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ENHANCEMENT OF PALM-LEAF MANUSCRIPT AND COLOR DOCUMENT IMAGES WITH SYNTHETIC BACKGROUND GENERATION

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ABSTRACT

This paper presents a new color document image enhancement technique that is suitable for both palm-leaf manuscripts and color document images. The proposed technique consists of three steps: preprocessing using Wiener filter, contrast enhancement and background enhancement, binarization using new global thresholding technique and post processing for synthetic background generation.

In the preprocessing stage, we propose three sub-stages. The first sub stage is used to eliminate the noisy areas and smooth out the background. Second sub-stage enhances the contrast between background and text areas where as the third sub-stage takes care of non-uniform background. Binarization is performed by using new global thresholding technique. This technique helps in properly extracting useful text information from the low quality document and palm-leaf manuscript images. Finally, the post-processing stage resynthesizes the color background. The proposed technique has been tested on a set of palm-leaf manuscript and color document images having various deformities such as uneven background color, folds, character breaks and localized spots.

Key words : *Palm-leaf manuscripts, color document images, synthetic background generation.*

I. INTRODUCTION

For over two thousand years, scribes have recorded much of India's literary and scientific heritage on the readily available medium of dried, smoothed and smoke-treated leaves of Talipot palm trees. When left undisturbed in the tropical climate, these palm-leaf manuscripts could last three or four centuries, after which they must be copied to new freshly treated palm-leaves.

Unlike the white background for book pages, palm leaves have a dark brown non-uniform background. Owing to the brittleness of the medium, these documents are prone to tear and damage and the text is found with very heavy noise.

With the arrival of printing press the process of transcription became extinct. Some palm leaves are fast approaching the end of their natural lifetime and remaining are facing imminent destruction from insects, weather conditions etc. These manuscript leaves stand to be recovered or lost forever depending upon the action or inaction taken now.

The text on the palm-leaf manuscripts can be rewritten on modern day paper. But the paper documents are found to have some problems. Initially the paper document images have uniform background but with the aging process problems like ink sipping and background color fading occur. As a result, the readability of text in the document is affected very badly. This results in the need for storing old document images in some other reliable way.

Digital storage is one of the best ways to preserve the old color documents and palm-leaf manuscripts. This way of storage is free from the problems faced by paper documents or palm-leaf manuscripts. Further, the digital representation of these documents allows improving the quality by applying various enhancement techniques.

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For digital processing, these documents are first scanned with digital scanners. The resolution used for scanning these documents depends on the importance of the text contents and decides the quality of reconstructed image. For recognizing the text, optical character recognition (OCR) techniques are used in document image analysis systems. These techniques are developed to work on binary images having text against clean backgrounds. The performance of subsequent steps in document image analysis (page segmentation or text retrieval) heavily depends on the performance of binarization technique. To obtain properly separated text against clean background preprocessing techniques must be applied before the binarization step.

Over the last three decades many different approaches have been proposed for binarizing a grayscale document. Color documents can either be converted to grayscale before binarization, or techniques specialized for binarizing color documents can be used. In most cases, color documents are first converted to grayscale without losing much information, as far as distinction between text and background is concerned. Also, the gray image can be processed at fast rates than color images due to smaller size.

Global binarization methods like Otsu's technique [1] try to find a single threshold value for the whole document. Each pixel is assigned to image foreground or background based on its gray value. Otsu binarization technique is very fast and gives good results for good quality documents. However, if the illumination over the documents is not uniform e.g. in case of scanned book pages or camera captured documents; this technique tends to produce big character gaps.

To overcome this difficulty, a new flexible locally adaptive thresholding technique has been proposed by Sittisak Rodtook et al. [2]. This technique is found useful for document image binarization. The threshold value is adjusted in accordance with the changeable component by using the Laplacian sign image. This method removes the background noise present in the document images to a greater extent. However, if contrast between the text and background in the scanned image is less e.g. in case of old palm-leaf manuscript images, this technique produces large character gaps.

For this purpose, we propose modifications in the global threshold computation which retain the shape of characters without introducing further noise in the image. This technique is fast and achieves good result even on severely degraded document and palm-leaf manuscript images.

II. REVIEW OF RELATED WORK

Most existing binarization techniques are thresholding related**.** Several thresholding methods have been developed and proposed to separate foreground text from background for grayscale document images. However, binarization methods proposed for grayscale documents have not been well tested for color documents.

