

Binary Image Analysis Technique for Preprocessing of Excessively dilated characters in Aged Kannada Document Images



Sridevi T.N, Lalitha Rangarajan

Abstract. In this paper, variety of document image enhancement techniques are applied for removal of background noise in the degraded document images. The noise removal techniques are applied on different forms of noise including non-uniform illuminations, complex stain marks, user annotations, show through effect and foxing effect. In this work, Binary Image Analysis (BIA) Technique is proposed for removal of aging degradation in ancient document images of Kannada literature. The method involves multiple phases comprising of contrast enhancement, Gaussian smoothing, binarization, morphological processing, object detection using connected component analysis and filtering followed by marginal noise removal of non-textual regions. The document samples employed for experimentation comprised of more than 175 aged and highly degraded scanned documents of old Kannada literature and poetry that are massively affected by noise and 25 images from DIBCO datasets collected across 2009 to 2017. The results of the experimentation are quite satisfactory and suitable enough for processing of document images in the subsequent stages of OCR. The experimentations are compared with some widely used approaches like Sauvola, Otsu, Gaussian. It is noticed that the proposed method outperforms other noise removal methods in terms of character retentions for extensively degraded and aged document images.

Keywords: Aged documents, Degradation removal, Ancient Kannada documents, Binarization, Connected component, Illumination correction.

I. INTRODUCTION

Document enhancement is the process of improving the quality of the contents in the document image by applying the pre-processing protocols in accordance with the type of noise. Enhancement is one of the pre-requisite and key stages for any of the document image processing tasks, especially for the document processing by Optical Character Recognition (OCR) system. Document images are available in variety of formats and the types of degradations or noise associated with each type of document are different. Basically the techniques employed for pre-processing include Sauvola [1], Otsu's [2], Gaussian noise model [3], and MSER [4], Xu et al [5].

As far as pre-processing is concerned, it is very challenging to make one method suitable for all types of noisy documents. The procedure of enhancement varies for each type of degradation present in the document.



Fig. 1. Noise types that usually occur in aged and highly degraded documents.

Noise present in document in various forms affects the efficiency of OCR systems. In this research work the noises which usually occur in old books of Kannada literature. Possible noise types addressed in this Research work are shown in Figure 1.

The objective is mainly to de-noise the degradations commonly found in aged Kannada document images [5]. Aged documents usually preserved from quite long years get affected with various noise patterns. These documents are affected with severe fading [6], foxing effect [7, 8, 9], show through effect [10] etc. Among these degradations, non-uniform illumination [11-12] is the most commonly found noise in all types of documents. Many researchers have contributed different approaches for enhancement of document images. The contributions are high in the area of binarization. Among these, the very popular methods namely Sauvola's [1], Niblack's [13-14] are categorized under local thresholding approaches, and Otsu's [2], categorized under global thresholding approaches. Local thresholding is the most successful and compatible with gray scale image document enhancement procedures. The gray scale manipulations on document images are constrained by stroke width and size of the characters/objects and are computationally intensive due to their pixel level (micro) processing operations [15,16]. In most of the binarization problems, the global thresholding techniques are used where only a single threshold is selected for the entire image. It is also a well known observation that global thresholding is a failure [17] for the documents with non uniform illumination and also for severe degradations in image.

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In the literature most of the works are experimented with global thresholding approaches for the binarization problems. J. Savoula and M. Pietikainen[1] proposed a new technique to document image binarization, using hybrid approach and taking document region class properties in to consideration. They employed a new method that performs a rapid classification of the local contents of a page to the background, pictures, and text. In their technique two different approaches were applied to define a threshold for each pixel: a Soft decision method (SDM) for background and pictures. And a specialized Text binarization method (TBM) for separating the textual and line drawing areas from badly illuminated background. Finally, the outcome of these algorithms are combined. Lee et al [17] and Sahoo et al [18] had compared efficiency of various thresholding algorithms and noticed the failures in enhancing certain regions in the image where background intensity dominated over the foreground regions. Lu et al [19] devised a method on binarization technique estimated background surface of degraded document images using polynomial smoothing procedure. The foreground or text stroke is detected using L1-Norm image gradient and hence, the two criteria had formed a basis for detection of noise in the image and the analysis is conducted on DIBCO challenge datasets which is proved to be good one among various others.

