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A Comparative Study of Specific Phase based Character Recognition Techniques for Various Scripts

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***Abstract*—** Character recognition creates an increasing demand on various evolving applications areas and methodologies of image processing in order to effectively recognize text of each script. It is considered as common method of digitizing an image in order to gather text of image more efficiently. The stages of character recognition include pre-processing, segmentation, feature extraction, classification and post processing. It has been noticed that there exist numerous languages such as Marathi, Gujarati, Gurumukhi, Arabic, Modi etc. where stages of character recognition lays important role for recognition of text image. Pre-processing and segmentation are considered as two crucial stages of character recognition with the purpose of providing smooth and clean image for further processing. These stages help in enhancing color format, to maintain skew angle of images, compresses size of image, separates line word and characters from images etc. A comparative study of various sub stages of pre-processing and segmentation is performed based on some parameters such as data type, window size, recognition rate, sample size, and so on. These parameters help in improving quality of image in order to achieve successful recognition rate.

***Keywords*—**Character recognition, binarization, noise reduction, segmentation, compression, normalization.

I. INTRODUCTION

Today, character recognition includes information about text collection, analysis and processing, classification and discrimination etc. where Optical Character Recognition (OCR) is becoming an important part of modern research based computer applications. Especially with the advent of Unicode and support of complex scripts on personal computers, the importance of the aforementioned application has increased [1]. Character recognition system involves processes namely; pre-processing, segmentation, feature extraction, classification and post-processing [2]. During pre-processing, the noise introduced by the optical scanning device or the writing instrument, causes disconnected line segments, bumps or gaps in lines, filled loops etc. It has been observed that noise is effectively removed by using median filters whereas in order to remove scanning artifact's morphological operations are performed [3]. On the other hand, local thresholding algorithm performs the binarization of image documents and utilizes the shape feature, stroke width of handwritten and printed characters in image for binarization. Local threshold algorithm uses threshold value locally and found to be superior in terms of segmentation quality to the threshold approaches that completely uses intensity information [4].Character segmentation performs some operation that seeks to decompose an image of a sequence of characters into sub-images of individual symbols. In the view of character segmentation, Arabic character script algorithm is applied based on morphological analysis which aims at the segmentation of isolated handwritten words into perfectly separated characters [5]. In this contrast, projection based approach identifies and tested on text image for segmenting non-overlapping lines and characters. This approach is based on nearest neighborhood method to cluster the connected components. It presents considerable results for broken characters that are over segmented [6].

Several recognizers must be capable of recognizing the characters, numbers/ other special characters existing in text of any language accompanied with various preprocessing and segmentation techniques. Literature reveals that lot of research efforts have been performed on the recognition of various scripts concerned with different languages. Section II basically deals with the description of numerous existing preprocessing techniques for various scripts in brief. Abundant existing segmentation techniques are discussed in Section III. In Section IV, we present the overview of these processes along with their input type, techniques, sample size, accuracy etc. for various languages. Finally, we conclude with the vital results and conclusion in Section V.

II. PRE-PROCESSING TECHNIQUES

The preliminary step for recognizing handwritten/ printed character of any script is the preprocessing which involves operation on the digitized image. At this stage, set of operations is engrossed to produce a modified image which is less complex to be used directly and efficiently by the feature extraction stage. Further, this process may be comprised of some sub-processes namely; noise reduction, binarization, compression, normalization, skew correction, slant angle correction and thinning [7] [8] [9] etc. We discuss some of these sub-processes that have found to be used in common in varied applications as follows:

A. Noise Reduction

In order to remove speckle noise which contains high frequency content, discrete wavelet transform thresholding technique has been used for ultrasound image where quantization method divides the input image into subsequent four filter coefficients. Thus, wavelet based technique is used to improve visual quality of an ultrasound images effectively [10]. On the other hand, median filtering technique is applied to remove salt and pepper noise on compound images. Performance analysis of compound document image as well as scanned compound images is measured by peak signal to noise ratio (PSNR) which shows highest PSNR value of 21.85 for compound document image [11]. Also, Mean Absolute Gradient is new adaptive noise reduction scheme used to identify pixels which are corrupted by salt and pepper noise. The aforementioned scheme removes salt and pepper noise with noise density as high as 90% measured by PSNR and produce better result in terms of qualitative and quantitative measures of images [12].

