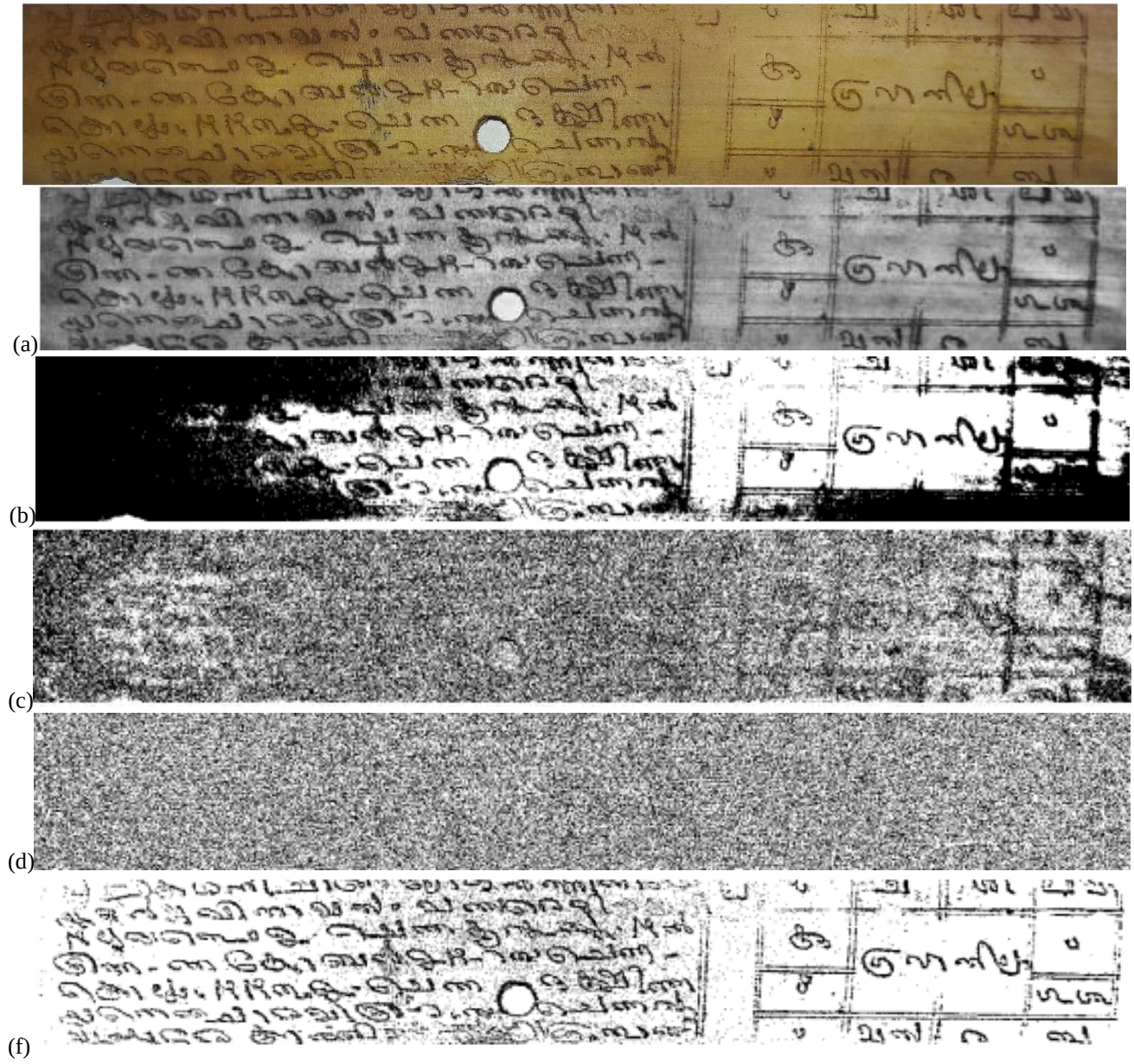


Figure 2.(a) Input Image(T1) b) Decision based median filter output, (c) Adaptive histogram equalization output, (d) Global thresholding output, (e)Bernsen local thresholding output, (f)Niblack local thresholding output,(g)Sauvola local thresholding output

The Sauvola algorithm has low computation time and thresholding result was also superior when compared with other techniques. From the results, it is clear that Sauvola local thresholding produces more efficient results than global thresholding and other local thresholding approaches. The window size was set to [20 20] and the constant threshold value of 0.34 is used. The results for other input images are also depicted below in figure 2.The Otsu thresholding was found to be efficient for the good quality palm leaf manuscript images; however, the old palm leaf manuscript images have to be processed by local thresholding algorithm for the extraction of information.

