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A new watershed model based system for character segmentation in degraded text lines

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ABSTRACT

Character segmentation from text lines in degraded historical document images is challenging due to complex background and non-availability of regular structures of text patterns. This paper proposes a new method based on watershed model for segmenting characters from text lines in degraded historical document images. The proposed method filters out noise pixels by exploring Sobel and Laplacian values of pixels, which results in edges that represent text components. We then propose watershed model for studying non-linear spacing between characters based on the fact that watersheds provide information about water flow and volume of collection of water. Experimental results on different datasets, which include degraded historical document images called Indus documents and other Indian scripts, show that the proposed method segments characters better than the existing character segmentation methods in terms of recall and precision.

1. Introduction

Recognition and understanding of degraded historical documents like Indus in India is a hard task due to aging, distortions, poor quality and different handwriting symbol styles along with picture-like animals. The recognition process in general involves the segmentation of text lines, the segmentation of characters and then the separation of foreground (text) and non-text to recognize characters with an Optical Character Recognizer (OCR) engine. The success of recognition thus depends on the result of character segmentation from text lines. It is justified from Khare et al. [10] that text line segmentation from video and natural scene images helps in achieving a better recognition rate compared to that at image level. Further, we can also notice from Roy et al. [21] that the method separates background and foreground (text) successfully such that character shapes are well preserved and the recognition rate of text line improves drastically. Achieving a good recognition rate is important for digitizing such historical documents, which helps us to preserve the documents for a longer time. Besides, the same recognition information can be used for annotating these documents automatically, which in turn can be used for indexing or retrieving. In this work, the scope is limited to segmenting characters from text lines detected by a segmentation method as character segmentation is a challenging step in the recognition process. Conventional character segmentation methods such as projection profile based methods may not work for degraded historical documents from text lines due to the absent of regular spacing between character components. Therefore, there is a need for developing a new method for segmenting such characters.

For example, the complexity of character segmentation can be seen in Fig. 1, where a sample Indus document, an Indian script (Telugu) and an English document are shown respectively in Fig. 1(a)–(c). It is observed from Fig. 1(a) that it is hard to differentiate text and non-text due to the causes generated by various backgrounds such as hard durable materials like stones and the presence of animals which create touching between text and non-text. In the same way, in Fig. 1(b) we can see cursive characters, which make character segmentation more challenging. Fig. 1 (c) shows the presence of noises and distortions. When we compare Fig. 1(a) and (b) with Fig. 1(c), it looks segmenting characters from an English document is easier than that from Fig. 1(a) and (b) because we can expect regular and uniform spacing for English documents, while for the other two documents, due to cursive characters and complex background, we cannot expect regular spacing between characters. Therefore, we can conclude that the

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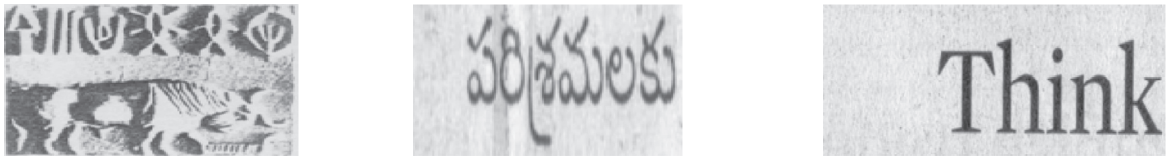


(a) Indus document (b) Telugu (c) English

Fig. 1. Different input text line images.

conventional projection profile based methods or the method which works based on character shapes may not work well for these documents.

2. Related work

As seen in literature, there are various approaches for character segmentation. However, when we look at Indus documents shown in Fig. 1(a), we can find that its background is distorted and the characters are cursive in nature because of the usage of tools by hands to engrave texts like pictures on hard materials (http://en.wikipedia.org/wiki/Indus_scripts). Therefore, the decipherment of Indus documents in history remains as a research issue in the field of document image analysis. Since there are not many methods on Indus character segmentation in literature, in this section, we review the literature on the segmentation of characters from degraded, historical and handwritten document images.