Boundary Discriminative Noise Detection Filter (BDND), Adaptive Bilateral Filter (ABF), Fuzzy Peer Group Filter (FPGF) and Switching Bilateral Filter (SBF) filtering technique has been implied to reduce high density impulse noise from gray scale images. Thus, investigational results depicts that the BDND denoising method shows better outcome for all five performance parameter [13]. In addition, several filtering techniques mainly; Linear Smoothing filter, Median filter, Wiener filter and Fuzzy filter are studied for color image to remove existing noises such as Gaussian noise, salt & pepper noise, speckle noise, shot noise etc. In this context, to measure the performances of filters, two performance parameters namely; Mean Square Error (MSE) and PSNR is used for color image. As a result, fuzzy filter gives better MSE and PSNR value as compared to other filters for reducing noises from image [14].

B. Binarization

Modified logical thresholding method based on adaptive logical level technique has been developed to binarized degraded gray scale text image. Binarization process segments 256 gray scale images into two levels such as black and white text image based on thresholds value. Thus, the values which are higher than threshold value are considered as white whereas those values which are lower than threshold value are considered as black. As a result, modified thresholding methods can threshold gray-scale text images with complex signal dependent noise and variable background intensity. According to the local run-length histogram for the selected regions, it can adaptively measure the size of local analysing area and logical thresholding level [15]. Further, handwritten cursive words are binarized by using Otsu thresholding as it automatically selects threshold value for handwritten cursive image [16]. In order to binarize Modi vowels, Otsu thresholding technique has been applied. Global threshold value is considered to separate foreground and background information more suitably. Edges are detected to carry out foreground information appropriately. Thus, image is filled with flood fill to avoid break in boundary contour [17]. Also, thresholding method used for determining threshold value of gray scale handwritten Guajarati numerals image where value for threshold is decided by considering bimodal distribution of gray level values [18]. Additionally, morphological transform method has been used to generate binarized Urdu handwritten characters image. Consequently, images are taken in any font in any size whereas only isolated characters will be recognized effectively [19].

C. Compression

JPEG image compression algorithm has been prepared which generates unique vector for identifying each numeral. Nonetheless, unique vector helps the system for recognizing the input numeral after measuring the Euclidean distance between the vector corresponding to the numeral and the vectors in the codebook as well as the length of vector. As a result, this technique is mainly focuses on recognizing numeral with reasonable recognition rate [20]. Specifically, an image compression technique named as DjVu has been adapted towards the compression of scanned documents in color at high resolution. On the other hand, the foreground is compressed with a bi-tonal image compression technique and background is compressed with a new progressive, wavelet-based compression method. Hence, text layout analysis is applied to index and edit text extracted from DjVu encoded text images [21]. Furthermore, connected component labelling algorithm is applied on background separated Devnagari scanned handwritten text image as it stores the components of two words/ among two words. Resultantly, overall reduction rate is measured as 75% for gray scale handwritten images [22].

D. Normalization

Normalization process mainly focuses on removing the variations of the writing on character image in order to obtain standardized image. Aspect ratio adaptive normalization (ARAN) method has been incorporated on image into normalization procedure as opposed to the aspect ratio

preserving normalization to control the aspect ratio of normalized numeric character images. Moreover, the aspect ratio of normalized image is a continuous function of the aspect ratio of original image whereas other normalization techniques are used to reduce shape variations. In this view, ARAN improved the shape distortion caused by conventional normalization and to preserve useful geometric information [23]. Further, slope and slant removal algorithm for cursive handwritten words is implemented which is composed of two steps mainly; deslope and deslant. The efficiency of algorithm is evaluated based on Bern and Cambridge databases as compared to traditional normalization techniques. Hence, slope and slant algorithm shows the effective improved recognition rate of 10.8% in comparison with traditional normalization techniques [24].

Text normalization method for Arabic handwritten characters has been projected which includes seven stages namely; connected component allocation, candidate baseline regions detection, text skeleton analysis, baseline allocating for each baseline straightening procedure, text slant correction for segmentation purposes. Exclusively, experiments are conducted on the IFN/ENIT dataset to validate the strength of the normalization method. In order to evaluate the performance, results of preferred method are compared visually with the results of Pechwitz, Farooq and Boukerma. Thus, result shows satisfying performance over other normalization methods and is also capable to process machine printed texts as well as handwritten texts without any modification [25].

