



A novel method of absolute noise removal from the degraded palm leaf manuscripts

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Document image denoising and binarisation is an essential pre-processing step while digitising and segmenting the characters from the degraded Palm Leaf Manuscripts (PLM). The accuracy of segmenting the characters lies in the clarity of the binarised images. As the quality of these manuscripts has deteriorated due to old age and fungal or bacterial attacks, the content carved onto them is affected and is less visible. This paper aims to explain a novel method to denoise and binarise the degraded PLM, thereby increasing visibility so that the characters can be segmented easily for further implementations. The paper also discusses a hybrid thresholding technique that blends existing global and adaptive binarisation methods. Circular contour analysis detects and removes the punch hole mark from these manuscripts by replacing it with a mask of the same size as white pixels for absolute denoising. The proposed method generated excellent results of Peak Signal to Noise Ratio and Structure Similarity Index Matrix of 15.64 dB and 88% respectively. The paper also gives a comparative study of the novel method with the currently available algorithms.

Keywords: Binarisation, Circular contour analysis, Denoising, Digitising, Palm leaf manuscripts, Thresholding

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Palm Leaf Manuscripts (PLM) are the treasure of Indian history as they reveal many untold life stories in India in the past. Before the paper existed, PLMs made from dried palm leaves were the only medium for documenting important information like house deeds, treatment plans for a particular disease-herbal medicine, and great Indian literature like Ramayana, Mahabharata, and many poetries in different languages. One or two punch holes are made in these leaves to tie them together with a thread. The quality of the PLMs has deteriorated because of fungal or bacterial attacks, climate change and the lack of proper maintenance. Figure 1a shows the sample image of the original PLM.

The PLMs are now found in different libraries or in individuals' personal collections which are preserved in different ways. Nishanthi *et al.*¹ discussed traditional and modern methods of preserving the physical copies of PLMs and xeroxing. The digitising methods they discussed in their paper are not long-lasting, and the authors have considered leaves of certain types. Storing the scanned copy or camera images of the palm leaf will be very costly regarding

memory size, as every leaf will be stored as an image. Cabrel *et al.*² discussed the importance of having metadata for PLMs for easy access to the materials. They suggested a metadata schema for Functional Requirement for Bibliographic Records (FRBR), a conceptual model developed by the International Federation of Library Associations and Institutions (IFLA) used in Thailand. The PLMS are prone to being destroyed quickly, and most of the characters engraved on the PLMS fade if left unattended. Hence, the goal must be storing the contents of the PLMS before they get lost due to damage and old age³. During the study of PLMs, it was understood that every PLM is different in size, shape and design and having varying number of punch hole in varying locations. Much work has been conducted on removing noise from the PLMs, but the results have not been completely achieved; the studies are as follows.

Paulus *et al.*⁴ conducted a study on Sudanese PLMs, it was understood that PLMs contain non-uniform lights, smears, and random noise. Hence, they binarised the PLMs using different methods like Otsu, Niblack, Sauvola, and Bernsen and applied special filtering to remove the noise. The clarity of the

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resultant images was very poor. From the research conducted on three different PLMs namely, Balinese, Khmer, and Sudanese, Kesiman *et al.*⁵ presented a research paper that discussed the multiple methods used in different types of PLMs. The ground truth image was developed using the standard International Conference on Frontier in Handwriting Recognition (ICFHR). After a fair comparison with ground truth and resultant images, the performance was average, and none of the methods could give more than 50% of results, and the clarity of the text is compromised when trying to remove the punch hole mark from the PLMs. Wang *et al.*⁶ explained the pre-processing and segmentation done on damaged Sanskrit PLMs in their paper; PLM-Seg Former was used for segmenting the damages in the PLMs automatically. Even though the method could segment 12064 pages of PLMs in 12 h, the model couldn't perform well in different situations, like if the boundaries of the image are not digitising the same by microfilming and manually labelling or when stain marks or cracks are found in the textual regions. Discussing about the different kinds of noises, Sulaiman *et al.*⁷ have explained the issues that can occur while digitising degraded manuscripts, for example, ink bleed, faded characters, folding marks, etc. They proposed a model that combines Otsu binarisation and Sauvola binarisation techniques; the method could not completely remove the noise. Applying the Image Gradient Approximations (IGA), Sudarsan and Sankar⁸ presented a work that removes the various types of noise, and enhances the clarity of the text, facilitating better readability and

preservation of historical documents, but may not generalise well to extreme variation and noise patterns. They also introduced a complete denoising solution⁹ that effectively removes different types of noise from Malayalam PLMs, without affecting the text imprinted on them. The method achieves good results. Singh *et al.*¹⁰ introduced a hybrid denoising technique by integrating Gaussian filtering and smoothing. Following the conversion of the colour space from BGR (Blue, Green, Red) to HSY (Hue, Saturation, Luminance), the hybrid method harnesses the strengths of both filters to enhance entropy and PSNR. In a related study, Alexander *et al.*¹¹ developed an edge-preserving filter for denoising degraded palm leaf manuscript images. Their approach demonstrated improved PSNR and MSE compared to conventional filters. Adaptive binarisation and a deep semantic model¹² using CNN and modified U-Net were used to produce excellent-quality binarised images of PLMs, but it needed a high-quality computational setup; the model created could not erase the intricate noise.