Most of the methods in [1,2,7,18,24,28] are based on projection profiles, whereas [15,17,25] use component grouping. These methods work well for plain and high resolution texts with clear spaces between characters. These methods segment lines using horizontal projection profile, and then use vertical projection profile to segment words or characters. Such a method scans vertically for black pixels. As a result, it may not be suitable for Indus documents. The segmentation of plain characters by Vornoi regions for non-document images is proposed in [18]. Vornoi edges are extended between connected components of characters. The minimum distance between connected components is then found for the elimination of Vornoi edges external to the boundary of connected components. The method in [17] uses skeleton segmentation paths to isolate connected characters. It determines feature points such as Fork, End and Corner points to construct all possible paths. However, the proposed method only deals with machine printed texts. These methods concentrate on fixed size characters with clear spacing column texts, and are error prone for unstructured backgrounds. Therefore, the methods may not perform well for Indus document images.

Furthermore, we can also see a few methods [4,5,9,16] for handwritten character segmentation. Most of the methods work well on the documents where there is no touching between text lines or characters. Segmentation methods for touching characters can be found in [3,12,22], which work based on concave or convex features. The cut positions are then derived as closely matching valleys of the original image and the rotated image. Segmentation methods for different scripts such as Romeo [6], Chinese [14,27], Arabic characters [29], historical documents [30] and document Image [26] are available in literature. However, these methods use language specific features for segmentation. Similarly, there are methods for character segmentation from text lines in video available in literature [10–12,21,23]. Though these methods work well for low resolution documents like Indus images, they expect regular shapes of characters and the spacing between characters.

There are methods which explore watershed algorithm for segmenting text lines in [13,31–33]. Most of the methods use the results of morphological operations as the input for watershed to segment text lines. It is true that the performance of the morphological operation depends on the size of mask and binary output. Therefore, the methods do not perform well for complex documents such as Indus.

We hardly found the literature on Indus documents [8] as introduced. The method in [19] discusses the characterization of Indus scripts, the probabilities of the sequences of symbols, the syntactic rules for generating analyzed sequences, and the correlations among symbols. This method analyzes the sequences of Indus scripts to predict missing letters [20]. Based on the above discussion, we can conclude that none of the methods used documents like Indus for character segmentation. Hence, there is an immense scope for developing a robust method for character segmentation in Indus documents.

The main contributions of the proposed work are as follows. (1) Since background of Indus documents usually contains clutter noises, we propose a new combination of Sobel and Laplacian operation for enhancing text pixels by suppressing noise ones, and (2) We explore watershed model for character segmentation from Indus text lines, which is unlike the other models that have been used for the segmentation of handwritten text lines in scanned document images.

3. Proposed method

For a given input image, the proposed method extracts text lines using the concept of the nearest neighbor criterion as described in [8] because the main objective of this work is to segment characters from text lines. One such example is shown in Fig. 2, where we can see for the input image in Fig. 2(a), the method extracts text lines as shown in Fig. 2(b). Therefore, the extracted text lines are the input for character segmentation in this work. It is known that a document image like Indus often has low resolution, low contrast and noise pixels due to background variations as shown in Fig. 2(b). Inspired by the work proposed in [23] for text enhancement for video images to detect text lines by Sobel and Laplacian gradients, we propose the combination of Sobel and Laplacian gradients to enhance the vital information like edges and suppress background noises. For the output of the enhancement step, we propose to explore watershed algorithm to segment characters from text line images based on the fact that Sobel and Laplacian operations give low values for pixels between characters and high values for text pixels. The main reason to propose the watershed model is that watershed algorithm helps in detecting non-linear spacing between characters.

3.1. Background noises removal

It is noticed from the image in Fig. 2(b) that it contains lots of background noises due to background variations in an Indus document image. To sharpen edges and suppress background noises, we obtain gradients by performing Sobel and Laplacian operations on the text line image because it is a fact that Sobel enhances high contrast pixels while Laplacian enhances both low contrast and high contrast pixels along with noises as shown in Fig. 3

(a) Indus Document

(b) Text line extracted

Fig. 2. Sample text line segmentation from Indus document image.