Further, Fisher et al [20] had proposed a technique using the Connected components detection, filtering based on the statistical properties of image for the removal of degradations in the images through separation of text and non-text regions. In connection with the illumination correction, Pilu et al [21] had devised a technique for enhancement of images captured by the handheld embedded cameras using HipasscolorDemosaicng method. Later, the open book scanning problems like illumination correction are addressed by Xu et al [5] using the multiple threshold values for segmenting the foreground region from background. Recently Ardizzone et al [22] had contributed a knowledge based architecture for virtual restoration of ancient photos using a restoration model developed based on ontology associated with a set of rules to suggest a particular action depending on the experimental data that is dynamically grown with database. Though the method works on photos well, the same efficiency is not realized on the document images containing minute objects.

Aiming to achieve a similar challenge in these directions, Roe et al [23] also attempted towards the restoration of historical document through a thresholding approach that works based on understanding of object structure, the experiments are conducted on DIBCO 2016 handwritten datasets. Few more prominent attempts on document image enhancement are as under: (i) Giacometti et al [24] used multi spectral image processing techniques for restoration of content primary historical documents using various frequency domain techniques. (ii) Roe et al [25] had also experimented to restore images from ancient post card images using various color image enhancement techniques including histogram equalization, noise spot detection, Gaussian filtering difference and edge detection techniques. However, the applicability of these is restricted to the context of non text images in the literature rather than text images.

In a nutshell, it is observed that most of the experiments are conducted on photo images, open book scanning problems, illumination correction, restoration of degraded document images, removal of stains, foxing effect and illumina-

tion correction. Likewise, the methods applied are a combination of global and local thresholding approaches (Hybrid approach) which usually requires intensive computing as these techniques adapt pixel level processing for the overall enhancement of images. Also, in all these works the common observation is, addressing of only specific degradations such as only illumination correction or stain removal or foxing effect removal etc. Adding to this, the enhancement procedures are implied on wide image categories like photos, post cards and open books and historical documents etc. Hence, all these factors motivated us to move in the proposed direction of research which addresses multiple degradation types in aged and highly degraded document images.

In view of this, in this paper a novel and efficient method called Binary Image Analysis (BIA) Technique is proposed for removal of different types of noise commonly found in aged Kannada document images [5]. Aged documents usually preserved from quite long years get affected with various noise patterns including non-uniform illuminations, complex stain marks, user annotations, show through effect and foxing effect. In this work, The BIA involves multiple phases comprising of contrast enhancement, Gaussian smoothing, binarization, morphological processing, object detection using connected component analysis and filtering followed by marginal noise removal of non-textual regions. The proposed method works well compared to other noise removal methods in terms of character retentions for extensively degraded and aged document images.

The remaining part of the paper is organized as follows. Section II involves preprocessing stages of the proposed approach. While section III gives the experimental analysis and the efficiency of the proposed model are compared with other existing approaches. Apart from the comparisons, section III also includes the important observations drawn from enhancing different types of degradations such as show through effect and non-uniform illumination. Finally The efficiency of the proposed model towards retention of multiple combinations of characters with some conclusions is brought out clearly in section IV.

II. METHOD PROPOSED

Preprocessing of documents is one of the key stages to be employed prior to any document recognition task. Recognition of textual contents in the document images with high accuracy is the motivation behind development of any OCR. Realization of expected recognition efficiencies is possible only with good quality images. The complexity involved in recognition task varies across images with low to high degradations. Highly degraded images such as aged document images should undergo intensive preprocessing procedures for the removal of variety of aging artifacts to minimize conflicts during the process of recognition. The proposed method is a step towards rescuing of old Kannada literature documents by transforming them into digital content. As the documents are aged and affected with variety of degradations which may adversely affect the textual contents. It is essential to eliminate the degradations and improve the quality of the image. The input to the proposed approach comprises of aged and highly degraded scanned document images of resolution around 300 dpi from the collections of old Kannada documents of literature and poetry.

The different degradations include foxing effect, show through effect, non-uniform illumination, pen/stain marks and user's annotations etc. Samples of some aged/degraded

documents are shown in figure 1 and processing stages are shown in figure 2.