Global thresholding methods compute threshold value for the entire image. Most of the basic global methods are based on the brightness histogram of images, which are called histogram derived thresholds such as fixed point threshold, an alternative way in very high contrast images.

Otsu thresholding was proposed in 1979 [1] as a threshold selection technique based on image histogram. It divides foreground and background by maximizing the discriminant measure. The threshold operation is regarded as the partitioning of the pixels of an image into two classes such as objects and background. An optimal threshold point is determined by minimizing within-class, between-class and the total variances.

Kapur et al. [3] proposed a technique, where entropy is used to separate global thresholding classes. The optimal threshold value is calculated by maximizing the sum of the foreground and background entropies. The technique uses the maximum of the sum of the entropy in the gray level distribution of the foreground and background. The scheme has shown good performance for picture images.

Solhin and Leedham [4] elaborated two global techniques, Native Integral Ratio (NIR) and Quadratic Integral Ratio (QIR). These methods are based on shape of the histogram. QIR uses equations formed from the intensity histogram to find a threshold value for entire image.

These methods do not produce satisfactory results in processing of color document images since the contrast between the foreground and background is typically low and the color intensity of the background varies throughout the image.

In locally adaptive binarization methods, the threshold values are established pixel by pixel on the basis of information contained in neighborhood pixels. These methods calculate a threshold surface for the entire image. If a pixel (x, y) in the input image has a higher gray level than the threshold surface evaluated at (x, y), then the pixel (x, y) is labeled as background, else as foreground.

In Bernsen's [5] technique, 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. This technique is fast; however it does not work well with varying gray level intensities of the background.

Niblack's [6] technique is based on calculation of the local mean and local standard deviation of gray levels. This technique calculates a threshold by using mean and standard deviation values in a local neighborhood. The threshold is calculated as

$$T(x, y) = m(x, y) + k * s(x, y) \qquad (1)$$

Where, m(x, y) and s(x, y) are the mean and standard deviation values of a local area. The size of neighborhood should be small enough to preserve local details, but at the same time large enough to suppress noise. However, determining optimum mask size k is important factor. Because use of small mask sizes adds additional noises and use of large mask sizes results in losing information.

An improved version of Niblack's algorithm was proposed by Zhang and Tan [7]. Compared to Niblack algorithm this performs well at shadow boundary detection. The threshold is calculated using following equation

$$T(x, y) = m(x, y) * [1 + k * (1 - s(x, y)/R)] \qquad (2)$$

Where, k and R are empirical constants.

Eikvil et al. [8] have proposed an adaptive thresholding technique in which the pixels inside a small window S are thresholded on the basis of clustering of the pixels inside a large window L. In this technique a small window S moves across an image in a zigzag fashion over a large window L.

Yanowitz and Bruckestin [9] proposed a local gradient based thresholding algorithm. It determines threshold by interpolating the image gray levels at the points where the gradient is high, indicating probable object edges. The gradient map of the image is used to point at well defined portions of object boundaries.

All the above reported thresholding methods have been demonstrated to be effective for certain classes of document images. None, however, has proven effective for all examples of document images which are frequently found in historical documents and palm-leaf manuscripts.

A flexible technique of adaptive thresholding for document image binarization has been proposed by Sittisak Rodtook et al. [2]. The threshold value is adjusted by applying Laplacian sign image. The Differential of Gaussian (DOG) is used to define the sign image. The Laplacian sign image of the document image is formed by using the operator based on the second direction derivative. Threshold value is changed whenever the Laplacian sign of the input image changes along the scanned line. Normally, the regions, where the sign of pixel has changed indicate the edges of the components in the image. The threshold value should be adjusted in accordance with the components.

Ergina Kavallieratou [10] proposed a new histogram based binarization algorithm. This technique is simple, fast, robust and appropriate for normal and historical documents provided the foreground is darker than background. The background generally corresponds to the great majority of the image pixels. Considering this fact, the average value of the pixel values of document image is determined mainly by the background if the document is quite clear. This technique can maintain the image in grayscale after the removal of background noise or can give binarized image.

In this paper, a new technique for enhancement of palm-leaf manuscript and color document images is proposed. For more efficient enhancement of color document and palm-leaf manuscript images, enhancement techniques are used in the preprocessing stage. They improve the contrast between text and background and make the background uniform. Binary image is obtained by using a new global threshold computation scheme.