(a) and (b), where we can notice that Sobel highlights edges and Laplacian enhances both low contrast and high contrast pixels along with noises. From the line graphs shown in Fig. 3(c) and (d), which draw pixels vs. gradient values for the results in Fig. 3 (a) and (b), we can see high sharp peaks for edge pixels in case Sobel gradient graphs compared to Laplacian gradient graph. Since Sobel gradient operation involves the first order derivative, it gives fine edges for high contrast pixels. As a result, there are chances of losing significant text pixels. To restore missing text pixels, the proposed method performs the Laplacian gradient operation, which involves the second order derivative and gives fine edges for both high and low contrast pixels. At the same time, the Laplacian gradient operation introduces noises as shown in Fig. 3(b). To remove such noises and use the advantage of both Sobel and Laplacian gradient operations, we propose to perform intersection operation for Sobel and Laplacian gradients. The result can be seen in Fig. 3(e), where one can notice that most of the significant information is retained and noises are reduced. When we look at the line graphs drawn for the results in Fig. 3(f), we can find better sharp peaks at edges and low peaks at spaces compared to the line graphs in Fig. 3(c) and (d). However, Fig. 3(e) still contains a few background noises. To remove such small noise pixels, the proposed method uses connected component analysis for the output of enhancement step as shown in Fig. 3 (g), where noise pixels are removed and we can see clear spaces between character components. The line graphs drawn in Fig. 3(h) for the image in Fig. 3 (g) shows that the enhancement step removes background noises clearly.

In this work, we prefer to use the above combination rather than popular Canny edge operator because Canny operator involves two thresholds, which are sensitive to background complexity and degradations in images compared to Sobel and Laplacian operations. As a result, it gives spurious edges for background information and hence is hard to differentiate text and non-text edges. It is illustrated in Fig. 3(i)–(n), where we can see that Sobel operator does not produce many spurious edges compared to Canny operator as shown in Fig. 3(i) and (k), respectively. The same thing can be confirmed from the line graphs in Fig. 3(j) and (l), where we can see space between characters in case of Sobel operation, while it is hard to see the space in case of Canny operation. Due to this, the intersection of Sobel and Canny operations may not yield good results for degraded documents like Indus as shown in Fig. 3(m) and (n), where it can be noted that the operation loses spaces between characters compared to Sobel and Canny operations. Therefore, it can be concluded that the Sobel and Laplacian combination is better for Indus documents.

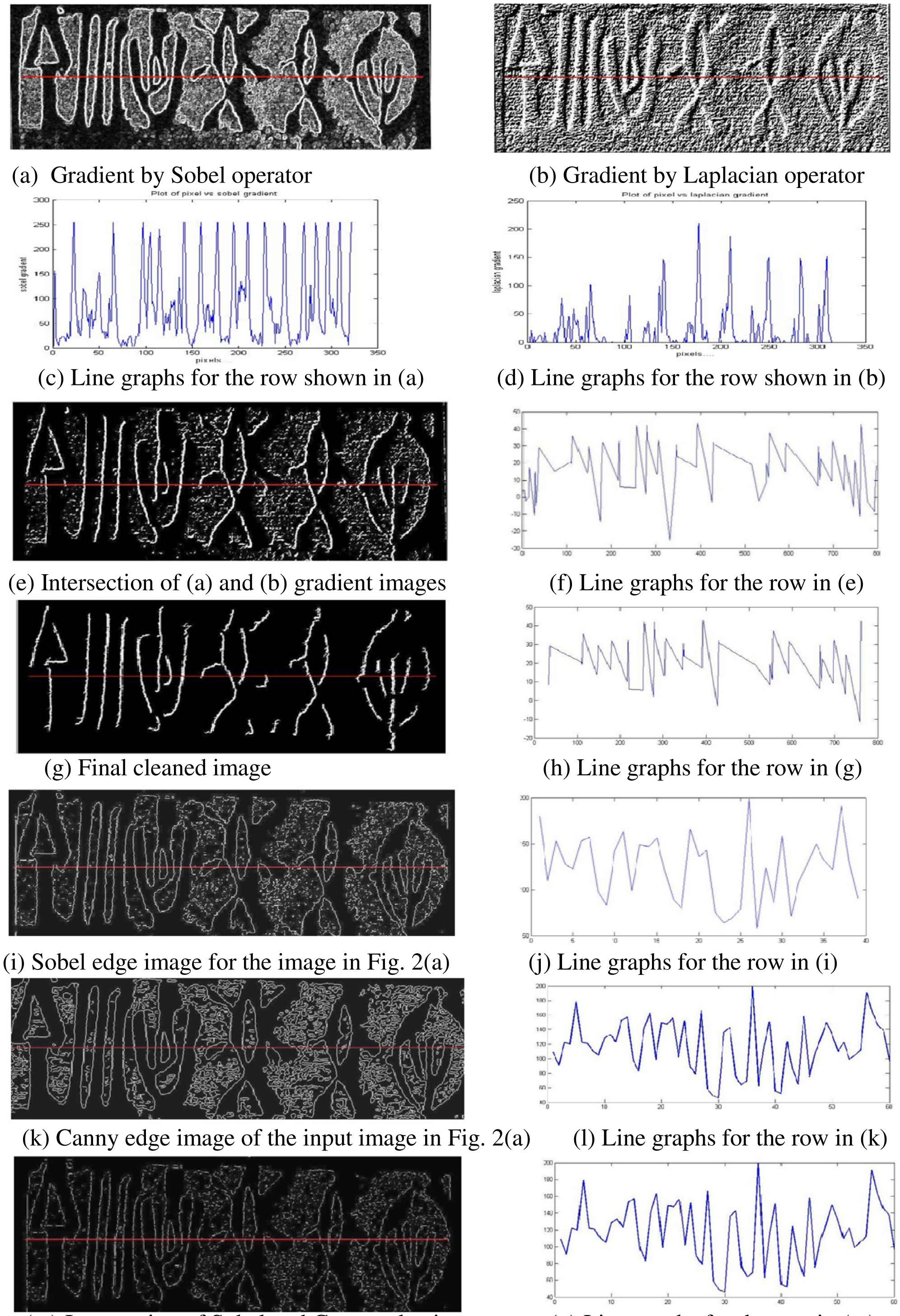
3.2. Watershed model for character segmentation