The paper aims to suggest a straightforward and novel method to denoise and binarise PLMs using a hybrid binarisation technique by combining the triangle and Sauvola binarisation techniques. Removed the punch hole mark using Circular Contour Analysis (CCA) by detecting the biggest circular shape in the PLMs. It also showcases the results obtained from various binarisation techniques, including the proposed model and compares the results. The evaluation metrics used in this paper are Peak Signal to Noise Ratio (PSNR), F-Measure (F1-Score), Structure Similarity Index Matrix (SSIM), Accuracy and Visual Quality

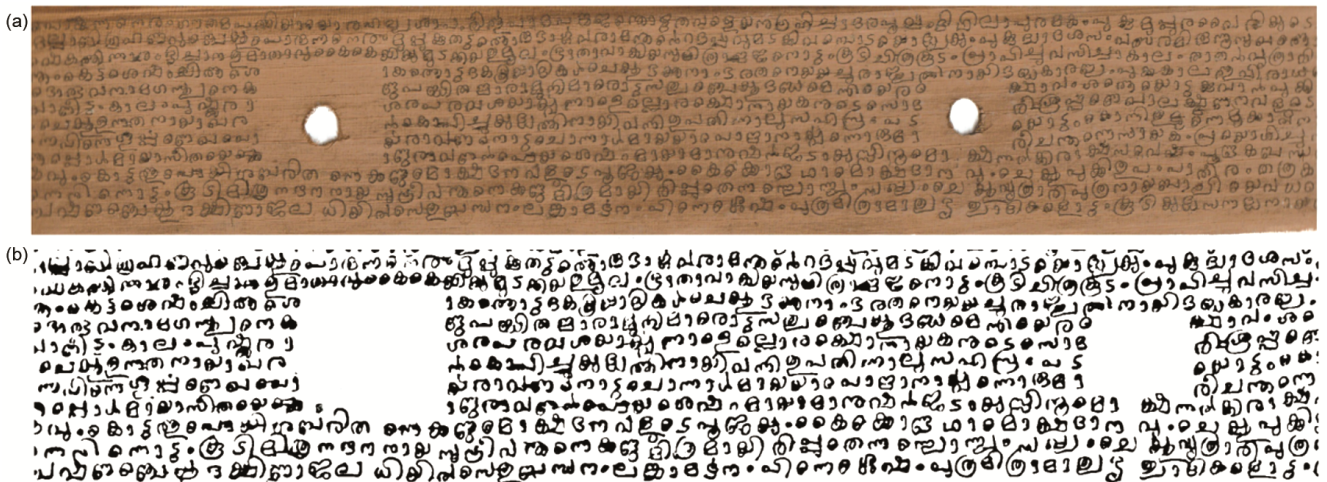


Fig. 1 — (a) Sample of original PLM, (b) Corresponding ground truth image developed for evaluation

Estimation (VQE). The binarisation algorithms used in this paper for comparisons are the elementary binarisation methods, Otsu's thresholding, Triangle binarisation method, Sauvola binarisation, and Niblack thresholding on denoised PLMs.

Materials and Methods

Image pre-processing is the primary step in processing the images. The section below discusses various methods applied to PLMs that have led to the development of the proposed method.

Denoising and histogram equalisation

For removing the noises present in the images of PLMs, the NL-Means Filtering algorithm is used. Since the character on the PLMs is engraved onto the PLMs, there is only a little difference between the foreground and the background pixels. So, any treatment to the images may erase some of the characters. To overcome this issue the images went through histogram equalization using Contrast Limited Adaptive Histogram Equalisation (CLAHE). Both processes are explained in detail in the following sections.

Non-local means filtering algorithm (NL-Means Filtering)

NL-Means Filtering works on a simple principle, where a set of pixel values, called a window, is replaced by a mean of similar pixel values, which need not be close to each other. The NL-Means filtering algorithm scans through the entire image to search for similar patches of pixels that must be denoised and calculates their average. The similarity of the grey-level patches is computed using the Euclidean distance by the standard deviation, which is computed using the Gaussian kernel, as the noise in the PLMs is Gaussian.

Contrast limited adaptive histogram equalisation (CLAHE)

As explained earlier in Section 1, the PLMs are degraded and damaged and must be pre-processed before segmentation without losing any required pixels. Since the pixel intensities between the foreground and background are low, there is a high chance of losing some of the required pixels from PLMs resulting in missing the completeness of the character. To resolve this issue, we can improve the contrast of the images by applying CLAHE^{13,14}.

The Adaptive Histogram Equalisation (AHE) is used to improve the contrast in the images and thereby improve the visibility of the image. However,

AHE also has the drawback of enhancing the noise. CLAHE is applied to overcome this issue. CLAHE limits over-amplifying the pixel values in areas with homogenous pixel values.

In our work, CLAHE is more suitable as the images can contain a lot of noise and increase the contrast of the background and foreground pixels, improving the extraction of characters from PLMs.

Image binarisation

The binarisation techniques can be divided into global and local or variable thresholding. A single thresholding value is taken in global thresholding, and the image is binarised using the threshold value. The global thresholding is unsuitable for images with different lighting conditions or high noise levels. The global thresholding used in this paper is an Elementary¹⁵, Otsu's¹⁶ and Triangle¹⁷ thresholding technique.