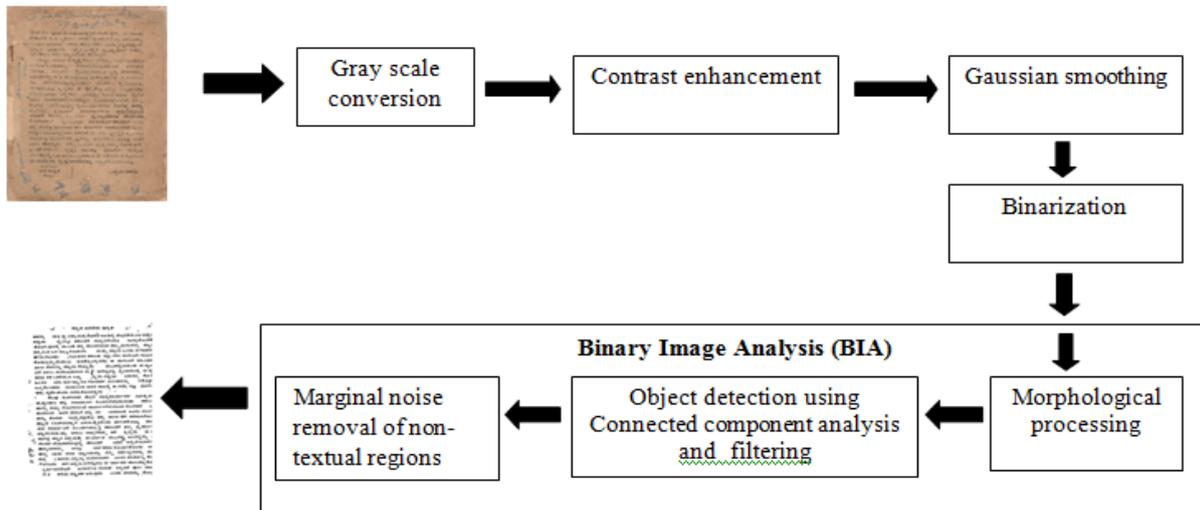


Fig. 2. The processing stages of the proposed approach

A. Contrast Enhancement

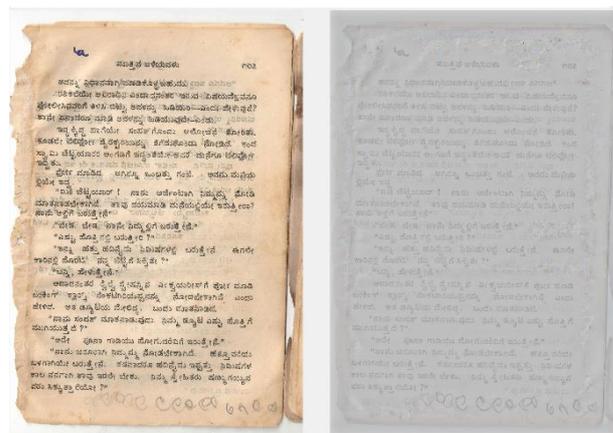
Initially the input images are subjected to the process of gray scale conversion, as these images are degraded massively in terms of illumination and content. Therefore, it is essential to perform the illumination correction. Execution of illumination correction protocols leads to the use of consistent thresholding technique in the process of binarization.

The process involves removal of uneven illumination in the images caused by aging of documents, pen scratch marks, ink stains, exposure to different environmental conditions etc [26]. Local Contrast Normalization (LCN) is the technique employed to uniformly distribute the illumination and regulate the contrast of an image. Unlike global normalization techniques which perform normalization by considering the whole range of gray level values of the entire image, LCN operates on the image by adapting to contents in a block. Let I represent a gray scale image with their intensities in the range of $[\min, \max]$. After normalization, the new intensity range of the image is $[\text{new min}, \text{newmax}]$. If (x, y) indicates a spatial location in an image I , then local normalization at location (x, y) is given by equation (1).

$$\bar{I}(x, y) = \frac{I(x, y) - \mu_b}{\sigma_b} \text{ if } \sigma_b > 1 \tag{1}$$

$$\bar{I}(x, y) = 0 \text{ otherwise}$$

Where μ_b is the local mean and σ_b is the local standard deviation and $\bar{I}(x, y)$ is the output image. The result of local normalization function on an input sample is shown in the figure 3. The local normalization is also employed on the documents where all the noise is cornered at one location which usually incurs during the process of scanning two sides of book at once. The local normalization is also tested on few of such input samples and the results of the same are as shown in the figure 4. In all the cases of illumination correction, the local mean and local standard deviation is calculated for a block of 35×35 . Subsequently, the image $\bar{I}(x, y)$ is subjected to Gaussian filtering for the removal of aging degradations.