For this step, the output of the previous step shown in Fig. 3(g) is the input for segmenting characters. Fig. 3(g) shows that character components are disconnected. Therefore, to group disconnected components, the proposed method performs well-known morphological operations as shown in Fig. 4(a), where it can be noted that the components are well grouped. In addition, we can also see from Fig. 4(a) that the space between character components is visible. To extract this observation, inspired by the characteristics of watershed algorithm, namely, water flow and volume of collection water, we propose to use watershed algorithm to detect spaces between character components. Since the previous step provides cleaned images without noises, the watershed algorithm finds water flow and high volume of collection of water where there is a space between two character components. These two properties work well even if any touching exists between character components. In this way, watershed algorithm helps in segmenting characters from Indus text lines by finding non-linear spacing between character components.

As illustrated in Fig. 4, for the image in Fig. 4(a), the watershed algorithm finds water flow and high volume of water collection where there is a space between character components as shown in Fig. 4(b). Fig. 4(b) shows that the white space between the characters indicates water flow from upward to downward and high volume of collection of water. The effect of the watershed algorithm can be seen in Fig. 4(c), where it is noted that all the characters are segmented correctly. One more illustration is presented in Fig. 5, where there is a touching exists between character components. Fig. 5 shows that for the input image in Fig. 5(a), the proposed method obtains a cleaned image by the previous step as shown in Fig. 5(b), and then the proposed method performs morphological operation to group disconnected components as a single component as shown in Fig. 5(c). For the image in Fig. 5(c), when we apply the watershed algorithm, there are chances of existing touching between character components due to complex background as shown in Fig. 5(d). In this case, when the proposed method estimates flow of water and volume of collection water, the space between the characters components satisfy the properties of water flow and the highest volume of the collection of water. Therefore, the watershed algorithm segments characters components successfully for the case of touching as shown in Fig. 5(e).

4. Experimental results

Since segmenting characters from text lines in Indus documents is a new problem, we create our own dataset consisting of 500 text line images from archeology survey of India, Mysore and magazines, which include 300 text line images from Indus documents, 100 text lines from English documents and 100 text lines from other south Indian scripts such as Telugu, Tamil and Malayalam. This dataset includes a variety of text lines due to the texts on different surfaces and different handwriting with different tools. As a result, this dataset is said to be complex compared to scanned document images. To measure the performance of the proposed character segmentation method, we use the well-known measures,



(a) Gradient by Sobel operator
(b) Gradient by Laplacian operator
(c) Line graphs for the row shown in (a)
(d) Line graphs for the row shown in (b)
(e) Intersection of (a) and (b) gradient images
(f) Line graphs for the row in (e)
(g) Final cleaned image
(h) Line graphs for the row in (g)
(i) Sobel edge image for the image in Fig. 2(a)
(j) Line graphs for the row in (i)
(k) Canny edge image of the input image in Fig. 2(a)
(l) Line graphs for the row in (k)
(m) Intersection of Sobel and Canny edge images
(n) Line graphs for the row in (m)

Fig. 3. Illustration of the proposed enhancement.