Local thresholding overcomes the drawback of global thresholding as it divides the image into different parts called as windows, and the threshold value is calculated based on the size of the windows. This method is suitable for images with different illumination at different parts of the images. In this paper, the local binarisation methods used are the Niblack method¹⁸, Adaptive thresholding¹⁹, and the Sauvola binarisation²⁰ methods. Adaptive thresholding followed by manual denoising is used to develop the ground truth image.

The binarisation algorithms applied in the work are described in the section below.

Elementary binarisation method

The elementary binarisation method is a global thresholding technique that applies a single thresholding value to the entire image. All the pixel values are converted to 0 or 1 based on the selected threshold value. This threshold value is given by checking the histogram of the image.

Triangle thresholding

The triangle thresholding will work well with unimodal histograms, which means the histogram with a single peak or with histograms that have a single, distinct peak, where the histogram falls from both sides of the peak. When we were studying the histogram images generated from the PLMs, most of them had single peaks, which led to the decision to select this method as a part of the proposed thresholding method, the hybrid thresholding technique.

Sauvola binarisation

The Sauvola method can overcome the problem of creating background noise in the blank spaces in the image when no text is present. It calculates the threshold value of each pixel in the image using local standard deviation and local mean, and an adjusting factor, k , which means the appropriate threshold value for high and low contrast with the mentioned window size. In a high contrast region, the threshold value will be almost equal to the mean of the pixel intensity in the window. In a low contrast region, the threshold value will be less than the mean value, resulting in the accurate removal of the dark regions. The value of k is susceptible while computing the threshold value. When the background and foreground of the grey image have the nearest values, the quality of the output image can be reduced.

Experimental setup

The digital copies of the PLMs are collected from the dataset developed and published by Nair *et al.*²¹ in their article published. The dataset contains two types of PLMs, Kamba Ramayana and *Jataka's* (Horoscopes). The bundle of Kamba Ramayana contains 151 *olas* (leaves). *Jatakas* have samples of 91 palm leaf *olas*. Both the PLMs were collected from Kerala, India. The dataset contains the original and binarised digital copies of Malayalam PLMs. We have done the work in this paper by using the original copies of PLMs from the dataset. The original copies of the PLMs contain degraded images due to poor maintenance and fungal and bacterial growth. The coding part of the work is completed using Python 3.10. in Google Collaboratory.

Creating the ground truth images

The ground truth images²² are developed based on a method where no human intervention is required to compare results. The Adaptive thresholding²³ method is utilised to create the ground truth image. The denoised image is binarised, and then a clear image that can be used to compare the processed image is generated by manual correction. The ground truth image created for one of the PLMs is depicted in Figure 1b.

The novel method

During the evaluation of the histogram images of PLMs, it was observed that a single binarisation algorithm could not be uniformly applied to all PLMs. This inconsistency is due to subtle variations in pixel value distributions caused by different levels of

degradation in the images. For instance, the triangle thresholding algorithm performed poorly when applied to the image. These limitations highlighted the need for a more robust approach, leading to the development of the proposed method.

The proposed method can be divided into three significant steps, as depicted in the Supplementary Figure S1. The implementation of the proposed method is explained in the subsequent sections.

Denoising and CLAHE

This section describes the denoising and the contrast-enhancing method applied to the degraded PLMs. In the first step, the input images were converted to RGB format. Then, the RGB images were converted to grey-scale images, and the histogram was taken to understand the pixel distribution. The following algorithms were applied to the grey-scale images: Fast NL-Means algorithm for denoising the image, and CLAHE for enhancing the contrast between the objects (characters).

NL- Means Filtering takes more time in computing²⁴ as it sweeps through the image pixel by pixel. To find the most similar patch, the fast NL-Means algorithm²⁵ divides the image into many parts of fixed size, called S , to compute the weights around a pixel. The scale $S=2^n$, where, $n = \{6,5,1\}$. The gradient orientation, which is the direction of greatest intensity change of the neighbourhood pixel is taken as the criterion for the similarity index. It is theoretically and experimentally proven that a better approach to fast NL-Means algorithms reduces the computational costs and speeds for noisy images. Assigning a large value to the template patch and window size can result in getting clear images, but it can also slow down the process.

As mentioned earlier, every palm leaf is different as it is damaged by germinal attacks. The fungal or bacterial growth on the surface of the PLMs is considered noise in the digital copies. The histogram equalisation is applied to enhance the sharpness of the text inscribed, compared to the background, in the denoised images, making the pixel intensity distribution suitable for the binarisation methods. CLAHE limits over-amplifying the pixel intensities by capping the histogram over a predefined value called the clip limit. The clip limit depends on the histogram equalisation and window size. Giving a high value to the window size can result in over-smoothing the images. The clipped histogram is not discarded but added to the next bin and redistributed equally.

Binarising the PLMs images using the hybrid thresholding technique

The proposed thresholding method combines the Triangle thresholding and the Sauvola thresholding method. The denoised-CLAHE image is binarised using the hybrid binarisation technique.

The triangle method of binarisation can be applied to specific images, such as unimodal images. Otherwise, this method computes the wrong threshold, which can produce a poor outcome. The second method used for binarising the image is the Sauvola thresholding method. The proposed hybrid binarisation method is a mixture of the Triangle thresholding and the Sauvola thresholding. The steps we have followed in the method are depicted in the diagram in detail, (Fig. 2).