(a)Original image (b) Image after LCN

Fig. 3. Result of LCN



(a) Image with Non-uniform illumination (b) Image with uniform illumination
Fig. 4. Results of Local Contrast Normalization on two sided scanned documents

In all the cases of illumination correction, the local mean and local standard deviation is calculated for a block of 35x35. Subsequently, the image $\bar{I}(x, y)$ is subjected to Gaussian filtering for the removal of aging degradations.

B. Gaussian Smoothing



(a) Image after LCN (b) Binarization without Gaussian smoothing (c) Binarization after Gaussian smoothing
Fig. 5. Result of Gaussian smoothing

Blurring is a convolution process which smoothens the image and reduces the grainy appearance so that image looks very transparent with reduction in some noise. Gaussian smoothing attenuates the high frequency components of the images so that the noisy regions in the image will be suppressed. It is basically a low pass filter in the frequency domain that accepts only the low frequency components of the image so that the resulting image will be noise free.

From figure 5(b), It is evident that binarization on the uniformly illuminated image(result of LCN) has highlighted a variety of document aging degradations as well as noise across both textual and non-textual regions.

The execution of adaptive binarization on the Gaussian filtered image had greatly reduced the noisy detail especially in the regions where text is present. However, despite filtering the image, the noisy content in the margin of the image is retained. Hence in this work, a heuristic technique for elimination of noise in all the regions of the document is proposed.

C. Binary Image Analysis (BIA)

The binary image has retained some aging degradations (figure 5(c)) particularly in the margin area. In order to reduce this, we have proposed an efficient Binary Image Analysis (BIA). In the proposed approach, Image has been subjected to the morphological erosion, followed by object

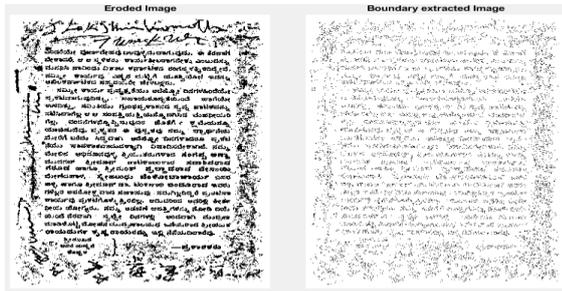
detection using connected components of binary images, and each connected component is subjected to analysis of local intensity distribution in order to deduce if the gradient regions in the image belong to textual contents or noise. Finally, marginal noise removal of non-textual regions is implemented to achieve the desired level of enhancement along with character retention. The proposed method has yielded promising results in terms of the removal of degradations like foxing effect, pen marks, and show through effect. In this work, the techniques employed for detection of text or non-text blocks includes only the manipulation of binary values performed directly on binary image rather than gray scale image such as Sauvola[1], Niblack[13] etc.

i) Morphological Processing

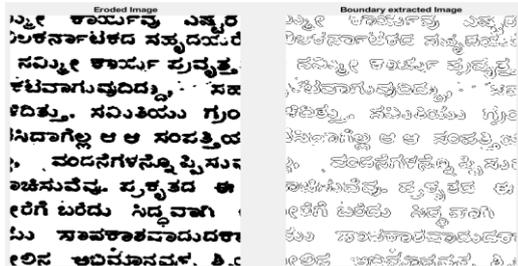
As most of the contents are excessively dilated close to the boundaries of the object contents, it is useful to apply morphological erosion [27] to uncover/detect/identify the boundaries of the objects and to separate touching objects in a binary image so that they can be counted using a labeling algorithm (Connected components labeling). Hence Morphological processing is done, and the operation is erosion using disk as a structuring element.



Figure 6 (a) and (b) provides the glimpse of the outputs obtained after erosion and boundary extraction from the eroded image and a section of the enlarged version of the figure 6(a) and 6 (b) are shown in figure 7(a) and (b).



(a) Erosion on binary image (b) Boundary extraction
Fig. 6. Result of morphological operations



(a) View of figure 6(a) (b)View of figure 6(b)
Fig. 7. Enlarged view

ii) Object detection using connected component analysis and filtering

Detection of objects in the binary image is carried out using connected component analysis. The binary image, which is the output of morphological processing (figure 6 (b)), is subjected to object detection using the connected component analysis [27]. Subsequently, features are extracted from each connected component to identify the type of content namely, text or non-text. Figure 8 shows the result of extraction of connected components.



Fig. 8. Object detection after erosion and boundary extraction from binary image.