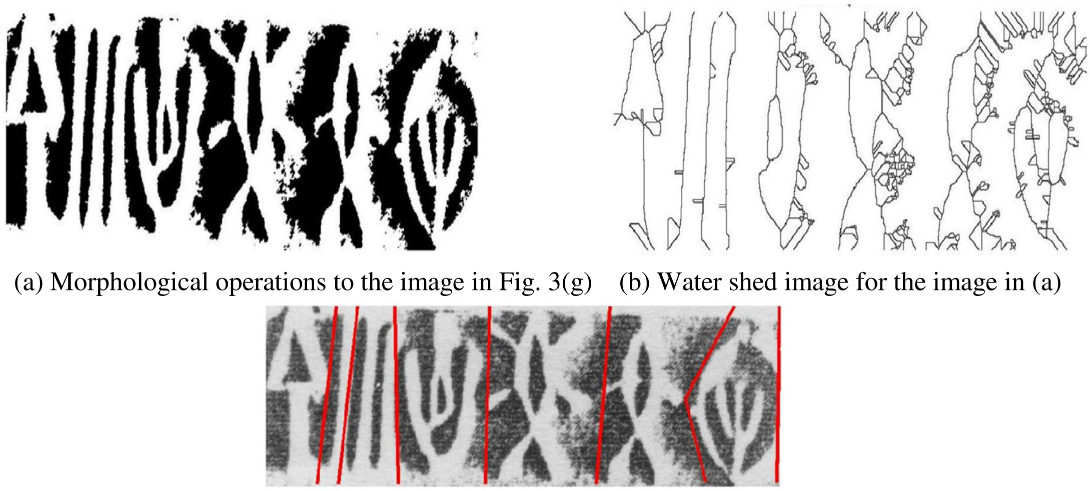
namely, recall and precision and F-measure as defined in Eqs. (1)–(3), where the test outcome may be in various facts such as TP (true positive) defined as the number of characters that are correctly segmented, Fp (false positive) is the number of false characters detected as true, and Fn (false negative) is the number of characters which is true w.r.t false category.