This can be mathematically represented as follows,

$$T_{Hybrid} = \alpha.T_{Triangle} + (1 - \alpha).T_{Sauvola} \quad \dots (1)$$

Where, T_{Hybrid} is the hybrid threshold value calculated from both the methods, Sauvola and Triangle, $T_{Triangle}$ is the resultant threshold value obtained from the triangle thresholding method, $T_{Sauvola}$ is the threshold value calculated and α is the factor to determine which algorithm the weightage has to be given. The value of α lies between 0 and 1. For example, if $\alpha = 0.4$, $(1 - \alpha) = 0.6$.

The hybrid thresholding technique, used for binarising, gave the best results compared to other thresholding techniques when applied individually. Sauvola is a local thresholding method that computes the threshold value on a fixed local window around a pixel value; due to this, a few pixel intensities were

there with some intermediate values between 0 and 255. To handle these values, post-processing of images is implemented by using an elementary binarisation method is applied with a threshold value of 110.

Punch hole mark removal

The punch hole mark in every PLM is also considered noise. However, the punch hole size compared to other noises on the PLMs is different. The pixel intensity of the punch hole will be similar to the intensity of the imprinted characters. So, removing the punch hole from the PLMs is challenging. In this paper, we developed a straightforward approach by using contour analysis. The process flow of the punch hole removal is depicted in Figure 3. Contour analysis is used to detect the connected points in the image. In this work, the Connected Component Algorithm (CCA) is applied to detect the circular shapes in the image. However, it is more complicated as the alphabet of Indian languages can form a lot of circles in various sizes, depending on the style of writing. As the dimension of the punch hole is larger than the circular patterns that can be created while writing the alphabet, the biggest circle is found by applying CCA - giving the threshold value depending on the size of the punch hole. The threshold value shown here is 0.4. After that, a bounding rectangle is drawn around the detected circular contour and replaced with high-intensity pixel values, resulting in the complete removal of the punch hole. The above-described CCA can be done if the punch hole mark in the image is continuous. But most of the time, after denoising and binarising, most of the pixels in the punch hole mark

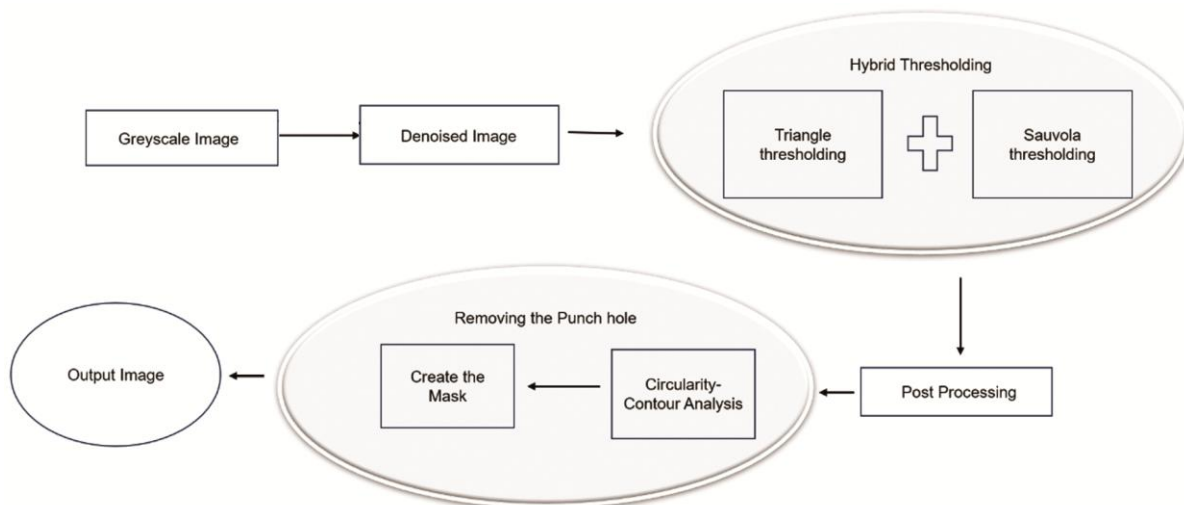


Fig. 2 — The Process Flow of the Novel Method

will be erased, which leads to failure to get the continuous points, and the detection of the same will not happen. To overcome this problem, the centre point of the punch hole in the image is identified by taking the coordinates and drawing a circle

Results

This section describes the results of the novel method in various stages of denoising, binarising and punch hole mark removal.

The PLMs used in this study were of different dimensions; since the idea is to create a generalised method for absolute denoising, as the first step, the PLMs were cropped to get the exact dimensions without losing the contents on the PLMs. Then, the images were converted to a grey scale, followed by a fast NL-Means filtering algorithm. As the PLMs were already degraded, applying denoising produced images with missing pixel values, affecting the clarity of the text written. CLAHE was applied to overcome this issue. The clip limit is 3 pixels, and the window size is 6. The resultant images are shown in Figure 4.