Once the connected components are detected and extracted, height and width features of connected components are used as filter parameters to identify text areas as shown in figure 9. The extracted components are sorted on heights and components whose heights are < 10 pixels and > 60 pixels are declared to be noise. These thresholds are empirically determined. Observe that some noisy connected components are detected to be text. Figure 10 is the result of filtering of connected components. The output of this stage retains some noise. Noisy components especially around the boundary regions are shown in green color in figure 10. The reasons for the partial removal of noise are perhaps due to the broken components in terms of its connectivity in non-textual area which is clearly seen in figure 10. Thus, further processing is needed.

Textual connected components with heights within threshold

Non-textual connected components with heights beyond threshold

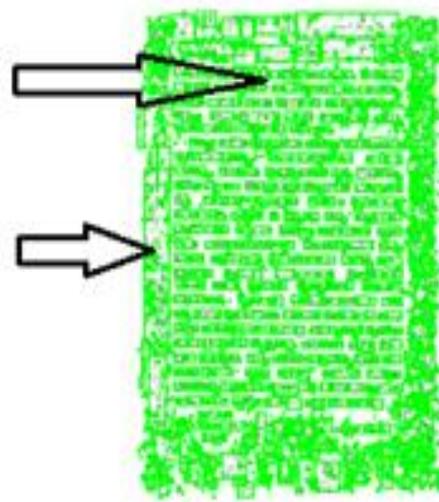


Fig. 9. Results before filtering of connected components

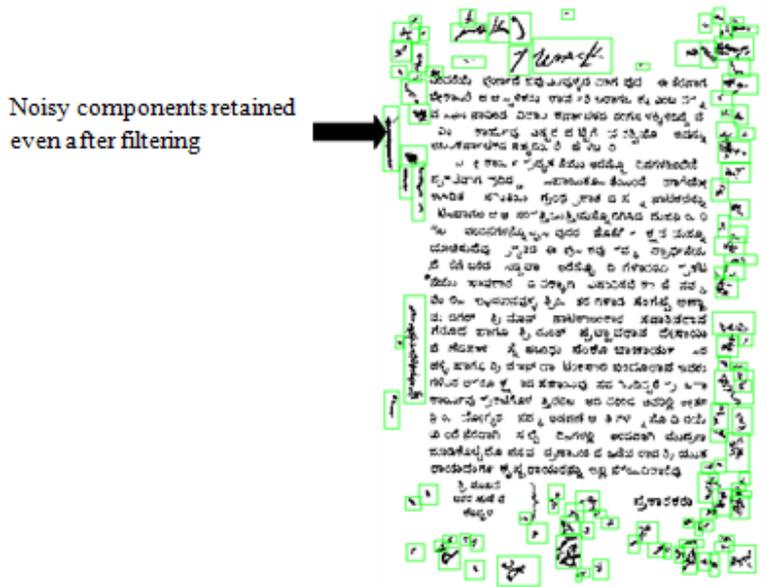


Fig. 10. Results after filtering of connected components

Figure 10 is the result after filtering of connected components on the binary image. The next step in removing the retained noise is, marginal noise removal. This is done in order to remove noise in the non-textual regions.

iii) Marginal noise removal of non-textual regions.

The marginal noise removal of non-textual regions is performed using the steps below.

- i) For each connected component, construct blocks of same size on top, bottom, left and right (refer figure 11)
- ii) Use count of black pixels in all two adjacent added blocks (top, left; left, bottom; bottom, right; right, top)
- iii) If any one of these counts is < 25 pixels (this threshold is determined experimentally) then the block considered as non-text.

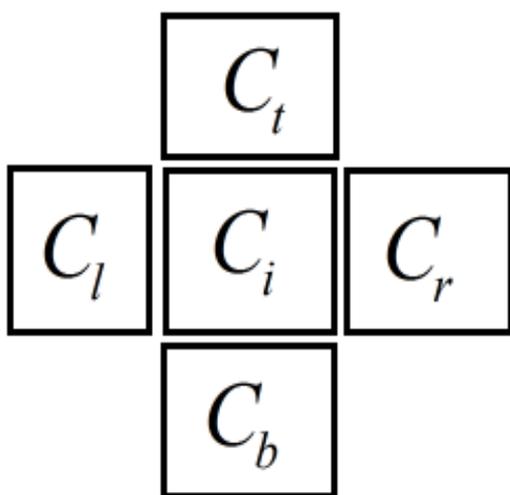


Fig. 11. 4 adjacent neighbors of a connected component

The output of marginal noise removal process is shown in figure 12.