E. Skew Angle Detection and Correction

Skew angle detection as well as correction methods are used to align the text image with the coordinate system of the selected area. There exists several approaches for skew detection which include mainly; Correlation, Projection Profiles, Hough Transform, Linear Regression etc. In this view, Linear Regression technique is projected for skew angle detection of handwritten and printed Gujarati script. In order to estimate the skew angle efficiently, this technique is applied on black pixels of an image as it is simple and fast for detecting angle of rotation as well as it corrects the skewed image rapidly. Correspondingly, in case of major rotational angle variation between ranges 15° to 40° angle, mentioned approach shows 59.63% of accuracy for printed along with 45.58% of accuracy for handwritten characters [26]. In the same manner, newfangled skew detection method based on least square method is introduced for unconstrained 700 cursive Sinhala words together with handwritten real postal addresses feeded in NSF database. During experimentation, thresholding approach based on NIR, QIR, gray level intensity distribution including noise removal approach based on median filtering and connected component analysis has been applied on text images. As a result, the envisaged method depicts overall 98.4% recognition rate for 1200 patterns of images and estimate accurate skew angle of Sinhala word images and indirect rotation method effectively correct skew angle of the cursive words with high accuracy. [27].

Word centroid method along with dilate & thin approach is implemented based on Connected Component Analysis and Hough Transform on machine printed text images. Moreover, word centroid method deals with the centroids of selected words which are used for skew detection whereas in dilate & thin approach; the selected characters are blocked and dilated to get word blocks and shortly thinning is applied on images. The final image fed to Hough transform has the thinned coordinates of word blocks in an image. The methods have been successful in reducing the computational complexity of Hough transform based on skew estimation algorithms [28].

III. SEGMENTAION TECHNIQUES

Segmentation of handwritten characters separates the characters into different zones such as upper, middle and lower zone based on variability in paragraph, words of line and characters of a word, skew, slant, size, curved etc. Sometimes components of two adjacent characters may be touched or overlapped and these situations generate difficulties in the segmentation task. Touching or overlapping problem occurs frequently because of modified characters in upper-zone and lower-zone [29]. In literature, we have observed that efforts have been put on word and line segmentation as well as on character segmentation reasonably. And hence, we discuss these issues involved in segmentation process as follows:

A. Character Segmentation

In course of character segmentation of Gurumukhi script the reverse engineering has been performed where one part is extracted from the word present in the line. The extracted part is checked whether it employ some meaningful symbol as per Gurumukhi script. However, if there exist some symbols, then the extracted part is marked and written in the file, otherwise the extracted part is readjusted to search the symbol [30]. Further, connected components approach has been implemented in order to segments character of Modi script effectively. In this method, the proposed system pursues to recognize words as a whole and as a result avoid the necessity to segment it into characters [31]. Moreover, an internal segmentation technique which is the isolation of letters especially in cursively written words has been applied in order to decompose series of characters image into sub-images of individual character of Devanagari script. Accordingly, internal segmentation techniques used to separate lines, words and characters of an image as well as comprise of classification of boundaries of characters [32].

Self-Organizing Feature Maps (SOFM) method is used for the character segmentation of the touching Sinhala character pairs in more uniform way. Henceforth, vertical

projection profile has been used for the basic segmentation of characters including touching characters as one single unit. Connected component labelling process applied to identify the presence of overlapping characters and if there exist more than two labels, each connected component is considered as a single character. The remaining segments which are gained only one label in the connected component labelling are recognized as touching characters [33]. Similarly, for segmenting Arabic script into independent characters, text are distributed into three different zones namely; baseline zone, middle zone and upper zone. In this aspect, vertical projection profile is designed for middle zone where a stable threshold value is determine for scattering Arabic words into individual character and achieved overall 73% recognition rate [34]. In this perspective, peculiar method based on a decision tree construction along with concept of projection profile histograms is proposed for distinguishing 4320 digits of Cursive script with 540 patterns of zip codes. The above mentioned method includes three major parts mainly; image compensation where projection histogram is performed, heuristic criteria and refinement which fragments the fragile connections into isolated form. As a result, decision tree effortlessly provides 320 correct segments, 48 multiple digit segments and achieved overall performance of 83.47% for segmenting digits [35].

B. Line Segmentation

A line wise identification model identifies and separates the text lines of Telugu, Hindi and English scripts from a trilingual document. The specified approach is based on the analysis of top and bottom profiles of individual text lines and hence does not require any character/ word segmentation. Resultantly, identifies and separates the different language portions of the document and place the individual language regions to appropriate OCR system [36]. A morphological operation performs the task of separating individual text lines from unconstrained handwritten text images. The process aims at segmenting individual text lines from text images using run length smearing algorithm. For this reason, the foreground portion of smoothed image is destroyed to get some crucial components from the individual words of the text as well as erosion has been performed on background portions to find some boundary information of text lines [37].