Then, the images were binarised using the Hybrid thresholding technique by applying Equation (1). Hybrid thresholding takes the threshold value computed from both methods and computes the threshold value based on it α . The exciting factor α is that the algorithm can decide which method is essential based on the noise levels and histogram of

PLMs. The various output images when hybrid thresholding is applied are depicted in (Fig. 5). The third stage of the proposed method is removing punch hole mark(s). The removal of punch hole marks from the PLMs is a tricky process because of the size and the pixel intensity value. The pixel intensity is almost the same as the pixel intensity of the characters in the images. Hence, removing the punch hole can blur the characters in the images, which is unacceptable. Hence, we developed a different approach by detecting the most enormous hole using CCA by computing the perimeter and area of the circular region. The issue that can be faced with this approach is that CCA will work only if the pixel values are continuous; sometimes, the punch hole mark will not be continuous to form a circle, which results in de-identifying the punch hole mark. To overcome this problem, the position of the punch hole mark is computed, a circle is drawn around the punch hole, and then CCA is applied, which helps correctly detect the punch hole mark in PLMs. After detecting the punch hole mark, a bounding box is drawn around the detected punch hole, and a mask of a high-intensity pixel of the same size as the bounding box is replaced with the mask created. The bounding box is created as the punch holes vary in shape and size. Replacing the same with a high-intensity pixel value may not give the desired output. The various stages of punch hole

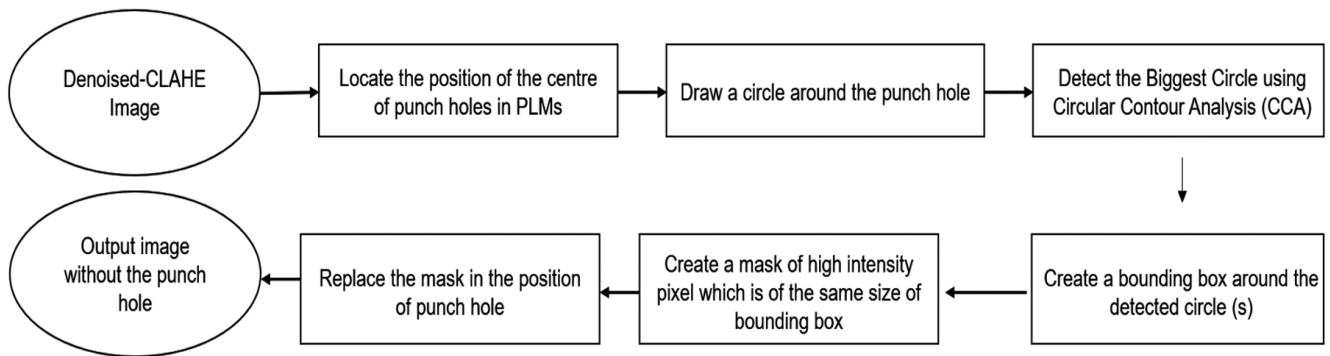


Fig. 3 — The Process Flow of Punch Hole Mark Removal from PLM

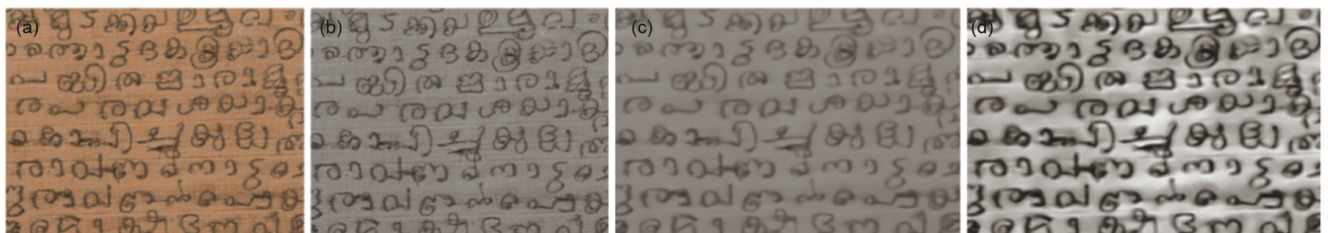


Fig. 4 — Results of denoising and CLAHE-(a) Original image, (b) Grey scale image, (c) Denoised image, (d) CLAHE image

removal are depicted in Figure 6. The hyperparameters used in various algorithms in this work are explained in Table 1. The resultant images obtained from various binarising algorithms are in Figure 7.

Evaluation metrics

The evaluation metrics²⁶ used are Mean Square Error (MSE), PSNR, SSIM²⁷, and calculating the F1-Score and VQE²⁸. These evaluation parameters are tested against the output image of every individual binarisation algorithm and the proposed model with

the ground truth image, developed as explained in section 4.1.

Mean squared error (MSE)

MSE is the cumulative squared error between the output image of the binarised algorithm and the ground truth image. The error rate depends on the value of MSE; the lesser the value of MSE, the lower the error.

Peak signal-to-noise ratio (PSNR)

PSNR is a measure used in images to assess the level of distortion or degradation in the images. It