TABLE 1. Computation time of thresholding algorithms

Algorithms Used	T1	T2	T3	T4	T5	T6
Global thresholding	0.66	0.39	0.39	0.39	0.40	0.37
Niblack	1.54	1.35	1.40	1.35	1.90	1.65
Bernsen	0.80	0.42	1.74	0.42	0.40	0.80
Sauvola	0.74	0.38	0.71	0.38	0.36	0.78

(a)

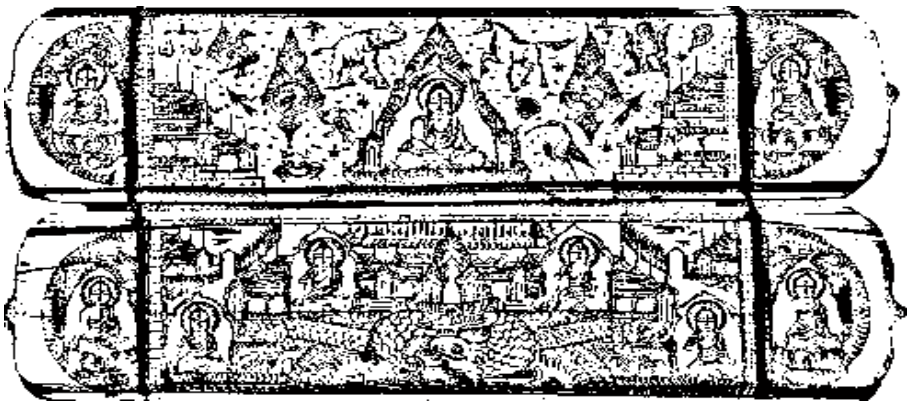
(b)

(c)

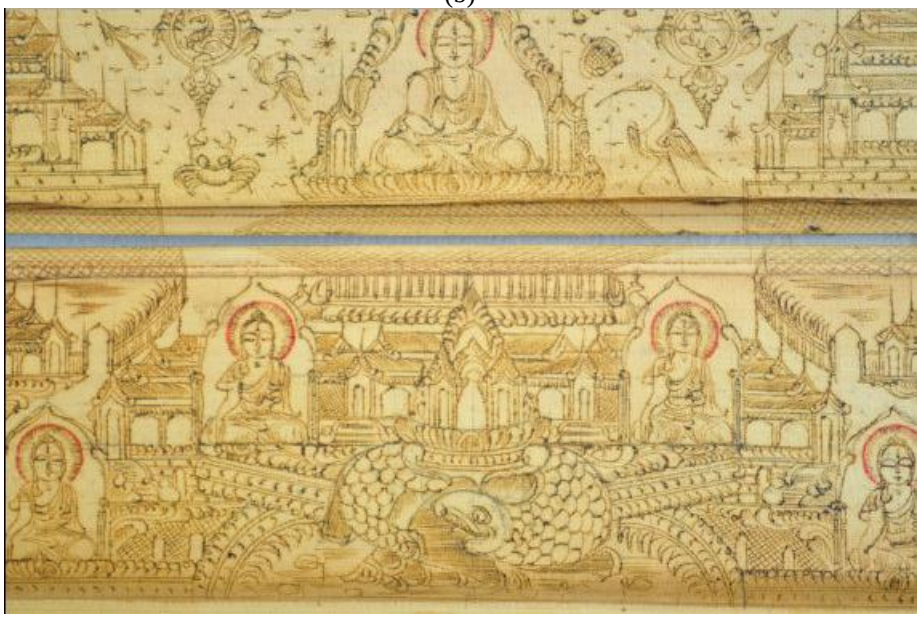
(d)

