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Research Article

A Comprehensive Analysis of Various Text Detection and Extraction Techniques for Complex Degraded Images

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Abstract - Text extraction is a process of converting the image text into plain text. Extraction of text plays a very important role in finding image texts, editing and archiving documents. However, extracting texts from complex degraded images is a tedious work. The main challenges in text detection and recognition from complex degraded images are orientation of text, font size, diversity of background, low quality, difference in color of texts and interference of noise. A significant problem in optical character recognition (OCR) process is to extract text from complex degraded images. Therefore, it is a challenging job to design an algorithm which can produce a good accuracy irrespective of the font sizes, background, color, quality and orientation of image or document texts. In this paper, we discuss about various text extraction techniques for complex degraded images and also discuss the performance analysis as well as compare the advantages and disadvantages of each techniques.

Keywords **- Optical Character Recognition (OCR), Segmentation, Classifiers, Projection profile, Hough transform, Gabor transform, Stroke width transform**

I. INTRODUCTION

Images are usually distorted by noise during its acquisition, processing, transmission and reproduction. Restoring the original image after removing the noise is a fundamental objective of image processing. While; text extraction is a method of eliminating the text from complex images or in other words, text extraction is a method of extracting the valuable information from complex images. Text extraction is useful for characters recognition. Recognition of text is known as optical character recognition (OCR). Along with noise some other parameters such as orientation, horizontal or vertical line and font size affect the accuracy and performance of these processes.

In this work, we discuss about text extraction methods for complex images. Also, various text segmentation or extraction algorithms is compared on the basis of multiple parameters. The remaining part of the paper is structured as follows. We discuss the image analysis, OCR process as well as various text extraction techniques in Section 2. In Section 3, performance analysis for different algorithms is discussed. Performance evaluation is discussed in Section 4. Comparative analysis for different algorithms is discussed in Section 5. Finally, the work is concluded in Section 6.

II. IMAGE ANALYSIS

The optical character recognition process consists of mainly three stages which are pre-processing stage, segmentation stage and character recognition stage. In pre-processing stage removal of noise and

image enhancement processes take place. While the segmentation stage is used to extract texts. In the last stage the character is recognized with the help of OCR as shown in Fig. 1.

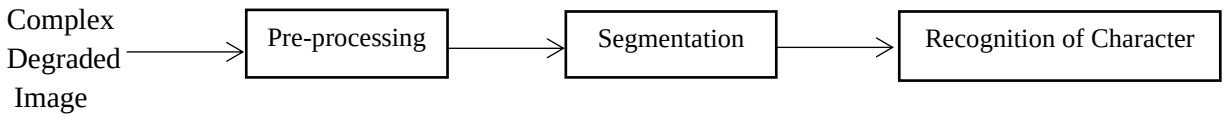

Fig. 1. Optical Character Recognition Process

A. Text Extraction

Text extraction from complex coloured images is a tedious work. Text extraction plays a vital role in image finding and archiving documents. The methods of text extraction from complex degraded images can be classified as shown in Fig. 2.

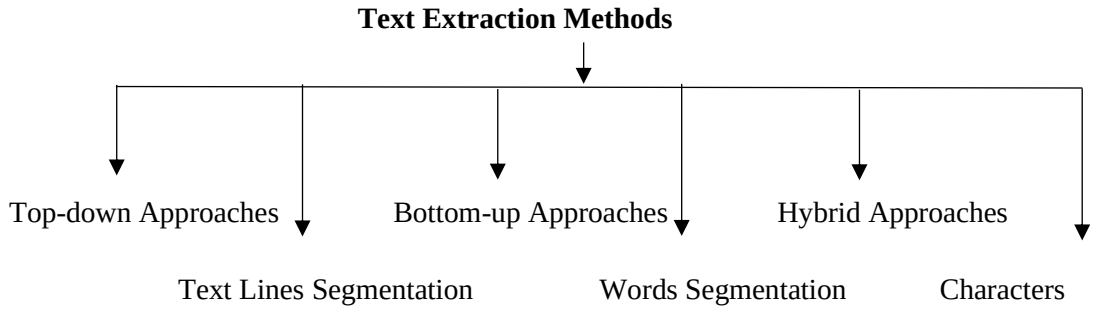

Fig. 2. Methods of Text Extraction

1) Top-down Approaches

In these approaches, the segmentation of text starts at block stage then proceeds to word stage then after character stage and in the last it goes to stroke stage.