Level set method has been suppressed to determine the boundary of neighbouring text lines by evolving an initial estimate. Gaussian window approach converts binary image into gray scale for enhancing text line structures. Initially, the level set method refined for binary image latter this method is extending to gray-scale and color based text images without any major change. Although, above named approach produces reasonable results under variation of skew angles, character sizes, and noise [38][39]. On the other hand, strip based projection profile technique is introduced to segment lines further to segment lines into words using white space and pitch method for Gurumukhi script. Specifically, the projected method divides the text image across its width into number of strip and later analyses the projection profiles of foreground pixels in each strip. Although, white space and pitch method detects the horizontal white space between successive words in lines in order to divides handwritten text lines. Consequently, achieve average accuracy rate of 98.2 % for lines segmentation whereas the average accuracy for words is 98.4 % attained [40].

C. Word Segmentation

Arabic word segmentation algorithm separates the horizontal overlapping between Arabic words/ sub words neglecting the segmentation step where one can easily determine the actual character segmentation points. Character stacking problem occurs during segmentation process of Arabic words. Thus, the problem is solved simply by including all possible deformed characters and stacked character sets in the databases. Alternatively, a horizontal fragmentation algorithm is needed to solve the character stacking problem [41]. Additionally, a database of machine-printed Arabic documents has been created for machine-printed Arabic words. The Arabic handwritten database contains words used for the numbers and quantities in cheques filling. In that event, the database deals with handwritten Arabic text, both in terms of the size of the database as well as the number of different writers involved. The former mentioned database mainly focuses on taking out bitmap of words using some pre-processing operations [42]. Nevertheless, isolated handwritten words segmentation technique is design especially for various handwritings in Gurumukhi scripts. Handwritten words are also prone to the problem of overlapped, connected, merged and broken characters. Segmentation accuracy of 88.1% acquires for segmenting all types of handwritten words in Gurumukhi script [43].

Furthermore, a unique segmentation algorithm based on contour and skeleton technique is investigated for segmentation of 6300 Arabic words from 45 distinct documents written by 18 writers. The devised algorithm segments the connected letters into tiny segments to create lexicon of at most three letters. In that order, segmentation algorithm is capable to segment more than 93% of the words into smaller segments each containing at most one letter, 6% of the words into segments that contains two letters and lastly 3% of the words into segments that contains three letters. Respectively, 21.3% of the segments contain exactly one letter, 90.4% of segments hold one letter including 2.5 segments on average whereas 9.6% of the segments sustain more than one letter [44].

IV. COMPARATIVE STUDY

Several pre-processing and segmentation techniques have been examined for numerous languages in detail. The standard parameters of concern are mainly; input type, pre-

processing phases, segmentation phases, sample size, window size, and recognition rate which are shown in Table 1. Basically, input type is particular kind of data item as defined by the values it holds to perform certain operations during recognition. In general, it is classified into two types namely; handwritten and printed. In case of handwritten input type, the source may be either an image/ scanned form of the document whereas printed input type deals with a data stream which inputs from a transducer while the user writes. Moreover, consonants, vowels and numerals are sub-categories of aforementioned input type. The main objective of pre-processing process is to transform the input image into the corresponding bitmap thinned image. It performs the digitization on handwritten/ printed characters by scanning the document. It comprises of these sub-processes namely; noise reduction, binarization, compression, normalization, skew correction, slant angle correction and thinning. Segmentation phase separates the different logical parts, such as text from graphical image, paragraph from text, followed by extraction of line from a paragraph, and finally words and characters from lines. Sample size determines number of consonants, vowels and numerals involved during recognition process. Further, window size defines group of pixels values in an image. It is mainly shows size of image in dots per inch. At last recognition rate depicts overall accuracy value of image in percentage mainly.

V. RESULTS AND CONCLUSIONS

In this paper, we attempted to perform comparative study of various existing pre-processing and segmentations techniques. It has been observed that several parameters exists for numerous scripts such as input type, preprocessing phase, segmentation phase, sample size etc. and we present the glimpses of desired parameters as shown in Table 1. Subsequently, the vital investigation associated with the performance issues of pre-processing and segmentation techniques in character recognition are as follows:

