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A Comprehensive Survey on Kannada Numerals and Character Recognition

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Abstract—In today's fast growing technology, digital recognitions are playing wide role and providing more scope to perform research in Optical Character Recognition (OCR) techniques. Character Recognition (CR) has been extensively studied in the last half century and progressed to a level, sufficient to produce technology driven applications. Now, the rapidly growing computational power enables the implementation of the present CR methodologies and also creates an increasing demand on many emerging application domains, which require more advanced methodologies. Recognition of Kannada handwritten as well as printed scripts are complicated compared to other western language scripts. Researchers for the recognition of Indic Languages and scripts are comparatively less with other languages.

This paper gives an overview of the ongoing research in OCR systems for Kannada scripts. This survey paper has been felt necessary when the work on developing OCRs for Indian scripts, mainly focused on Kannada script is very promising and is still in emerging status. The aim of this paper is to provide a starting point for the researchers entering into this field. Peculiarities, present status of the OCRs, techniques used in Kannada scripts, recognition accuracies and the resources available are discussed in detail.

Keywords—Handwritten character recognition,Kannada Script, Directional chain code, Run length count, K-Nearest Neighbour, Linear classifier.

I. INTRODUCTION

Machine simulation of human reading has become a topic of serious research since the introduction of digital computers. The main reason for such an effort was not only the challenges in simulating human reading but also the possibility of efficient applications in which the data present on paper documents has to be transferred into machine readable format. Automatic recognition of printed and handwritten information present on documents like cheques, envelopes, forms, and other manuscripts has a variety of practical and commercial applications in banks, post offices, libraries, and publishing houses. Currently there are many OCR systems available for handling printed English documents with reasonable levels of accuracy. Such systems are available for many European languages as well as some of the Asian languages such as Japanese, Chinese, etc. However there are not many reported efforts at developing OCR systems for Indian languages especially for a South Indian language like Kannada.

Kannada is the officiallanguage of South Indian state Karnataka. It has its own script derived from Bramhi script. It is one of the earliest languages evidencedepigraphically in India and spoken by about 50 million peoplein the Indian state of Karnataka, Tamil Nadu, Andhra Pradeshand Maharashtra.Kannada script has a base set of 52 characters, comprising 16 vowels and 36 consonants.The scripts alsoinclude 10 different Kannada numerals of the decimal numbersystem. Further there are distinct symbols that modify the base consonants called consonant and vowel modifiers. The numbers of these modifiers are same as that of the base characters. The characters called aksharas are formed by graphically combining the symbols corresponding to consonants, consonant modifiers (optional) and vowel modifiers using well defined rules of combination. Therefore, the numbers of theoretically possible combinations of Kannada characters are as follows:

The number of possible consonant-vowel combinations is 36*16=576 and number of possible consonant-consonant-vowel combinations is 36*36*16=20736, as there are 16 vowels and 36 consonants. So, any character can be one of the following:

- A stand-alone vowel or a consonant,
- A consonant modified by a vowel,
- A consonant modified by one or more consonants and a vowel.

Almost all South Indian languages are with curve shape. The curve shape and 19600 combinations of Kannada characters are made lot of difficulties for Character Segmentation as well as for Character Recognition. Some of the complex-characters are listed below to show the complications of the segmentation. The following Figure 1 shows the conjunct consonant (Subscript/Vatthu) [3]. The full set of Kannada alphabet is given in [9]. The study investigates the direction of the CR research, analysing the limitations of methodologies for the systems which can be classified based upon two major criteria: a) the data acquisition process (on-line or off-line) and b) the text type (machine-printed or handwritten).

No matter in which class the problem belongs, in general there are five major stages in the CR problem, as follows:

1) Pre-processing;
2) Segmentation;
3) Feature Extraction;
4) Classification;
5) Post processing.

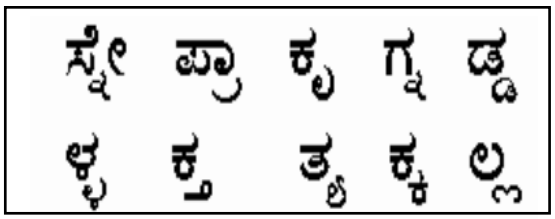

Fig. 1 the conjunct consonant (Subscript/Vatthu)

The paper is arranged to review the CR methodologies with respect to the stages of the CR systems, rather than surveyingthe complete solutions. This paper is organized as follows: Pre-processing techniques are surveyed in section II. Section III illustrates the various segmentation techniques available for offline Kannada character recognition. Feature extraction methods are explained in section IV. Section V explains the various classification approaches. Section VI illustrates different post-processing techniques. Section VII gives brief information of all the methods explained in above sections in tabular form and in section VIII, there is conclusion of survey.

II. PRE-PROCESSING

There are numerous tasks to be completed before performing character recognition. A handwritten document must be scanned and converted into a suitable format for processing. Pre-processing consists of a few types of sub processes to clean the document image and make it appropriate to carry the recognition process accurately. The sub processes which get involved in pre-processing are illustrated below:

A. Binarization,
B. Noise Removal,
C. Normalization,
D. Skew correction, thinning and slant removal.

A. Binarization

Binarization is a method of transforming a gray scale image into a black and white image. Image binarization is categorized in two main classes: Global and Local.