Q. Ye et al. [1] projected image decomposition using wavelet transform later the text areas are find out with the help of properties of wavelet energy. In the last, parameters such as wavelet moment and histograms were calculated and features of histograms were separated. These features were used as an input to classifiers for validating the texts.

M. Priya and C. Gobu [2] reduced the number of colors of the image using quantization. After that, wavelet transform is used to decompose the image for feature vector generation. This feature vector is then used to form foreground and background clusters using FCM. Further, remaining noise is removed using erosion operation.

2) Bottom-up Approaches

The bottom-up approaches use the reverse process of top-down approaches i.e. text segmentation initiates from stroke stage then proceeds to character stage then to word stage and in the last it goes to block stage. These approaches do not depend on font styles or sizes of characters.

N. Ezaki, M. Bulacu, and L. Schomaker [3] proposed a method of text detection for visually challenged people. They extracted the small sized characters using geometrical operations but, for large characters, Sobel filter is used. Geometrical operation removes very small texts by assuming it as noise.

Moreover, this approach detects high intensity non-texts as well.

S. H. Lee et al. [4] first segmented the complex image into many regions. Then all the segmented regions are assigned different labels. This is done by using CRF model. All the segmented regions provide proposal for character regions. Text lines are formed when these proposals are grouped. This segmentation helps to deal with the images of complex backgrounds as well.

B. Epshtein et al. [5] projected an algorithm that used a transform called stroke width transform which is used to combine pixels and form letter. Filtering and clustering operations are used to merge these letters into texts. These texts are then merged using histogram features to form words.

S. Karaoglu et al. [6] used the binarization of complex degraded images and extracted some important features such as occupy ratio, aspect ratio and filled area. Random Forest Classifier (RFC) is having high accuracy since it can tackle huge quantity of input variables and for classification they are treated equally.

3) Hybrid Approaches

Hybrid approaches are a blend of top-down and bottom-up approaches. Unlike top-down as well as bottom-up approaches, they do not follow a definite order for segmentation. These approaches are efficiently used instead of two aforementioned approaches due to huge variations of text.

T. Saoi et al. [7] proposed texture feature evaluation in which they used a 2-D wavelet transform. In addition to that, evaluation is also done for different clusters such as: texts and complex background. After that, OR logic gate is used to combine different results obtained from the classifier so that text regions can be detected.

A. Gonzalez and L. M. Bergasa [8] used the Maximally Stable Extermal Regions (MSER) algorithm to find out characters in complex image. MSER algorithm is used due to higher stability and multi-scale detection without any smoothing. Then merging of same characters is done for text segmentation. Text segmentation is done by using classifier. After that, words are extracted from these texts.

Deepa et al. [9] projected a technique in which they started with the classification of the image on the basis of their features using convolutional neural network. After that text extraction is performed with the help of an OCR tool called Tesseract. Finally, this extracted text is stored.

Islam R. et al. [10] proposed an algorithm which is a blend of edge and connected component methods. Since, using edge based algorithm can only extract texture information while, algorithm based on connected component can filter only texts from non-texts. So, merging these two methods improve the accuracy of text extraction process.

Chakraborty et al. [11] proposed a text extraction algorithm with the help of MATLAB. They basically used template matching method in addition to OCR system. First, they find MSER from the image text then Canny edge detector is used for text division and later Stroke width transform is performed to filter the characters. Finally, OCR process is applied to text regions for the extraction. The proposed algorithm has been applied to various types of text images and obtained good results.

In this projected work by Akash et al. [12] a system is built for detection of traffic instruction which is written in Bangla and convert them into English. In this method three steps are involved which are text extraction from sign image, its post-processing using language model and in last machine translation. Here, Canny edge detector has been used for edge detection in the pre-filtering process so the effect due to noise is less.

