Restoration of Ancient Kannada Handwritten Palm Leaf Manuscripts Using Image Enhancement Techniques

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1 Introduction

In the recent days, the research area of handwritten character recognition has got much attention towards ancient inscriptions, since they contain lots of unfolding knowledge in the field of science, literature, astronomy, medicine, etc. The materials used to write these inscriptions are paper, palm leaf, stone rocks, and temple walls, etc., and these materials are now degrading in nature due to climatic condition, ink bleeding, lack of attention, and unscientific storage. In digital image processing, the binarization of document image is often the first stage. Ancient documents are ruined, where extensive noise in the background or lots of changes exists. Hence, it is very difficult to categorize foreground and background pixels. Figure 1 shows a sample manuscript of historical degraded Kannada handwritten manuscripts written on palm leaf.

The goal of this research is to apply local and global thresholding to improve the quality of ancient Kannada handwritten palm leaf manuscripts that have already degraded. There has been very little research work done in this area in the literature. The global threshold, introduced by N. Otsu, defines a universal value for all pixel of the image's intensities in order to distinguish between themselves as foreground and background [1]. Non-uniformly distributed noise in an image cannot be removed with a global threshold. There is no way to use a global threshold to get rid of the noise in an image if it is not equally distributed. In contrast, local thresholding, where the threshold varies dependent on local region, offers an adaptable solution for images with distinct background intensities described by B. Gatos et al. [6]. Niblack thresholding is a local thresholding method that

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Fig. 1 Images of degraded historical Kannada handwritten documents written on palm leaf

calculates a threshold for each pixel based on the mean and standard deviation of the pixel's local neighborhood was explained by W. Niblack [3]. Sauvola used two algorithms to calculate the threshold of each pixel based on the local mean, and standard deviation (SD) has been proposed by J. Sauvola and M. Pietikainen [4]. Neha Kundal and Anantdeep analyzed the performance of a novel historical document restoration algorithm based on Sau-vola thresholding, as well as a hybrid method integrating both with certain local filters [2]. N Venkata Rao et al. proposed cleaning outdated document images using a modified Iterative Global Threshold [7]. Degraded Kannada handwritten paper inscriptions were restored using image enhancement techniques (Hastaprati) has been proposed by Parashuram Bannigidad and Chandrashekar Gudada [5]. B. Gatos et al. and E. Kaval-lieratou proposed native threshold, which provides an adaptive result for images with variable background intensities, with the threshold value varying on the attributes of the entire image [6, 9]. Images of degraded non-uniformly illuminated historical Kannada handwritten documents were restored has been proposed by Parashuram Bannigidad and Chandrashekar Gudada [10]. A combined method for binarizing historical Tibetan document images was described by Han, Yuehui et al. [11]. Sauvolanet is a degraded document binarization adaptive learning sauvola network has been evolved by Li, Deng, Yue Wu, and Yicong Zhou [12]. "Text Line Segmentation with LBP Features for Digitization and Recognition of Historical Kannada Handwritten Manuscripts" has been proposed by Bannigidad, Parashuram, and Chandrashekar Gudada [13, 16]. A framework for improved binarization of degraded historical document images was described by Xiong, Wei et al. [14]. Binarization of non-uniformly illuminated document images using the K-Means clustering algorithm has been proposed by Yang, Xingxin, and Yi Wan [15].

In this paper, the Iterative Global Thresholding (IGT) is used for segmentation and the performance evaluation measures; MSE and PSNR are used as quality measurements for degraded manuscripts. In particular, the results are compared with other standard methods in the literature, such as Souvola, Niblack, and adaptive thresholds, using our own dataset. We also used AMADI LONTARSET, a standard palm leaf dataset, to evaluate and measure the performance of our algorithm and to demonstrate that the proposed technique is exhaustive.

2 Proposed Method

2.1 Iterative Global Thresholding (IGT)

The primary goal of this research study is to improve the quality of degraded palm leaf images by using various segmentation techniques, namely, local and global thresholding and IGT. In this paper, the Iterative Global Thresholding (IGT) algorithm is developed. In order to distinguish the image's pixel intensities into text, object, and background categories, the global threshold provides a single, unified value [7]. In each iteration following image equalization, the relative proximity to background intensity is calculated. In each iteration, this method is able to handle a variety of degraded conditions. The intermediate tones are shifted toward the background, making it easy to distinguish between the foreground and background. This method does not completely remove the image's non-uniformly distributed noise. The Iterative Global Thresholding (IGT) algorithm is also implemented with AMADI_LONTARSET, a benchmark palm leaf dataset. The quality of the image is measured by using performance evaluation measures, i.e., PSNR and MSE. The Iterative Global Thresholding (IGT) with PSNR gives better results as compared to traditional thresholding algorithms, which is discussed below:

Thresholding is an easiest form of image segmentation based on intensity values of pixels which is given in Eq. (1).

$$D(x, y) = \begin{cases} 255, & \text{if } S\Big(S(x, y) > \text{thresh} \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

Where,

thresh = Thresholding values
$D(x, y)$ = Final pixel values
$S(x, y)$ = Initial pixel values

The most common and significant function used for classification is the pixel intensity value because it is the primary piece of information stored in each pixel. The pixels' intensity value is shown in Eq. (1).