$$Recall = \frac{Tp}{(Tp + Fn)} \quad (1)$$

$$Precision = \frac{Tp}{(Tp + Fp)} \quad (2)$$

$$F_{Score} = \frac{2Tp}{(2Tp + Fp + Fn)} \quad (3)$$

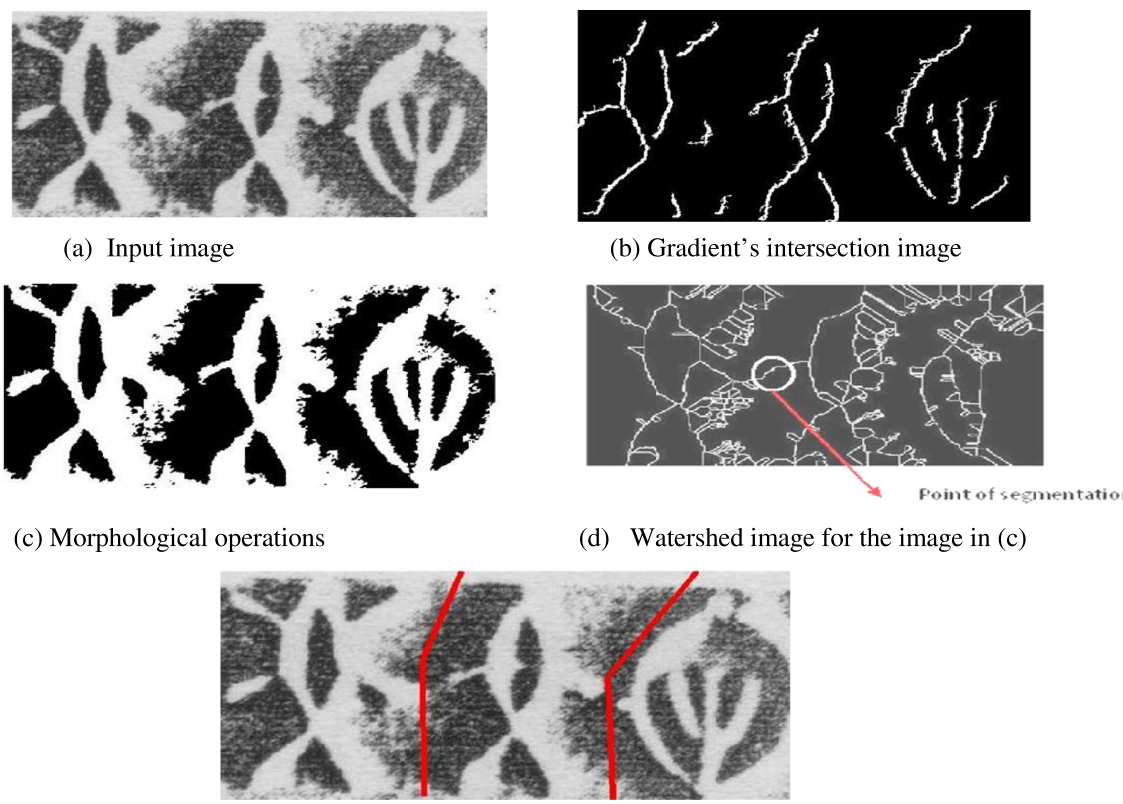
To show the effectiveness of the proposed method, we implement three methods for comparative studies, namely, [14] which uses connected components analysis and boundary of segmenta-



(a) Morphological operations to the image in Fig. 3(g) (b) Water shed image for the image in (a)

(c) Character segmentation

Fig. 4. Steps of the proposed character segmentation.



(a) Input image (b) Gradient's intersection image

(c) Morphological operations (d) Watershed image for the image in (c)

(e) Character Segmentation

Fig. 5. One more illustration for proposed character segmentation.

tion obtained using vertical projection profile for character segmentation, [30] finds segmentation points using feature points and the distances between feature points, and [3] works based on the structure of Arabic script for segmenting characters. The main reason to choose these methods is that they are the state of the art methods and work well for degraded plain document images.

Sample qualitative results of the proposed and existing methods are shown in Fig. 6 for the different scripts text lines shown in Fig. 6(a), where it is observed that Vamvakas et al.'s method [30] gives poor results for Indus text line and the south Indian scripts because the performance of the method depends on projection profiles. At the same time, the proposed features are sensitive to background noises. [14] Gives good results for south Indian script text line images compared to Indus script text line images. This is better than Vamvakas et al.'s method [30] because projection profile based features are good for script lines, where there exists clear spacing between character components and homogenous background. However, the same features are not good for clutter background and noisy images and hence it gives poor