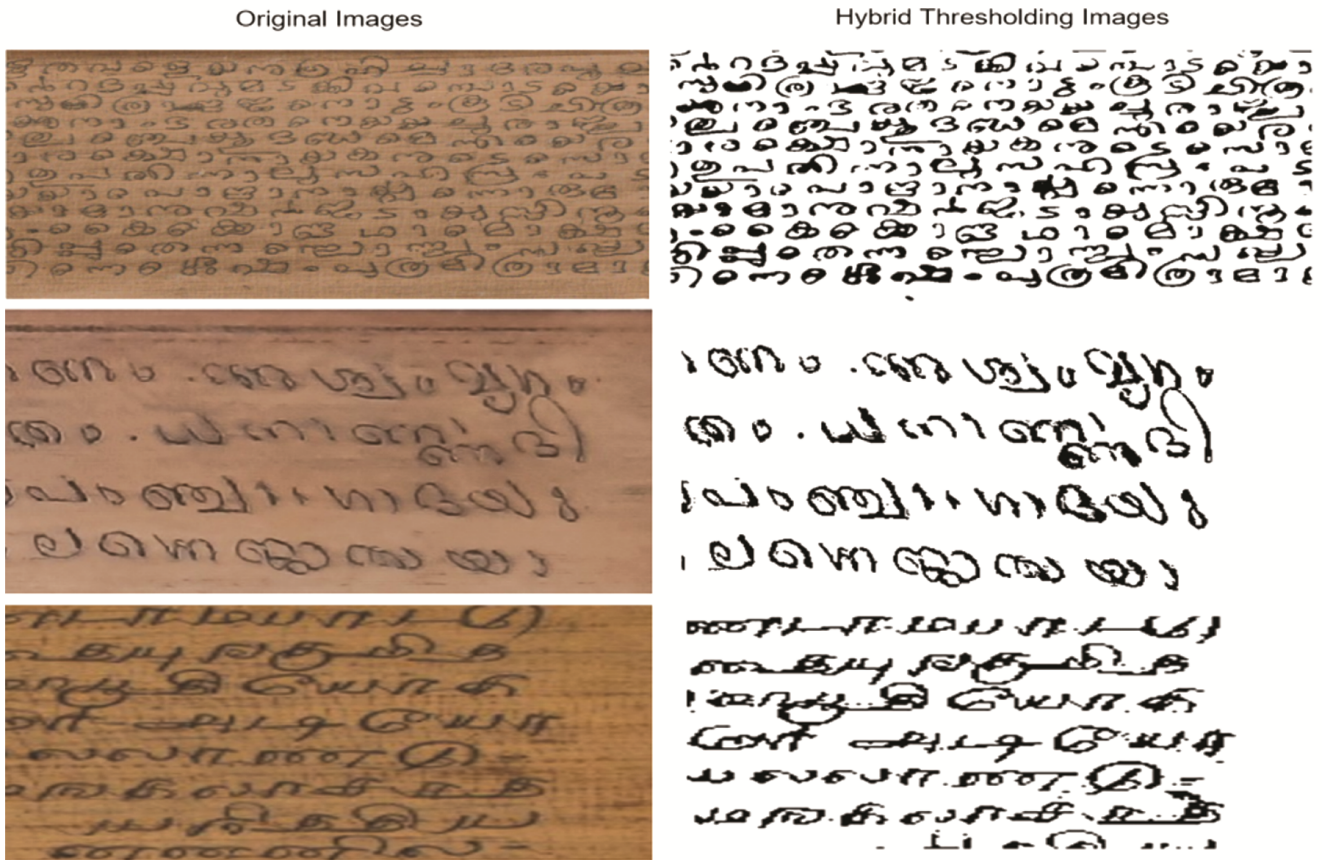


Fig. 5 — Results of hybrid binarisation thresholding on various images

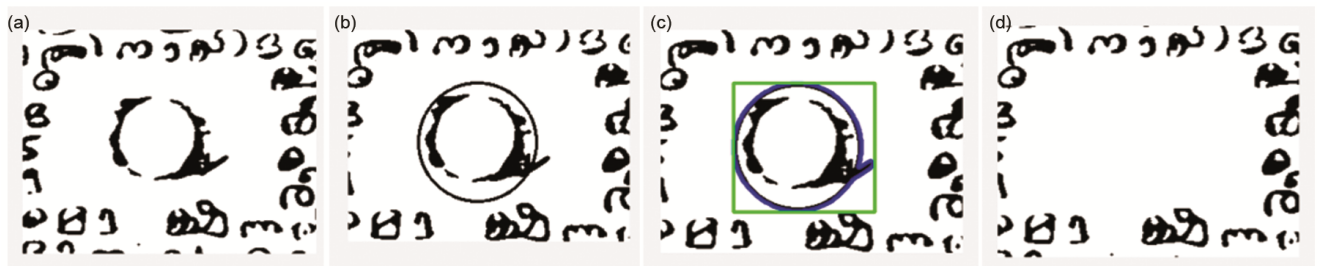


Fig. 6 — Different stages of punch hole removal-(a) punch hole mark incomplete, (b) a circle is drawn around the punch hole, (c) detecting the CCA and drawing bounding box (in Blue), (d) replacing the bounding box (in Green) with white pixel values

compares the processed image with the original one. It measures decibels (dB) and is a logarithmic scale used to compare two ratios. It converts multiplicative relationships to additive ones, which will help to compare the ratios. A small change in the PSNR value can lead to a significant change in the quality of the image Supplementary Fig. S2).

Structural similarity index matrix (SSIM)

Unlike MSE and PSNR, which assess the pixel-to-pixel differences between ground truth images and processed images, SSIM is a perceptual evaluation metric used to measure the resemblance between the two given images. It examines the structural information, contrast and luminous.