K.N. Natei et al. [13] proposed a method that provides good performance in text extraction as they

combined Edge Based and Connected Components algorithms. In this projected algorithm various images of DIBCO 2017 dataset has been tested and it provides good result.

4) Text Lines Segmentation

Text segmentation plays an important part in word segmentation as well as recognition stages. However, it faces some difficulty in handwritten texts. Efficiency also is a major concerned for degraded images.

Adaptive run-length smoothening algorithm has been used in this methodology proposed by N. Nikolaou et al. [14]. In this algorithm, the removal of noise is done by using binarization of the complex image and after that they applied the algorithm on the obtained image, it is then used to form the text regions. The advantage of this algorithm is

that the limitation of run length smoothening algorithm has been removed. Words segmentation as well as characters segmentation has also been performed.

X. Du et al. [15] projected a method that can be used for handwritten documents. In this methodology, they first used Gaussian filter to blur the handwritten document. In the last, they used morphological operations remove noises. Also, this helps in identification of text lines. The speed of this method is better than the methods discussed above.

A. Alaei et al. [16] proposed a method in which prior to binarization of complex image they divide it into segments using piecewise linear segmentation algorithm. Due to the binarization, there might be some loss in texts of complex images. Later, dilation operation is done to remove discontinuity in text lines. They also used the text line separators. At last, the overlapped text lines are filtered out using the contour points between touched text components.

Z. Liu, H. Zhou, and N. Yang [17] proposed an algorithm that consists of image binarization and image masking. Masking of image is done by using Vincent seed filling. After that, histogram technique and classifier are used to remove border noise and content noise respectively.

W. Boussellaa et al. [18] used handwritten Arabic documents for text extraction. The handwritten document is first divided into vertical sections and after that the sections are classified in small, medium and large using clustering technique. Then horizontal histogram is used for calculating the initial points of every horizontal line. At last, text lines are determined in a vertical section at the center.

V. Malleron et al. [19] also used binarization of document image. After that, edge of document images is extracted with the help of clustering technique. Then after text lines are extracted using borders of document images and Hough transform. Finally, the missed components are grouped together with text lines using line orientation.

D. Pandey et al. [20] projected a deep learning (DL) technique for text extraction. In this technique, first the complex image is resized in pre-processing stage. Then guided image filter has been added to enhance the contrast of this complex image. After that, a watershed segmentation is put over the enhanced text image. Next, the feature extraction is performed with the help of Gabor transform and Stroke width transform. After that, the text or non-text part has been identified using Weighted Naive Bayes Classifier. At last, recognition process takes place using deep neural network as well as adaptive galactic swarm optimization

5) Word Segmentation

Some techniques performs the word segmentation directly from document images but, some other techniques require text lines segmentation for word segmentation. The factors which determine the

performance of the word segmentation are same as for text line segmentation.

C. Huang and S. Srihari [21] used a pre-processing step to segment the texts lines. The pre-processing step involved statistical methods. After this, various features such as height, width, average height and average width are calculated for words segmentation from text lines. By including some more features this approach can be used for different scripts as well.

S. Saha et al [22] eliminated background information using image binarization and then in pre-processing step they used edge detection and after that Hough transform is applied for word segmentation. Finally, for each word a bounding box has been created.

V. K. Koppula et al. [23] chose handwritten text in Telugu scripts. They first found the connected components. Later, they found spatial relations between neighboring components using an undirected graph. In this graph, each component forms a node and these nodes are then connected to form the text segmentation. At last, they formed word segmentation using vertical projection of each text line.

J. Ryu et al. [24] calculated intra and inter word gaps. And then they marked labels to each gap by evaluating their cost functions with the help of feature vectors corresponding to the adjacent pixels such as projection profiles, distances and gap ratios.

Y. Zheng, H. Li, and D. Doermann [25] proposed a method in which they also chose handwritten texts for word segmentation. They first found the connected components and created bounding box. After that, they calculated average width and height of each connected components and on the basis of these values, they merged the characters and formed words segmentation. After that they used classifier for identification of handwritten texts. The features of the classifier are based on histograms, projection profiles and frequency response by FFT.