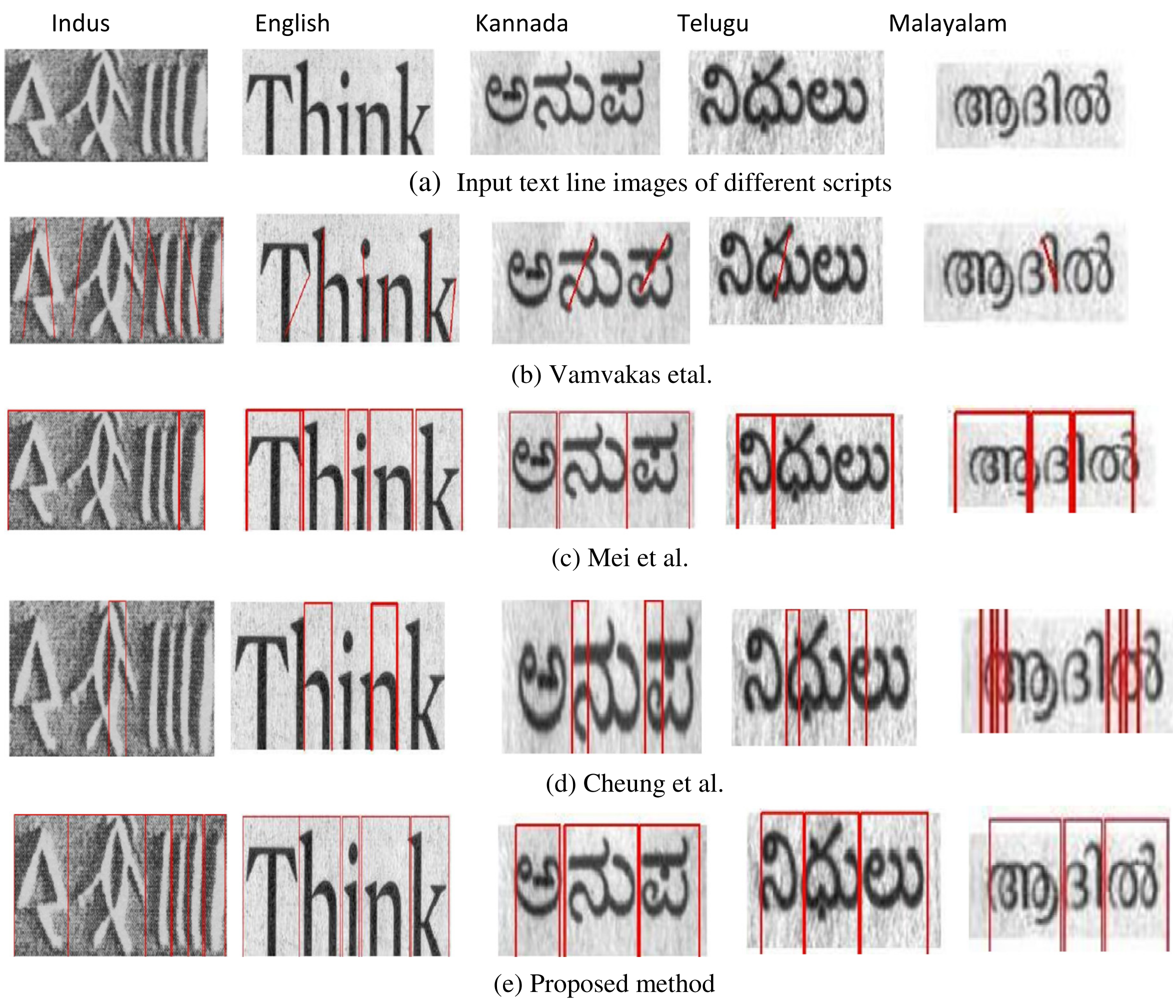


Fig. 6. Qualitative results of the proposed method for Character segmentation.

results for Indus script text line image. Similarly, Cheung et al.'s method [3] does not segment characters properly because the proposed features extracted are based on the structure of a specific script. On the other hand, the proposed method gives good results for Indus and other script text line images because of the advantage of the enhancement step and the watershed model.

To evaluate the performance of the proposed and existing methods in terms of quantitative measures, such as recall, precision and f-measure for different types of script data, we calculate the measures for Indus, English, South Indian scripts for all data as reported in Tables 1–4, respectively. It is noted from Tables 1–4 that the proposed method achieves better results compared to the existing methods in terms of recall, precision and f-measure. When we compare the results of Table 1 with those of Tables 2 and 3, the proposed and existing methods score low results for the Indus script data compared to other scripts data. When we compare the results on English script data with the results on south Indian script data, the methods gives poor results for south Indian scripts compared to English scripts data because South Indian scripts are more cursive in nature compared to English scripts. To test the contribution of the enhancement step of the proposed method, we conduct experiments without segmentation

Table 1
Performance of the proposed and existing methods on Indus script data.

Methods	Recall	Precision	F_Measure
Mei et al. [14]	0.016	0.047	0.024
Vamvakas et al. [30]	0.016	0.024	0.019
Cheung et al. [3]	0.006	0.1	0.0116
Proposed method without enhancement	0.03	0.285	0.059
Proposed method with enhancement	**0.99**	**100**	**0.99**

Table 2
Performance of the proposed and existing methods on English script data.

Methods	Recall	Precision	F_Measure
Mei et al. [14]	0.95	100	0.97
Vamvakas et al. [30]	0.3	0.375	0.33
Cheung et al. [3]	0.18	0.33	0.235
Proposed method without enhancement	0.84	0.875	0.85
Proposed method with enhancement	**100**	**100**	**100**

Table 3
Performance of the proposed and existing methods on other script (Kannada, Telugu, and Malayalam) data.