The final color image is obtained through synthetic background generation. This paper is organized as follows: Section 3 describes our proposed technique in detail while in Section 4 our experimental results are discussed. Finally, the conclusions drawn from this study are summarized in Section 5.

III. PROPOSED SCHEME

The proposed scheme for elimination of noise and binarization of low quality document images and palm-leaf manuscript images is described in this section.

The palm-leaf manuscript and document images used in this paper are taken from [13], [14].

Our proposed technique takes into account many artifacts like noise, non uniform background and low contrast present in the palm-leaf manuscript and document images. To take care of these artifacts we use:

A) Preprocessing Stage that includes Wiener filtering contrast enhancement and background enhancement.

B) Binarization Stage

C) Post Processing Stage which encompasses synthetic background generation.

The original background colors in many of the aged palm-leaf manuscripts are so dark that the foreground text colors are very close to the background. For processing these documents scanned images are first converted to grayscale images. The grayscale images are processed with the help of low pass Wiener filter which removes the noisy areas and smoothens out the background. The filtered grayscale images need further enhancement to improve the contrast between text and the background. To effect this enhancement, a contrast enhancement technique is applied to the filtered grayscale image.

The problem of uneven background color intensity across the image is often seen in historical document images. This deformity must be reduced to produce images suitable for binarization. For this purpose background enhancement technique is applied on histogram enhanced image. This technique evens out the background for easier binarization and also gives a better approximation of the enhanced background level.

A new global binarization technique is the next step in our proposed scheme. This binarization technique converts the given input grayscale or color document into a bi-level representation. This representation is convenient because most of the documents that occur in practice have one color for text (e.g. black), and a different color (e.g. white) for background. These colors result in high contrast, so the text can be easily read by humans.

In our proposed technique, we retain the color aspect of the image using original background colors from the scanned image. With the help of color (R, G and B) histograms we determine a suitable R-G-B intensity value to be assigned to the background. After binarization, we combine the background and binarized image to obtain enhanced, uniform background color image.

In the proposed technique, color document or palm-leaf manuscript images are first converted to grayscale images. Grayscale image is obtained by using RGB to YIQ conversion [11]. The luminance signal Y represents the grayscale component of an image.

The RGB to YIQ conversion is done by using

$$Y = (0.299 * R + 0.587 * G + 0.1114 * B) \quad (3)$$

$$I = (0.596 * R - 0.274 * G - 0.322 * B) \quad (4)$$

$$Q = (0.211 * R - 0.523 * G + 0.312 * B) \quad (5)$$

The Y component is used as the input grayscale image for the preprocessing stage.

A) Preprocessing Stage

Most of the document and palm-leaf manuscript images contain noise which is introduced during the document generation or scanning phase. For degraded and poor quality document or palm-leaf manuscript images, a preprocessing of the grayscale image before binarization is essential for enhancing the contrast between background and text areas, making the background texture uniform and making the document images analysis more robust to the noise.

Our preprocessing stage involves low pass Wiener filtering, contrast enhancement and background enhancement.

Wiener Filtering [12]

Wiener filtering technique is based on statistics estimated from a local neighborhood around each pixel. The Wiener filter is commonly used in filtering theory for image restoration. The preprocessing stage consists of following steps for removing the noise in document and palm-leaf manuscript images.

- At each pixel position, compute the mean value from an average of the values in the local neighborhood (e.g. 3x3 neighborhood) of the pixel position.

$$mean = \frac{\sum_{i=1}^{N} I_i}{N} \quad (6)$$

Where N is the total number of pixels and Ii is the pixel value at position of i.

- Compute variance at 3x3 neighborhood V by using the equation,

$$V = (1/N) * \sum_{i=1}^{N} (I_i - mean)^2 \quad (7)$$

- Calculate the average of all estimated variances for each pixel in the neighborhood Vavg.
- Transform the grayscale source image Is(x, y) into filtered grayscale image Iw(x, y) by using low-pass Wiener filtering process,

$$Iw(x, y) = mean + \frac{(V - Vavg) * (Is(x, y) - mean)}{V} \quad (8)$$

- Repeat the above steps for all pixels in the image.

Contrast Enhancement

Many of the old leaf-manuscripts have very dark background colors that make it difficult to differentiate between text colors and background colors. Thus, further enhancement techniques must be applied to improve the contrast between text and background. We propose following technique to improve the contrast of the image.