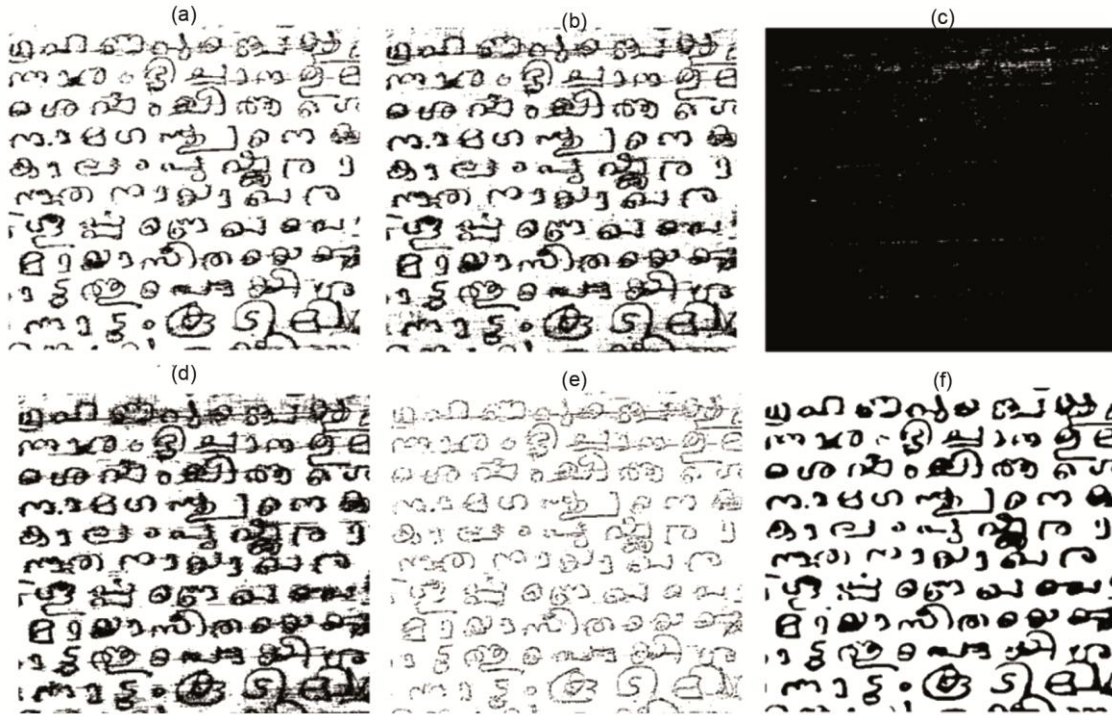


Fig. 7 — The resultant images of various binarising algorithms- (a) Elementary binarisation, (b) Otsu, (c) Triangle, (d) Niblack, (e) Sauvola, (f) Hybrid thresholding

Table 1 — The hyperparameters used in this work on different methodologies

Algorithms	Parameter values (in pixels)	Description
Fast NL-Means	$h=5, t=9, s=15$	Where h is the filtering value, t is the template window size, and s is the search window size, which specifies the window size.
CLAHE	$cl=3.0, tgs=6$	cl is the clip limit, and tgs is the tile grid size. The clip limit limits the contrast by limiting the over-enhancement of the objects. The tgs is the window size, based on the image being divided equally.
Elementary binarisation method	$thr=110$	Where thr is the threshold value.
Otsu	-	Otsu computes the threshold value automatically based on the input image. If the pixel intensity exceeds the threshold value, it is set to 1; otherwise, it is set to 0.
Triangle	-	The triangle thresholding method computes the threshold value automatically. It is a histogram-based binarisation method.
Niblack	$Kernel=301, k=-0.3$	Where $kernel$ is the local size window, within the mean and standard deviation is calculated. The binarised images can produce keystrokes with varying thicknesses depending on the variation in the value of k .
Sauvola	$w=5, k=0.2, R=50$	w is the window size around each pixel, k is a constant value, which can be adjusted, where the value of k and threshold value are inversely proportional to each other, and R is the maximum standard deviation.
Hybrid Thresholding	$\alpha=0.8, w=25, k=0.5, R=128$	Where α is a factor between 0 and 1, based on that, it is decided which algorithm to be given more weightage, w is the window size, k is the adjusting factor, and R is the maximum standard deviation.

Confusion matrix

The confusion Matrix is used to evaluate the performance of a model. Here, by using the confusion matrix, we judge the performance of the results of different binarisation methods comparing it to the ground truth Image. The components of the confusion matrix are true positives (*tp*), true negatives (*tn*), false positives (*fp*), and false negatives (*fn*). Here, the true positives can be the total number of noise pixels that are recognised as noises, and the false positives can be the total number of pixels that are wrongly recognised as noises. The performance metrics that can be derived from the components of the confusion matrix are Accuracy, Precision, Recall and F1-Score.

Discussion

The proficiency of the novel method is evaluated against five other algorithms which includes the elementary binarisation method, Otsu thresholding, triangle method, Niblack and Sauvola. The resultant

images are depicted in Figure 7. The final image obtained after the punch hole removal is shown in Figure 8.

The result comparisons based on some of the parameters used in DIBCO 2009²⁹ are described in Table 2.

The comparison result obtained by comparing the developed novel method with the state-of-the-art techniques, such as Image gradient approximation for PLM denoising, a complete denoising solution for PLM, Gaussian filter and Smoothing technique and Wavelet Anisotropic Bilateral Filter based method, is also presented in Table 2. Based on the results obtained, it is possible to comprehend that the proposed method gives much better results than other methods.