The various steps used for reducing the noise in the image of the manuscripts are as follows: (i) extraction of degraded (noisy) documents; (ii) converting a noisy document to a grayscale image; (iii) average background+object intensity; (iv) pixel intensity shifting towards the background of an image; (v) equalize the image by considering how the intensity of the foreground objects affects the background information; (vi) compute the mean intensity of the image; and (vii) determine the threshold value among recursive mean levels of intensity [8].

The Iterative Global Thresholding (IGT) algorithm first applies to degraded palm leaf images. The degraded palm leaf image, if it still contains noise, then detects that noise and reprocessed separately. The proposed algorithm is made up of the following steps:

Algorithm 1 Applying Iterative Global Thresholding (IGT)
Procedure:
Input: Palm Leaf Image
Output: Background Image

1. Applying Iterative Global Thresholding (IGT) to the palm leaf image.
2. Convert image to NumPy array.
3. Calculate the mean of all pixels as a threshold.
4. Subtract threshold from pixel: npimage ← (1 − threshold) + npimage.
5. Make it Histogram Equalization.
6. If the number of pixels transformed between 2 iterations < 3%, then we terminate.
7. If the pixel is not already background (1), then convert to the foreground (0).

End Procedure.

Remaining Noise Area Detection
Apply Iterative Global Thresholding (IGT) to each identified area individually. This technique is both straightforward and efficient. It determines a global threshold for a palm leaf manuscript image iteratively. The following steps are performed in each iteration:

Algorithm 2 The Calculated Average Pixel Value
Procedure:
Input: Converted Palm Leaf Image
Output: The final image is binarized.

1. Subtraction of Ti from each pixel. (i.e., npimage ← (1 − threshold) + npimage).
2. The gray scale histogram is stretched to distribute the remaining pixels across all grey scale tones.

min_pixel_value ← np.min(npimage)
npimage ← 1 – ((1 − npimage) / (1 − min_pixel_value))

3. Repeat steps 1–3 until the termination condition satisfied.
4. The ultimate image is binarized image with the value of MSE and PSNR for performance evaluation.

End Procedure.

2.2 Mathematical Analysis

(i) The Eq. (2) calculates the Ti threshold values with the *i*th repetition of a MXN image.

$$\mathrm{Ti} = \frac{\sum\sum \mathrm{I}_i\,(x, y)}{\mathrm{MxN}} \tag{2}$$

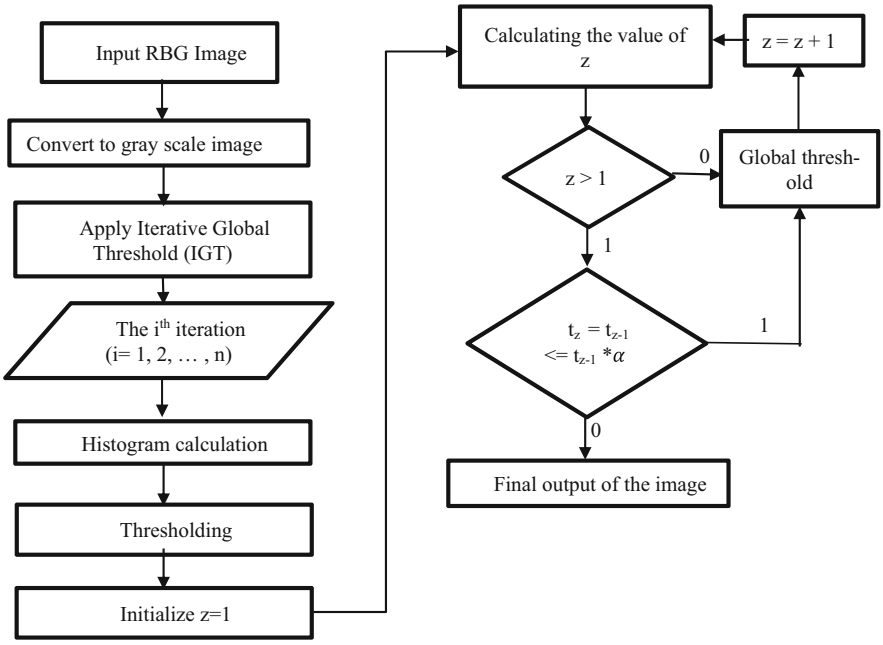

Fig. 2 The flow diagram of the proposed technique

(ii) Every pixel in the image has its average pixel value calculated by Eq. (3) and subtracted.

$$I_s(x, y) = I_i(x, y) - \mathrm{Ti} + 1 \tag{3}$$

(iii) The histogram is then extended to divide the remaining pixels into all grey scale tones.