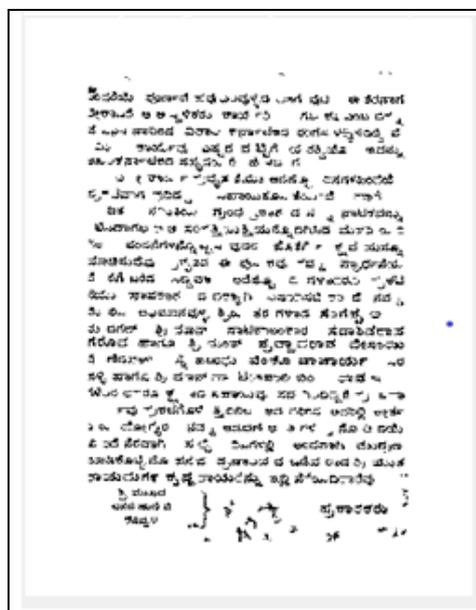


Fig. 12. Result of marginal noise removal

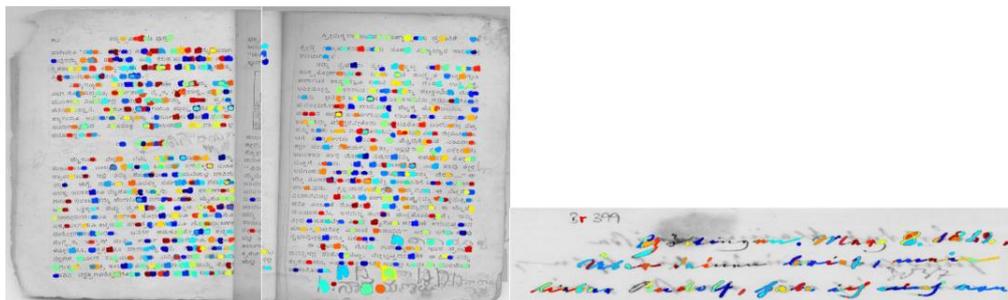
The proposed approach is also employed on various other types of degraded document images obtained from multiple books with degraded pages.

III. EXPERIMENTAL ANALYSIS

Pre-processing as far as the degraded documents are concerned is a quite challenging task, since the documents are affected with different types of noises. Evaluation of text detection is commonly carried out using widely used techniques like Maximally Stable Extremal Regions MSERs[4]. The experiments of proposed approach are conducted on created a dataset of 175 scanned pages from ten old Kannada books (dataset 1). Apart from these datasets, we have also experimented with bench mark data ‘Document Image Binarization Contest (DIBCO)’ comprising of 25 images (dataset 2).

The performance of MSER text detection technique on two of these degraded document image samples is shown in figure 13(a) and 13(b). Figure 13(c) is the result of MSER on a page from Document Image Binarization Contest (DIBCO) dataset. Figure 14 is the result of proposed ap-

proach on these documents. The number of connected components on these samples are 301, 224 and 67 with MSER and 651,713, and 54 using the proposed approach. Performance of MSER is very poor as compared to proposed method. Hence this is not taken for performance comparison.



(a) & (b) MSER on our dataset (c) MSER on DIBCO dataset
Fig. 13. Performance of MSER technique for text detection



Fig. 14. Performance of proposed approach on the pages in figure 13

The dataset for experimental analysis consists of 200 scanned pages from various sources. Around 35 documents are considered from an ancient book 'Maharshi Dayananda Saraswathi', another 40 documents from a book 'Vaidya shastradanaveenasahasagalu', 100 documents from 'SiddharamaChaarithra' and remaining 25 are drawn randomly from DIBCO.

Experiment 1 is on the 175 sample pages of dataset 1. The table I represents top 10 outputs of each method chosen for comparison. Number of connected components extracted are counted and the average of 10 instances out of 175 that extracted maximum number of connected components is reported in table I. The proposed method exhibits better efficiency of 70.01% for the retention of characters for highly degraded aged documents. Though the level of degradation removal in document is not to the level of Sauvola, the character retention efficiency is higher with the use

of Binary Image Analysis Technique as compared to Sauvola. This is evident from figures 15(b) and 15(c). Otsu seems to be better as far as character retention (refer output of book1 in table I). However, the noise removal is not addressed efficiently (compare figures 15(b) and 15(d)) and further the noise is also counted as characters. It may be observed that Gaussian smoothing performs marginally better with book 2 as far as character retention is concerned, whereas there is a steep drop in performance with other two books. As Otsu method, noise is not eliminated properly in Gaussian smoothing (compare figures 15(b) and 15(e)). Retention of noise can result in reduction of efficiency when given as input to OCR. Output of Otsu and Gaussian smoothing can not be considered for good quality images for OCR.