The high values of PSNR show that there is not much difference in the ground truth image and the processed image using the new novel method of binarising. The PSNR values obtained for the Ramayana and Jataka PLMs are 15.08 and 15.64,

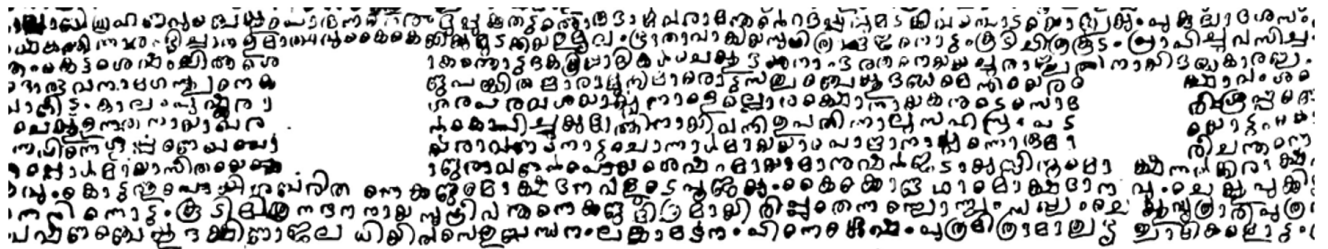


Fig. 8 — Final binarised image - after removing the punch hole mark

Table 2 — Comparison of PSNR, F1-Score, Accuracy and SSIM obtained from different Binarisation Algorithms and state-of-the-art methods when applied to PLMs.

Binarisation algorithms	Images	PSNR (dB)	MSE	SSIM	Accuracy	F1-Score	VQE
Elementary binarisation	Ramayana	9.98	6.41	0.70	0.89	0.93	Fair
	Jataka	12.27	5.52	0.80	0.93	0.96	Good
Otsu	Ramayana	10.31	6.47	0.66	0.90	0.93	Poor
	Jataka	7.47	6.17	0.67	0.81	0.88	Poor
Triangle	Ramayana	1.24	8.10	0.09	0.24	0.03	Bad
	Jataka	12.51	5.49	0.80	0.94	0.96	Good
Niblack	Ramayana	9.83	6.47	0.64	0.89	0.92	Fair
	Jataka	11.02	5.67	0.77	0.91	0.95	Fair
Sauvola	Ramayana	7.66	7.21	0.65	0.82	0.89	Poor
	Jataka	11.50	5.66	0.78	0.92	0.95	Fair
Image gradient approximation (IGA)	Ramayana	8.78	5.40	0.60	0.80	0.89	Fair
	Jataka	10.17	6.52	0.50	0.81	0.90	Fair
Complete denoising solution (CDS)	Ramayana	15.01	2.47	0.84	0.95	0.96	Excellent
	Jataka	15.47	5.17	0.84	0.95	0.98	Excellent
Gaussian filter and smoothening (GFS)	Ramayana	10.83	6.47	0.64	0.89	0.92	Fair
	Jataka	12.02	5.67	0.77	0.91	0.95	Fair
Wavelet anisotropic bilateral filter (WAB)	Ramayana	11.83	5.47	0.65	0.89	0.92	Fair
	Jataka	12.02	5.67	0.79	0.91	0.95	Fair
Proposed method	Ramayana	15.08	5.54	0.85	0.96	0.97	Excellent
	Jataka	15.64	5.10	0.88	0.97	0.98	Excellent

respectively, showing that the new method does an excellent job compared to other methods for binarising. The F1-Score obtained are 0.97 and 0.98, for the same PLMs compared to the ground-truth images. The measure of SSIM tells the structural similarity between the two images and also shows the quality degradation that happened due to the data transmission; the value obtained for the resultant image, when compared to the ground truth image is 0.85 and 0.88, which is excellent compared to the other results. The SSIM value 1 shows that both images have perfect similarity. Here, the SSIM results are very close to 1 showing an excellent similarity between the images. It also shows that the algorithm could deal with the problems caused by the data transmission. Apart from the objective method comparisons of results, the subjective method is also used to compare the results as explained in section 6.6, and the proposed method could generate impressive results using the DSCQS scaling method.

Conclusion

The palm leaf manuscripts are an invaluable source of cultural, religious, and artistic information about ancient India. It is foremost to preserve the PLMs and their content. Although many techniques are already available to preserve PLMs, they are prone to getting damaged very fast as every leaf in the PLMs is developed naturally from the palm tree. The content can be extracted from the images of PLMs using advanced technologies in image processing and machine learning. The method we proposed in this paper is a straightforward way to implement the first level of absolute denoising and binarising of the PLMs. The novel algorithm was able to produce a good PSNR and SSIM with a minimum error rate and perfect similarity between the images. Some of the earlier work shows the punch hole removal, but it affected the continuity of the character pixels, resulting in broken characters in the PLMs. In this paper, we have suggested a method to binarise and remove the punch hole mark as the first step of the segmentation and classification of objects (characters) from the PLMs. Based on the results, it is evident that the proposed method gives an excellent result compared to the other binarisation algorithms.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at

[https://nopr.niscpr.res.in/jinfo/ijtk/IJTK_24\(6\)\(2025\)595-605_SupplData.pdf](https://nopr.niscpr.res.in/jinfo/ijtk/IJTK_24(6)(2025)595-605_SupplData.pdf)

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Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

DU: Conceptualisation, Methodology, Formal analysis, Investigation, Writing –original draft and review. DS: Overall correction, Review editing and Writing. RV: Supervision and review.

Ethics Approval

Not applicable

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article and will be made available by the corresponding author upon reasonable request.

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