Figure 3. (a,c) Input Images(T2, T3) , (b,d) Sauvola local thresholding output

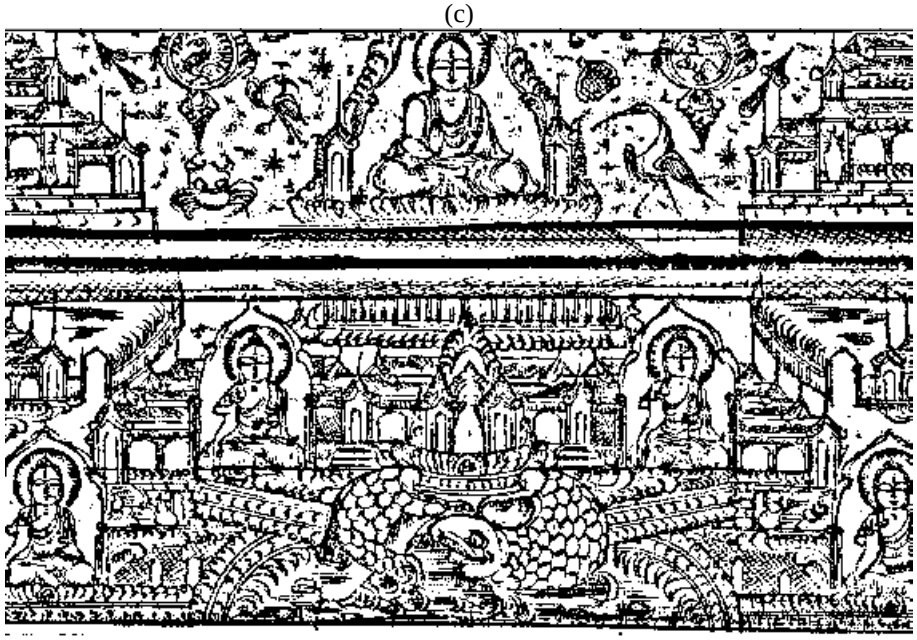
(a)



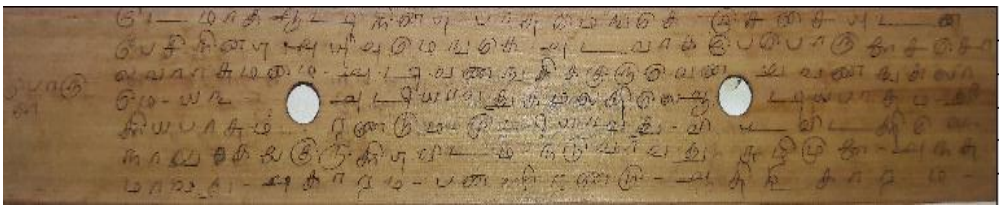
(b)



(c)



(d)



(e)

(f)

Figure 4.(a, c, e) Input images (T4,T5,T6), (b, d, f) Sauvola thresholding output

The efficiency of the algorithm was also evaluated by entropy measure. The entropy is a measure of randomness of pixel information in the image. The lower value of entropy indicates less randomness in image information and for efficient segmentation, the value should be low.

TABLE 1. Entropy measure of thresholding algorithms

Algorithms Used	T1	T2	T3	T4	T5	T6
Global thresholding	0.998	0.710	0.960	0.463	0.505	0.986
Niblack	0.994	0.999	0.999	0.979	0.991	0.998
Bernsen	0.959	0.963	0.967	0.951	0.996	0.954
Sauvola	0.624	0.750	0.666	0.733	0.944	0.522

The Shannon entropy measure is defined as follows

$$E = -\sum_{i=1}^{a} e_i \log e_i \qquad (5)$$

Where 'y' represents the pixel frequency and 'i' represents the gray level intensity of pixel. The low entropy measure also reveals that, the Sauvola algorithm is efficient for palm leaf manuscript images.

V. CONCLUSION AND FUTURE SCOPE

This work analyzes various thresholding techniques for the extraction of characters on palm leaf manuscript images. Prior to segmentation, filtering was performed by decision based median filter, efficient results were produced when compared with the conventional filtering approaches like median and Wiener filter. The decision based median filter alters the noisy pixels only and adaptive histogram equalization was applied, that enhances the image. Out of the local thresholding techniques, Sauvola algorithm produces efficient results. The computation time is low for the Sauvola algorithm and low value of entropy measure reveals its efficiency in the segmentation of palm leaf manuscript images. The future work will be the compression of images for data transfer through cloud network for easy access by the researchers.

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