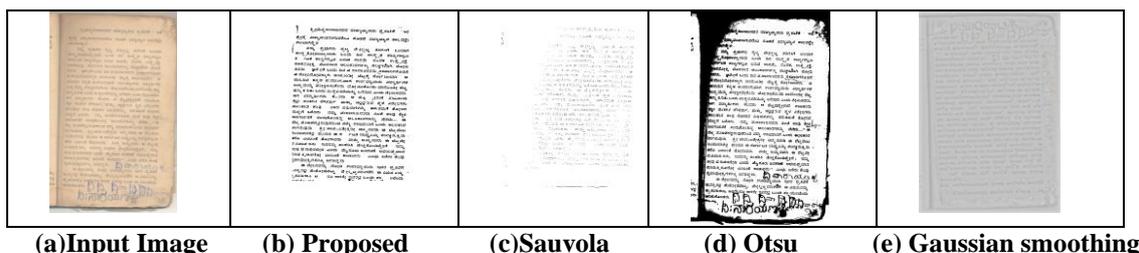


Fig. 15. Original scan image and output of methods 1 to 4 (Table I)

Table-I: Performance metrics of proposed approach (BIA)

SI No	Method	Book 1	Book 2	Book 3
1	Proposed	70.01353	41.02241	61.47089
2	Sauvola's approach	64.53688	18.42409	47.38472
3	Otsu Thresholding	73.56001	41.29177	41.29177
4	Gaussian smoothing	35.20677	43.99598	43.99598

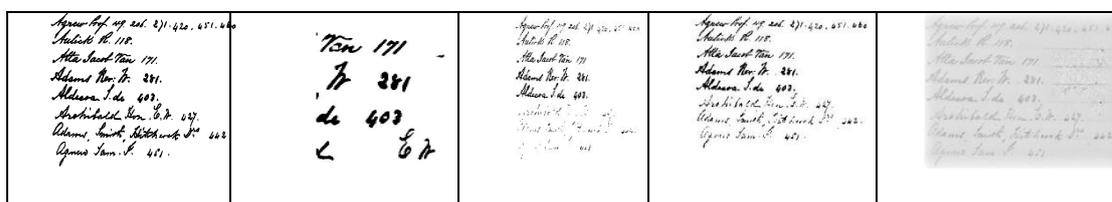
Table-II : Performance metrics of proposed approach (BIA) across samples from 5 books compared with ground truth.

SI No	Comparative Mehtods	Sample 1	Sample 2	Sample3	Sample4	Sample5
1	Ground Truth	756	825	779	665	800
2	proposed Method(BIA)	651/756=86.11%	681/825=82.54%	595/779=76.37%	489/665=73.53%	713/800=89.12%
3	sauvola	317/756=41.93%	75/825=9.09%	160/779=20.5%	282/665=42.40%	162/800=20.2%
4	Otsu	731/756=96.6%	754/825=91.39%	657/779=84.33%	662/665=99.54%	752/800=94%
5	Gaussian	754/756=99.73%	777/825=94.18%	703/779=90.02%	650/665=97.74%	762/800=95.2%

In five random pages of data set 1 the number of characters is manually counted. This is taken as reference ground truth. The four methods are executed on these 5 pages and again the number of characters extracted are counted. Table II is summary of performance of the four methods against the ground truth. The performance is measured quantitatively in terms of retention of number of characters. The accuracy is calculated as the proportion of number of characters

retained $N(R)$ to the total number of characters in the original document $N(C)$ as given by (2).

$$Accuracy = \frac{N(R)}{N(C)} \tag{2}$$



(a)Input Image (b) Proposed (c)Sauvola (d) Otsu (e) Gaussian smoothing

Fig. 16. Output of the proposed and three other methods on a page from DIBCO dataset.

The images used as test data in our proposed method were chosen from the DIBCO contests. Figure 16 shows binarization result on using our method to a set of 25 sample images from DIBCO 2009 to 2017. As it is evident from the above results that, the proposed approach, binary Image analysis is specifically designed for the removal noise like handwritten annotations, show through effect, aging marks etc. For the proposed datasets, the BIA technique provides satisfactory results by removing variety of noise as mentioned. Hence handwritten annotations in DIBCO datasets are considered as noise by BIA and resulted in erosion of text when experimented. Results of DIBCO using BIA shown in figure 16. As the DIBCO datasets consists of handwritten documents written in different orientations with no specified space in between the letters as it is varied across different writers. Table III is summary of performance of average performance of all 25 pages from DIBCO dataset over 2009 to 2017.