- Compute the histogram of filtered grayscale image i.e. distribution of gray levels in the image (hist).
- Compute normalized histogram by
  histnorm = hist / size of image (9)
- Find the maximum and minimum non-zero intensity values present in the image as I_{max} and I_{min} respectively.

Transform the filtered grayscale source image Iw(x, y) into histogram enhanced grayscale image Ih(x, y) by using

$$Ih(x, y) = 255 * \frac{(Iw(x, y) - I_{min})}{I_{max} - I_{min}} \quad (10)$$

- Repeat the above step for all pixels in the image to get histogram enhanced image.

Background Enhancement

Most of the old palm-leaf manuscript and document images have non uniform background color intensity. Background must be made uniform to improve the output of binarization stage. Our proposed background enhancement technique helps in making the background uniform. The steps for this technique are as follows:

- Calculate mean value for histogram enhanced image

$$mean = \frac{\sum_{i=1}^{N} Ih_i}{N} \quad (11)$$

Where N is the total number of pixels in the image and Ih_i is the pixel intensity at position i.

- For each pixel position, check whether the pixel intensity is greater than or less than mean value.
- If the current pixel intensity is less than mean then update the variable low with the current pixel intensity, else keep low as it is. Simultaneously, create an intermediate image having intensity values as that of low.

$$low = low \quad \text{if } Ih_i > mean \quad (12)$$
$$= I_i \quad \text{else}$$
$$Iinter_i = low \quad (13)$$

Where Ih_i is the pixel intensity at position i and Iinter is the intermediate image.

- At each pixel position of the intermediate image, compute the mean value from an average of the values in the local neighborhood (e.g. 3x3 neighborhood) of the pixel position. Using the local mean values create another image Iavg .

$$localmean = \frac{\sum_{i=1}^{9} I_i}{9} \quad (14)$$

$$Iavg\ (x, y) = localmean \quad (15)$$

Where I_i is the pixel intensity at position i and (x, y) is the current pixel position.

- Repeat this step for each pixel in intermediate image.
- For each pixel position in input image, find the difference between input image and average image. Find the maximum and minimum (non-zero) intensity values in the difference image. Calculate a constant k from the minimum and maximum values.

$$k = \frac{(Max + Min)}{2} \quad (16)$$

- Transform the gray histogram enhanced image Ih(x, y) into background enhanced image Ib (x, y) by using

$$Ib(x, y) = Is(x, y) - Iavg\ (x, y) + k \quad (17)$$

- Scale Ib(x, y) to grayscale range i.e. 0 to 255.
- Repeat the above 2 steps to obtain background enhanced image.

B) Binarization Technique

We propose a global thresholding technique to perform binarization. This technique is based on global gray value variations to extract useful text information from low quality document or palm-leaf manuscript images. The threshold value is computed based on mean and range of intensity values present in the background enhanced image.

The procedure for calculating threshold is as follows:

- Compute the mean value for background enhanced image.

$$mean = \frac{\sum_{i=1}^{N} Ib_i}{N} \quad (18)$$

Where N is the total number of pixels and Ibi is the pixel value at position of i.

- Find the maximum and minimum non-zero intensity values present in the Ib image i.e. Ibmax and Ibmin.
- Calculate range of intensities in the image as

$$range = (Ibmax - Ibmin) \quad (19)$$

- Compute the global threshold using

$$Th = \left(\frac{(2 * mean) - range}{((k+2) * mean) - range} \right) * range \quad (20)$$

Where k is a constant and its value depends on mean and range. If mean of image is greater than range of image (low contrast) then k is negative else (high contrast) k is positive. The value of k has been found to lie in the following range

$$-1.0 \leq k \leq 0 \text{ and } 1.0 \leq k \leq 2.5 \quad (21)$$

- If the pixel value in the image is greater than threshold then the intensity of pixel in the binarized image will be 255 otherwise it will be 0.

$$Ith(x, y) = 255 \quad \text{if } Ib(x, y) > Th \quad (22)$$
$$= 0 \quad \text{else}$$

Where Ith is the binarized image and (x, y) is the current pixel position.

- Repeat the above step for all pixels in the image to get binarized image as output.