1. In order to recognize Modi characters median filter for removing noise and edge detection method has been used which provide 68.15% and 73.5% recognition rate respectively.
2. Higher accuracy of 100% has been gained for Devanagari script using horizontal and vertical projections for segmenting line and word of text. Also, morphological operations are performed for binarization subsequently.
3. Projection profiles and detecting horizontal spaces have been performed for segmenting Gurumukhi characters on 10 documents which acquired 98.4% recognition rate productively.
4. Preprocessing approaches such as noise reduction, thresholding, skew detection and thinning has been performed for Gurumukhi numerals on 1500 samples with 10*10 window size achieved 99.73% accuracy effectively.
5. Skew Algorithm has been prepared for Sinhala script on 1200 samples for detecting skew angle which achieved 98.40 % accuracy.
6. Chain code method is applied to binarized handwritten Arabic characters as well as skeletonization is done in order to perform thinning which achieve 93% precision rate.
7. It has been observed that pre-processing and segmentation techniques have been widely applied to improve the recognition rate of handwritten/ printed characters of various regional languages over the years. However, there remains a lot of scope to analyze these techniques for recognition of Modi characters.

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Table 1. Comparative Study of Various Scripts

Scripts	Input Type						Preprocessing Phases						Segmentation Phases			Sample Size	Window Size	Recognition Rate
	Handwritten			*Printed*														
	Cons	*Vowels*	*Num*	*Cons*	*Vowels*	*Num*	*Noise Removal Technique*	*Binarization Technique*	*Compression Technique*	*Normalization Technique*	*Skew Angle Correction Technique*	*Thinning Technique*	*Line*	*Word*	*Char*			
Arabic [44] [34]	Yes	Yes	No	No	No	No	Filters	Chain Code	-----	-----	-----	Skeletons	-----	Contour	-----	28300	-----	93%
	No	No	No	Yes	Yes	Yes	Filters	-----	-----	-----	Drift Correction	-----	Histogram	Vertical	Horizontal	28 n 10 Num	640*480	73%
Cursive [16] [35]	Yes	Yes	No	No	No	No	-----	Otsu algo	-----	-----	Yes	Yes	-----	-----	Segments	2936	-----	91.21%
	No	No	Yes	No	No	No	Filters	Thresholding	-----	-----	-----	-----	compensation	Segments	Segments	500	500*120	83.47%
Devanagari [32] [22]	No	No	No	Yes	Yes	No	Median Filter	Histogram	-----	-----	-----	-----	Horizontal	Vertical	both	77	48*57	-----
	No	No	No	Yes	Yes	No	Filters, Morphological	-----	Thresholding Thining	Skew, slant and size	-----	-----	-----	-----	Internal, External	44	-----	98.78%
	No	No	No	Yes	Yes	No	Conn Compons	Morphological	-----	-----	-----	-----	Horizontal	Vertical Projection	Active Contours	202	-----	100%
Gujarati [18]	Yes	Yes	No	No	No	No	Median Filter	Thresholding	-----	-----	-----	-----	-----	-----	-----	1500		90.6%
	No	No	Yes	No	No	No	Median Filter	Hist Equalization Algorithm	-----	-----	-----	-----	-----	-----	-----	2650	16*16	82%
Gurumuthi [40]	No	No	Yes	No	No	No	Filters, Morphological	Otsu Method	-----	Normalized Form	Skew Alignment	Thining	Yes	Yes	Yes	1500	10*10	99.73%
	Yes	Yes	No	No	No	No	Yes	Yes	-----	-----	Yes	Yes	Projection	Horizontal spaces	-----	10 doc	-----	98.4%
	Yes	Yes	No	No	No	No	Morphological	Otsu Method	-----	Contour Smoothing	Yes	Yes	Yes	Yes	Yes	7000	10*10	95.11%
Modi [17] [31][45]	Yes	Yes	No	No	No	No	Median filter	Otsu Method	-----	Interpolation	Canny method	-----	-----	-----	-----	65	56*56	68.15%
	Yes	No	No	No	No	No	Gray Scale	Otsu Method	-----	-----	-----	-----	-----	-----	Hit And Deflect	22	-----	72.6%
	No	No	No	No	Yes	No	Median Filter	Yes	-----	Yes	Edge Detection	-----	-----	-----	-----	10	-----	65.3% to 73.5%
Sinahala [33]	Yes	Yes	No	No	No	No		Otsu method	-----	-----	-----	-----	Horizontal	Vertical	Vertical	23	-----	-----
	Yes	Yes	No	No	No	No	Median Filter	Thresholding	-----	-----	skew algo	-----	-----	-----	-----	1200	-----	98.4%
Urdu[19]	Yes	Yes	No	No	No	No	Filters	Morphological transform	-----	-----	-----	-----	Yes	-----	Yes	40	-----	89%