Table-III: Performance metrics on DIBCO dataset

SI No	Comparative Mehtods	Sample
1	Ground Truth	116
2	Proposed method(BIA)	23/116=19.82%
3	Sauvola	52/116=44.82%
4	Otsu	74/116=63.79%
5	Gaussian	81/116=69.82%

Apart from the above comparisons, the important observation drawn from the analysis of proposed approach with Sauvola's is that, Sauvola's approach failed to retain the text when the amount of the smoothing/blurred appearance is high which is common in severely aged and improperly preserved documents (figure 17). However, the proposed approach does not retain symbols and logos in the page because the threshold is designed to retain only characters. Whereas, Sauvola can retain variable size symbols also.

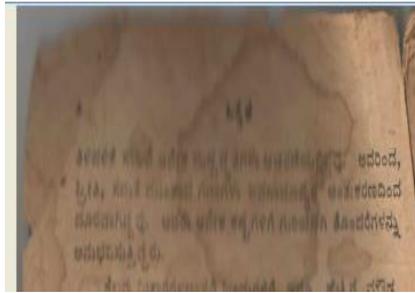
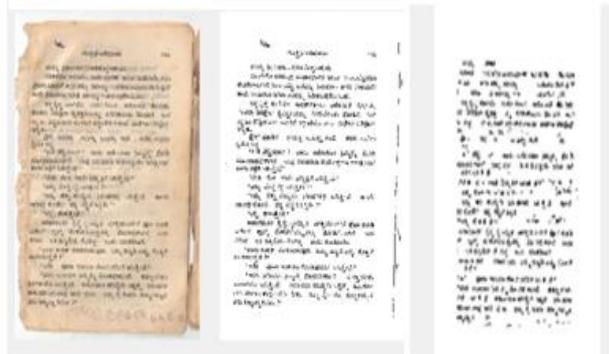


Fig. 17. Type of regions where enhancement fails using Sauvola’s approach



(a) Original Image (b) Sauvola performance (c) BIA performance

Fig. 18. Document with show through effect

(a) Original image	(b) Proposed technique	(c) Sauvola
(d) Otsu's thresholding	(e) Gaussian smoothing	

Fig. 19. Comparison Results Of Various Methods And The Proposed Method On Non-Uniform Illumination.

The other experimental inferences include the removal of show through effect in images, it is observed the gray scale analysis technique adopted by Sauvola does not perform well on documents with show through effects. Some characters are lost in the process of noise removal. However, the proposed approach takes binary image as input and performs far better on documents with show through effects (figure 18). devised based on the Binary Image Analysis operations is also intelligent enough in removal of the noise from images. Figure 18 depicts the results of show through effect removal.

Comparatively, the BIA outperforms existing models in terms of factors like computational efficiency by applying the manipulations on binary images rather than gray scale image processing unlike Savoula and Gaussian smoothing techniques. The contribution with respect to BIA is unique for its reliability in processing variety of noise in degraded documents when compared with existing models. Further,

the proposed technique is also tested on the images which has some adverse effects of scanning such as dark area appearance while scanning two adjacent pages of a book at a time.

Proposed algorithm responds well to such type of noises as compared to other three methods (figure 19).

IV. CONCLUSION

Retention of data in the aged document images with severe degradations is considered as one of the significant problems in the area of document image analysis. In this work, attempts are made towards the development of document image enhancement techniques based on binary image manipulations for the removal of noise patterns found in aged Kannada document images.

Though the existing techniques for image enhancement are successful at noise removal they exhibited poor character retention rate. It is obvious, in Roman/Greek scripts, each character is of same length/height etc, but in case of Kannada the characters are combinations of vowels, consonants and its modifiers, and hence size/length/height of each character varies within same document. Hence, retention of these multiple combinations of characters is a challenging task. The retention of these possible combinations is well achieved through a sequence of steps experimented consisting of contrast enhancement, Gaussian smoothing, followed by morphological analysis, object detection using Connected comp extraction on binary image. Finally marginal noise filtering of non-textual regions is used to achieve the desired level of enhancement along with character retention on highly degraded aged documents.

It is observed that, the efficiency of the devised approach is better compared to the existing approaches. Future work is to segment characters and classification of characters.

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