C) Post Processing Stage

The binarization stage gives two level or binary image as output. Most of the existing schemes stop at this stage. But we propose a technique to retain the color aspect of the original scanned image without affecting its background uniformity. This will give color image output which is suitable not only for OCR applications but also for future references or storage purposes. We call this as synthetic background generation.

Synthetic Background Generation

In this technique we have used original color image and binarized image for the generation of final enhanced color image. The proposed technique is:

- Find the R, G and B histograms of original color image.
- Find the non-zero intensities for which a peak is seen in all the three i.e. R, G and B histograms.
- The pixel values for the resultant color image are decided as:

$$R(x, y) = 0 \quad \text{if } Ith(x, y) = 0$$
$$= rm \quad else \qquad (23)$$

$$G(x, y) = 0 \quad \text{if } Ith(x, y) = 0$$
$$= gm \quad else \qquad (24)$$

$$B(x, y) = 0 \quad \text{if } Ith(x, y) = 0$$
$$= bm \quad else \qquad (25)$$

Where rm, gm, bm are the non-zero intensities for which a peak is seen in the R, G and B histograms, Ith is the binarized image taken as input.

- Repeat the above step, for all pixels in the color image to get final color image as output.

IV. RESULTS

The proposed scheme has been applied on a number of palm-leaf manuscript and color document images. These images were having various deformities like low contrast between the character and background intensities, non uniform background, character breaks and localized spots.

Our experimentation results are compared with the following existing techniques:

- Global thresholding using Otsu technique [1]

  This is a well known technique for binarization of document images. Many techniques have been developed from Otsu technique. But this technique fails to give good results for images with low contrast e.g. palm-leaf manuscript and old document images.

- Locally adaptive thresholding using Laplacian Sign [2]

  This is a good technique in the class of locally adaptive thresholding techniques. It is able to remove the non-uniform background but some of the characters retrieved are severely broken.

The results obtained using our proposed technique depict improvement in the quality of images.

Figure 1 shows binarization of palm-leaf manuscript image. The Laplacian Sign technique uses local thresholds depending on the Laplacian Sign image. The result for this technique is shown in figure 1(b). As mentioned earlier, Otsu method uses single threshold for entire image. For this image, Otsu technique gives the threshold value as 189. The corresponding result is shown in figure 1(c). Figure 1(d) shows the binarized image output of our proposed technique. The value of k for this image is taken as 1.15. The color image output of our proposed technique can be seen in figure 1(e).

Figure 2 shows binarization of color document image. The threshold value for Laplacian Sign technique is calculated on the basis of Laplacian Sign image. The result for this technique is shown in figure 2(b). The result for Otsu technique is shown in figure 2(c). For this image the threshold value is 239. Figure 2(d) shows the binarized image output of our proposed technique. The value of k for this image is taken as 2.16. The color image output of our proposed technique can be seen in figure 2(e).

In figure 1(c) the characters are broken whereas in figure1 (d) the continuity of characters is maintained. Similarly we can see that in figure 2(c) the text is not visible but it is very clearly visible in figure 2(d). Circled areas are enlarged to show the improvement clearly.

In this paper, we have compared the performance of our technique with Laplacian Sign technique and Otsu technique.