It is possible to compute the Iterative global threshold value iteratively. The proposed technique includes several steps, which are represented in the flow diagram in Fig. 2.

3 Experimental Results and Discussion

The historical Kannada handwritten palm leaf manuscripts are collected from e-Sahithya Documentation Forum, Bangalore. The implementation is done on a windows system containing AMD processor 8GB RAM, 2.50 GHz speed, on the system using Anaconda3 Distribution, Jupyter Notebook, Python 2.9. Camera captures mediaeval Kannada handwritten palm leaf manuscripts as shown in Fig. 3.

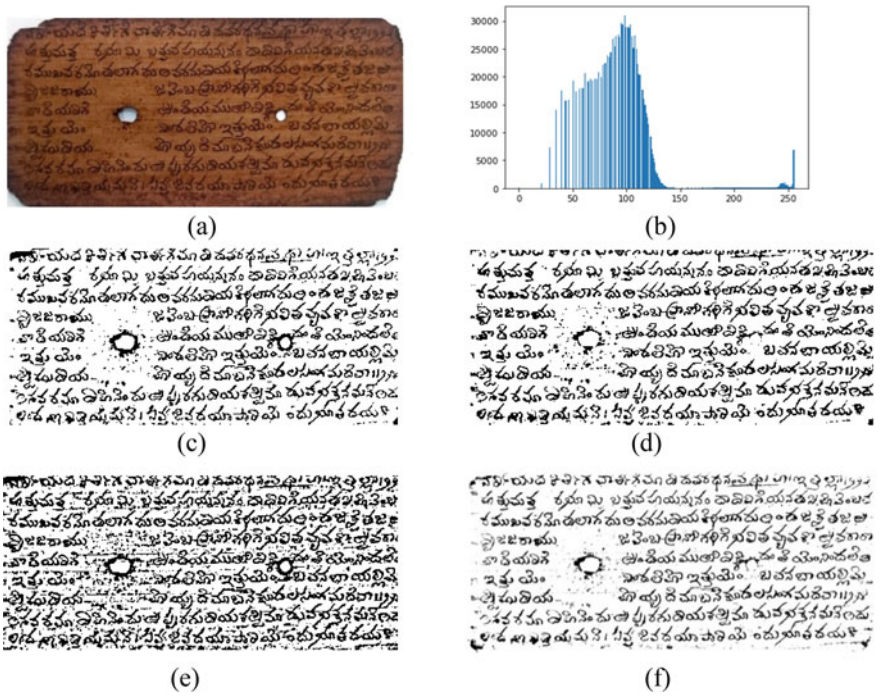

Fig. 3 (**a**) Sample images of historical Kannada handwritten palm leaf. (**b**) Histogram of original image. (**c**) Savoula threshold applied gray images. (**d**) Niblack threshold applied gray images. (**e**) Adaptive threshold applied gray images, (**f**) IGT Threshold applied gray images

Figure 3a shows a typical noisy document with non-uniformly distributed noise. The image's background is golden brown in color. Computed histogram of the original noisy document is shown in Fig. 3b. The anticipated result was then compared to the Souvola, Niblack, and Adaptive threshold which are shown in Fig. 3c–e. All the methods produce some noise in the manuscript while maintaining image clarity. After repeatedly applying the IGT algorithm to the grayscale image till the requirement is satisfied. Each steps removes some of the noise from the manuscript. Once it is completed all the repetitive steps, the intensity values of the histogram are stretched back to the background, and the resulting IGT manuscript are shown in Fig. 3h.