Methods	Recall	Precision	F_Measure
Mei et al. [14]	0.3	0.5	0.375
Vamvakas et al. [30]	0.3	0.33	0.315
Cheung et al. [3]	0.12	0.54	0.196
Proposed method without enhancement	0.4	0.5	0.44
Proposed method with enhancement	**0.95**	**0.97**	**0.96**

Table 4
Overall performance of the proposed and existing methods on the whole data.

Methods	Recall	Precision	F_Measure
Mei et al. [14]	0.37	0.92	0.5
Vamvakas et al. [30]	0.04	0.36	0.072
Cheung et al. [3]	0.2	0.32	0.147
Proposed method without enhancement	0.3	0.65	0.41
Proposed method with enhancement	**0.98**	**0.99**	**0.98**

step for all the datasets and the results are reported in Tables 1–4, which show that the proposed method without enhancement gives noticeable results for English scripts but fails for other scripts. The reason is the south Indian script is more cursive than English script. Due to this cursiveness, the proposed watershed model gets confusion in choosing correct columns of spacing between character components. The same thing is true for Indus script line because this script contains more noisy background and distortion compared to English. Therefore, to achieve good results for all the types of scripts, we need the enhancement step to clean background before applying the watershed model. In this way, the proposed enhancement step contributes for achieving good character segmentation results in this work.

We also noticed that the proposed method gives poor results when text line images contain blur, too low resolution, and clutter background as shown in a few samples results in Fig. 7, where one can see the background of the Indus text line images is too complex and human vision fails to identify the text information in them. In case of Kannada, Telugu script text line images, the characters look like touching each other due to cursiveness and compound characters. In case of Malayalam, the compound characters cause poor segmentation results. Therefore, there is a scope for the improvement of the proposed method.

5. Conclusions and future work

We have proposed a new method for segmenting characters from text lines in degraded historical document images like Indus. The proposed method explores the combination of Laplacian and Sobel operations for enhancing low contrast pixels in images by suppressing background noises. The characteristics of text components in an enhanced image are studied to eliminate unwanted background noise components, which results in a cleaned image with only edges which represent text components. We have proposed the watershed model for identifying non-linear spacing between characters by exploiting catchment basin and flow of water. Experimental results and the comparisons with the existing methods show that the proposed method outperforms the existing methods in terms of recall and precision. Our future plan would be extending the same method for blur images and multiple touching character component images in multi scales or multi oriented environments.

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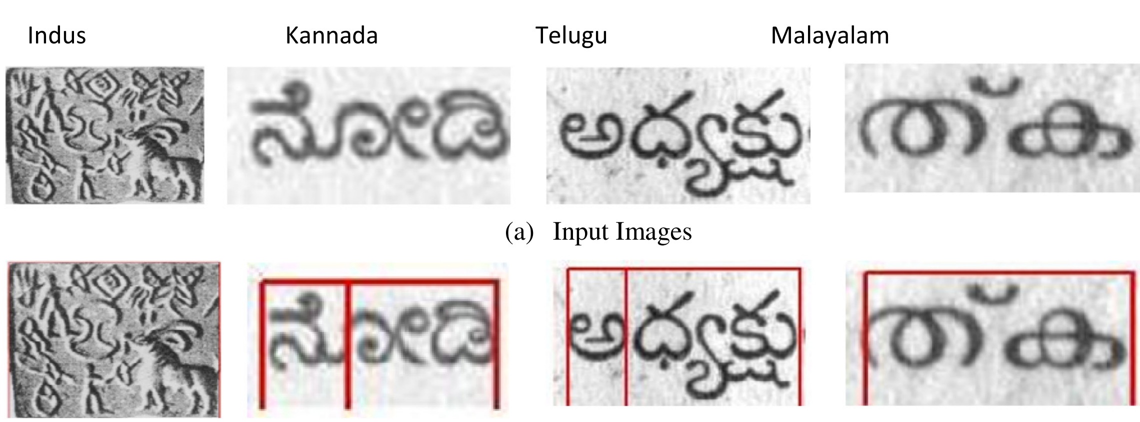

(b) Character segmentation results of the proposed method

Fig. 7. Limitation of the proposed method.

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