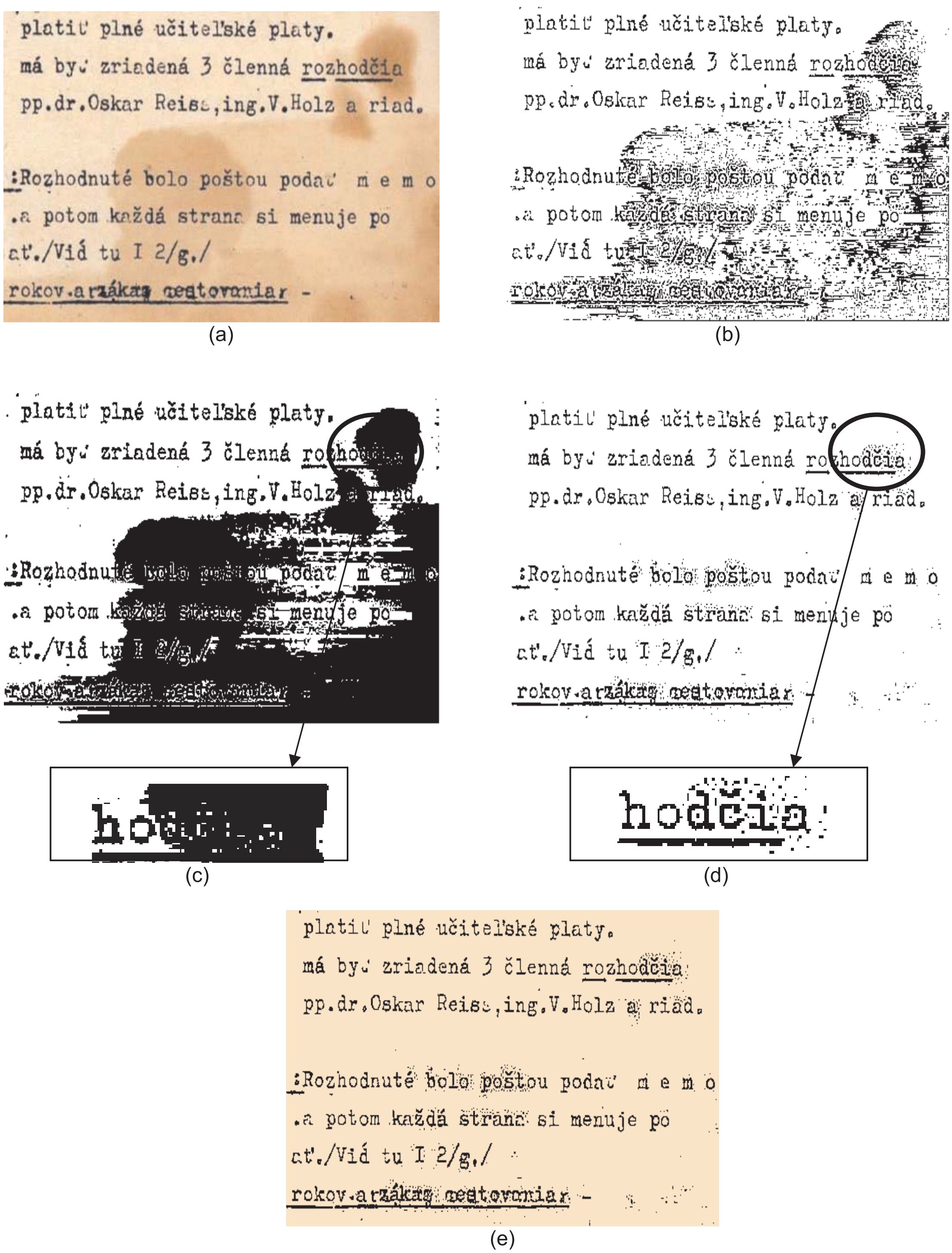
- In Laplacian Sign technique, the boundary noise present at boundaries is eliminated, but some of the text areas are not properly extracted and background noise is not removed.
- The approach of Otsu Technique solves the problem of character extraction better than Laplacian Sign technique but in some cases characters are broken and most times the background is very noisy.
- Our proposed technique outperforms the above two methods. The proposed technique performs well even when the documents are having very high noise, uneven background and character breaks.

The input images are having different backgrounds; dark background in figure 1(a) and dark and light backgrounds in figure 2(a). The text contrasts in the figure 1(a) are different. Text extraction

(a) (b) (c) (d) (e)

(a) Original image (b) Laplacian Sign technique (c) Otsu technique (d)Proposed technique (e) Color Image output with synthetic background.

Figure 1 : Binarization of Palm-leaf Manuscript Image



(a) Original image (b) Laplacian Sign technique (c) Otsu technique (d) Proposed technique (e) Color Image output with synthetic background

Figure 2 : Binarization of Document Image

in darker background is very difficult. If the background is eliminated, text is not properly visible and vice-versa. We can see that the standard binarization techniques fail to give good results, whereas results obtained using our proposed technique depict the improvement in the quality of palm-leaf manuscript and documents images.

V. CONCLUSION

In this paper, a new global binarization technique suitable for enhancing the palm-leaf manuscripts and color document images is proposed. The results show that our technique performs better than the other existing standard techniques for binarization of palm-leaf manuscript and document image enhancement.

Results show enormous adaptability of the proposed technique for the documents distorted with low contrast character gaps, uneven background and localized spots.

This three step technique is found to work successfully in improving the readability of the aged and degraded historical document images. It provides color or binarized form of the scanned palm-leaf manuscript and document images, suitable for preservation and OCR applications.

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