The proposed algorithm was also tested and implemented on standard palm leaf datasets, such as the AMADI LONTARSET dataset. The AMADI LONTARSET dataset results are shown in Fig. 4. A typical noisy document AMADI LONTARSET dataset image is shown in Fig. 4a, and Ground truth image of AMADI LONTARSET dataset image is shown in Fig. 4b. Then, we compared the results of

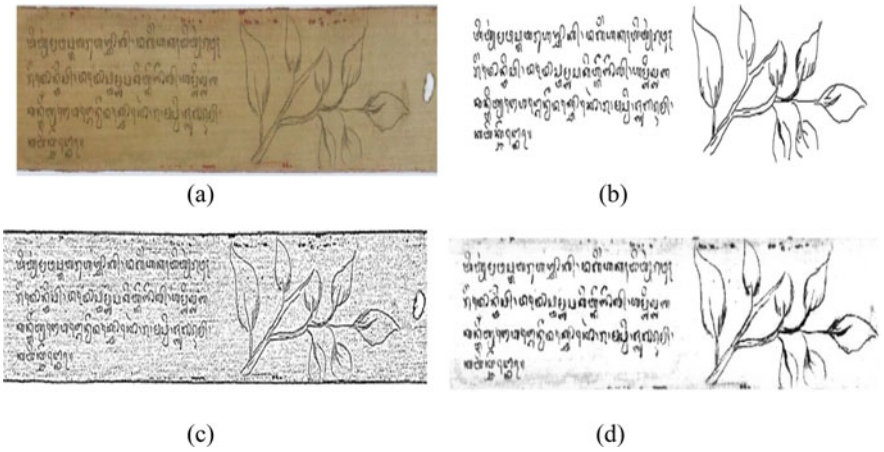

Fig. 4 (**a**) Sample palm leaf handwritten images of LONTARSET dataset. (**b**) Original palm leaf handwritten Ground Truth Image. (**c**) Adaptive method of MSE: 0.19 and PSNR: 7.18 value. (**d**) Proposed method of MSE: 0.24 and PSNR: 7.18 value

our method with the Adaptive threshold, which are given in Fig. 4c, the resultant proposed image is presented in Fig. 4d.

MSE and PSNR geometric feature values are extracted for statistical performance evaluation and calculated using Eqs. (4) and (5), respectively.

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}} \sum \sum (g\,(x, y)) - (f\,(x, y))^2 \tag{4}$$

Where $g(x, y)$ represents the output image and $f(x, y)$ represents the input image

$$\mathrm{PSNR} = 10\ \log\ \left(\frac{\mathrm{MAXi} * \mathrm{MAXi}}{\mathrm{MSE}}\right) \mathrm{dB} \tag{5}$$

The maximum image intensity is 255 when the pixel is represented in 8 bits. The MSE and PSNR are calculated for each of the 50 images, and the sample MSE and PSNR values are shown in the Table 1. The performance of the proposed method is visualized by epigraphists and language experts. PSNR and MSE average values are 6.198 and 0.234, respectively. According to the literature, the image quality is determined by the PSNR and MSE.

Table 1 The proposed results are compared with other standard methods

Segmentation methods	Degraded Kannada handwritten palm leaf image performance evaluation						
	Evaluation methods	Image 1	Image 2	Image 3	Image 4	Image 5	Avg
Niblack method	PSNR	4.46	4.16	4.7	4.84	4.16	4.464
	MSE	0.33	0.19	0.32	0.29	0.38	0.302
Souvola method	PSNR	4.71	4.57	5.58	6.52	4.55	5.186
	MSE	0.33	0.34	0.27	0.22	0.34	0.300
Adaptive threshold	PSNR	5.4	5.25	6.36	7.1	5.24	5.870
	MSE	0.28	0.35	0.29	0.38	0.23	0.306
Proposed method	*PSNR*	*5.65*	*5.62*	*6.61*	*7.49*	*5.62*	*6.198*
	MSE	*0.27*	*0.27*	*0.21*	*0.17*	*0.27*	*0.234*

4 Conclusion

The digitization and restoration of Kannada handwritten palm leaf manuscripts have a significant role to understand the ancient history and cultural customs, and this also helps in understanding and identifying the age of palm leaf. In this study, the Iterative Global Thresholding is applied for degraded Kannada handwritten palm leaf image and MSE and PSNR were used to evaluate the performance of the proposed techniques. The average values of PSNR and MSE is 6.198 and 0.234, respectively. In the literature, the higher the PSNR and lower the MSE determines the quality of the image. The promising results are achieved as compared to the other standard methods, namely, Souvola, Niblack, and Adaptive threshold (Gaussion+ Binary_Inverse) in the literature. Iterative global threshold removed non-uniformly illuminated background noise and better accuracy is obtained in the proposed attempt. The proposed algorithm was also tested and implemented on other standard palm leaf benchmark datasets, such as the AMADI LONTARSET dataset, obtaining positive results. In the future, the classification and recognition of Kannada handwritten manuscripts written on palm leaf will be considered.

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