R. Deepa et al. [26] proposed a technique that classifies the complex image first then text extraction is done. The image classification is performed using the Convolutional Neural Network (CNN), in which classification of images is done on the basis of feature extraction. Later, text is extracted using Python-Tesseract. Finally, the extracted text can be stored in a database. The CNN methodology improves the overall system performance since it removes the issue of overfitting.

6) Character Segmentation

Character segmentation phase plays a vital role in optical character recognition process. The proper character segmentation enhances the accuracy of classifiers. Problem appears when spreading of characters occur because of touching or overlapping. This is caused due to ambiguous handwritten texts.

S. Nomura et al. [27] proposed a morphological approach for character segmentation of complex degraded images. They started with binarization of degraded images after that they used thickening and pruning method to remove the noise. Then a vertical histogram is used to calculate the segmentation points using the width of digits and letters. Then they calculated the standard deviation to group the fragments of same character. Finally, the overlapped characters are filtered out by evaluating the crossing points.

W. L. Hwang et al. [28] used wavelet transform to find the edges of the characters. The character at various scales of

wavelet transform is preserved by removing noise; this is done by using threshold. After that, the inside

pixels of the characters are evaluated by neighborhood. At last, they used Bayes' classification for evaluating the character pixels and hence segmented the characters.

A. Choudhary et al. [29] used binarization of the document image. After that, the area of each connected components region is calculated. Then, the areas which are too large or too small have been removed. At last, true connected components are segmented as individual characters.

S. Urolagin et al. [30] first used the Gabor transform and obtained its response of connected characters. Later, they evaluated the vertical projection profile and based on that column index on valleys within the projection profile is obtained.

III. PERFORMANCE ANALYSIS OF DIFFERENT APPROACHES

A list of existing text extraction approaches with their performance analysis is shown in Table I.

Table I. Performance analysis of different approaches

S. N.	Approaches	Authors	Year	Techniques Used	Recall rate (%)	Precision (%)	F-Scale (%)	Accura (%)
1.	Top-down Approach	Q. Ye et al.	2005	Wavelet transform, wavelet energy Histograms	94.2	-	-	-
		M. Priya et al.	2013	Wavelet transform, FCM	87.6	82.7	-	-
2.	Bottom-up Approach	N. Ezaki et al.	2004	Geometrical operations, Sobel filter	76	48	62	-
		S. H. Lee et al.	2013	CRF model	75	66	70	-
		B. Epshtein et al.	2010	Stroke width transform	67	62	-	-
		S. Karaoglu et al.	2010	Random forest classifier	78	80	-	-
3.	Hybrid Approach	T. Saoi et al.	2005	2-D wavelet transform, OR logic gate	74	52	-	-
		A. Gonzalez et al.	2013	Maximally Stable Extermal Regions	56	72.67	63.25	-
		Islam R. et al.	2016	Edge based and connected component	96.68	89.05	-	87.25
		Chakraborty et al.	2020	MATLAB, Canny edge detector	-	-	-	90-100
4.	Text Lines Segmentation	N. Nikolaou et al.	2010	Adaptive run-length smoothening algorithm	-	-	60.4	-
		D. Pandey et al.	2020	Deep learning, Vincent seed filling, GT, SWT, WNBC	96.8	93.79	95.2	98.38
		C. Huang et al.	2008	Statistical methods	-	-	-	90.82

5.	Word Segmentation	S. Saha et al.	2010	Edge detection and Hough transform	-	-	-	88-95
		V. K. Koppula et al.	2009	Vertical projection profile	-	-	-	98.7
		J. Ryu et al.	2015	Feature vectors	-	-	-	94.25
		Y. Zheng et al.	2002	Connected components, FFT	-	-	-	97.3
6.	Character Segmentation	A. Choudhary et al.	2013	Connected components	-	-	-	98.47-98.92
		S. Urolagin et al.	2010	Low frequency Gabor filter response	-	-	-	93.82

IV. PERFORMANCE EVALUATION

There are various parameters that helps to evaluate the robustness, strength and efficiency of an algorithm used for text extraction. Most of the algorithms discussed here used Recall rate, Precision rate and F-Score parameters to calculate its performance. These terms are evaluated on the basis of number of correctly detected characters in an image. These parameters are defined as follows:

1. False Positives: Those non-text regions which are detected as text by the algorithm.
2. False Negatives: Those text regions which are not detected by the algorithm.
3. Recall rate: It is defined as the ratio of the accurately detected texts to the sum of accurately detected texts and false negatives.
4. Precision rate: It is defined as the ratio of accurately detected texts to the sum of accurately detected texts and false positives.
5. F-Score: It is defined as the harmonic mean of recall rate and precision rate.

V. COMPARATIVE ANALYSIS FOR VARIOUS ALGORITHMS

A comparative analysis for different algorithms on the basis of their benefits and drawbacks is depicted in Table II.

Table II. Comparative analysis for Various Algorithms

S. N.	**Methods**	**Techniques used**	**Advantages**	**Disadvantages**
1.	Top-down Approaches	Learning based [1]	-Accuracy is high -It can handle complex background images very efficiently.	-Comparatively slow -Sometimes detect non-text as text.
		Clustering based [2]	-It is highly accurate to complex varying background and font.	-Faces difficulty for text and non-text regions having similar features. -Does not work properly for large reflection images.

2.	Bottom-up Approaches	Learning based [3-6]	-Accuracy is high -It can handle complex varying background and font.	-Gives error in same color background. -Slow -Does not work well for large reflection images.
3.	Hybrid Approaches	Clustering based [7, 8]	-It can smoothly handle texts of varying font as well as size.	-Sluggish -It is not very suitable for complex document images.
		Region based [10-12]	-Less expensive -Script independent -Robust to varying font size and skew.	-Small text regions can't be detected.
4.	Text Lines Segmentation	Smoothening Based [14, 15]	-It can be used for printed as well as handwritten texts. -Can handle noise well.	-Sometimes detect two or more text lines. -Sometimes miss page number and date.
		Region based [16-18]	-It can be used for printed as well as handwritten documents. -Speed is good if the document does not contain any graphical objects.	-Sometimes miss some small texts and diacritics. -Error in vertically merging with other text regions.
		Hough transform Based [19]	- It can handle skew and overlapping components.	- Gives error in segmentation. -Difficulty in separating vertically connected texts.
		Clustering based [20]	-It can handle multilingual scripts. -Robust to skew and spaces.	-Slow -Noise error is present. -Error in vertically connected lines.
5.	Words Segmentation	Gap distance based [21]	- It can be used for printed as well as handwritten texts. - It can be applied directly on entire image.	- Sensitive to noise. -Does not work properly on large word gaps.
		Projection profile Based [22-24]	-Fast -Easy to implement. -It works well on uniform and printed documents.	-Error due to noise is present. -Does not work properly for touching components.
		Learning based [26]	-Accuracy is high. -Works for both handwritten and printed document scripts.	-Produces error in case of handwritten variations. -Error is present when inter and intra words gaps are same.
6.	Characters Segmentation	Projection profile based [27]	-It can handle printed documents only. -It can work at different scales.	-Error is present due to noise and skewed characters.
		Graph based [28]	-It can work well for multilingual, touched and overlapped characters.	-Sometimes shortest segmentation paths get confused to decide boundaries.

		Learning based [29, 30]	-It can work well for multilingual, skew touched and overlapped characters. -It can also be used for non-linear segmentation.	-Produces error when characters contain overlapping. -Sometimes characters are falsely segmented because of noise.

VI. CONCLUSION

The methods of text segmentation or extraction have been discussed in details. We have tried to analyze different algorithms for various types of complex images. All the methods discussed here are then compared on the basis of different parameters such as accuracy, detection rate and precision and a comparative chart has been made. This chart would really help researchers in the field of complex image segmentation and analysis. Since, no algorithm is perfect that can work well on every complex image. Every algorithm has its own advantages and disadvantages. Depending on the types of images, we choose the best suitable algorithm for text segmentation or extraction. After text segmentation, the OCR process begins. This OCR process depends on classifiers. The accuracy of recognition depends on the feature vectors. Larger the feature vectors data more will be the accuracy. Usually, text segmentation algorithms improve the efficacy of OCR process.

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