In a global approach, threshold selection results in a single threshold value for the entire image. The most commonly used method is Otsu's method [15]. Global thresholding has a good performance in the case that there is a good separation between the foreground and the background. Implementation of bit plane method is simple and efficient.

Using the local information that guides the threshold value pixel wise in an adaptive manner is well suited for degraded documents [20, 21]. Another global approach for converting gray scale image to binary image is by using the bit plane method [19]. In bit plane method, gray scale imagescan be transformed into a sequence of binary images by breaking them up into their bit-planes. The bit planes is isolated by simply dividing the image matrix by successive powers of 2, throwing away remainder and seeing if the final bit is 0 or 1.

Histogram based thresholding approach can also be used to convert a gray-scale image into a twotone image. In contrast, Adaptive Binarization method can also be used to identify the local gray value contrast of Image. This will help to extract text information from low quality documents.

B. Noise Removal

Digital images are prone to many types of noises. Noise in a document image is due to poorly photocopied pages. Salt and pepper noise arises due to scanning process and quality of the paper being scanned thereby corrupting the pixels. Median filter is used for removal of salt and pepper noise [1]. The median will in general replace a noisy-value with one closer to its surroundings. Wiener Filtering method [17] and morphological operations can be performed to remove noise.

C. Normalization

Normalization is the process of converting a random sized image into a standard size. To bring all characters into a common size platform in order to extract features on the same footing, a minimum bounding box is fitted to the character and the element is cropped. The cropped element is normalized to a size of 36x36 pixels without disturbing the aspect ratio using bilinear standard transformation [1]. There is another method for resampling which is based on equiarc length [2]. Java Image Class [12] normalization techniques could be used for standard sized images.

D. Skew correction, thinning and slant removal

Thinning is a pre-process which results in single pixel width image to recognize the handwritten character easily. It is applied repeatedly leaving only pixel wise linear representations of the image characters. Thinning extracts the shape information of the characters. The detailed information about the thinning algorithm is available in [10]. Another morphology based thinning algorithm for better symbol representation is available in [10]. Skew is inevitably introduced into the incoming document image during document scanning. Normalization [2], Fourier Spectrum techniques are used for correction of the slant, angle stroke, width and vertical scaling.

III. SEGMENTATION

Segmentation is a process which is used to split the document images into lines, words and characters. Segmentation of handwritten documents is more complex than typewritten documents. Segmentation process involves three steps namely Line segmentation, Word segmentation and Character segmentation. Segmentation of lines and words are done using the horizontal and vertical projection profiles of the scanned document image [4]. Characters are extracted using a two-stage method, in which each segmented word is examined for the presence of subscript characters. If subscript characters are present in the word, then they are extracted using the connected component method in the first stage. If subscripts are not present or when all the subscripts are extracted, then the main characters from the word are segmented using vertical projection profile in the second stage. A two stage segmentation technique has been adopted [4, 11].Yungang Zhang and Changshui proposed a new algorithm for character segmentation. They use Hough transformation for a Character Segmentation of License plate [7]. David D. Palmer [13] proposed a trainable rulebased algorithm for performing word segmentation. The algorithm provides a simple, language independent alternative to large scale lexicalbased segmenters requiring large amounts of knowledge engineering. Again there are some segmentation algorithms present such as brute force approach and dividing the individual character by 3 parts Top region, Middle region and Bottom region [8, 14].

In Kannada script, there are some aksharas formed by combining consonants and vowel modifiers in such a way that they have vowel modifiers attached at the top of consonants. For such aksharas, top segmentation method is developed. In the top segmentation, it is required to find a row index along which the top portion and middle portion of an akshara can be separated. Along the top row index, the top portion of an akshara is segmented and using consonant row index, the consonant portion from the akshara is extracted, as shown in figure 2 [5]. To do this, a new top portion segmentation method is developed using Gabor filters [5].

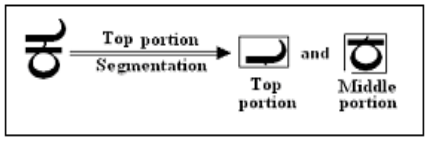

Fig. 2 Top portion segmentation

For some akshara, it may happen that, the right side vowel modifier's part may occur in top portion as illustrated by figure 3b[5]. To remove these extraneous pixels from top potion, here an algorithm is devised called as Maximum Area based Subpart Selection (MASS).

In [18], a method based on the analysing the vertical projection of a character is developed to find column index (break point). With the help of column index, segmentation is carried out.

IV. FEATURE EXTRACTION

Feature extraction is very problem dependent. Good features are those whose values are similar for objects belonging to the same category and distinct for objects in different categories. The better approach for recognition is to segment characters into basic symbol and recognize each symbol subsequently. The most important aspect of handwriting recognition scheme is the selection of good feature set, which is reasonably invariant with respect to shape variations caused by various writing styles.

In [4], Discrete Wavelet Transform is applied on the contour points to get wavelet descriptors which serve as features for the character. Pre-trained neural classifiers uses those features to recognize the character and generate the class information. The Kannada Kagunita is a set of compound characters formed by combining vowels and consonants. To recognize the kagunita, both vowel and consonant are to be recognized.Leena Ragha and M Sasikumar [6] worked on a method in which they combine both Gabor transforms and momentsand a cut image concept to extract portions of original image dominant with vowel information and consonant information separately. They considered statistical features as probability distribution of character shape information by dividing the image into three fixed size horizontal and vertical zones for cut images and five for whole original and directional images.

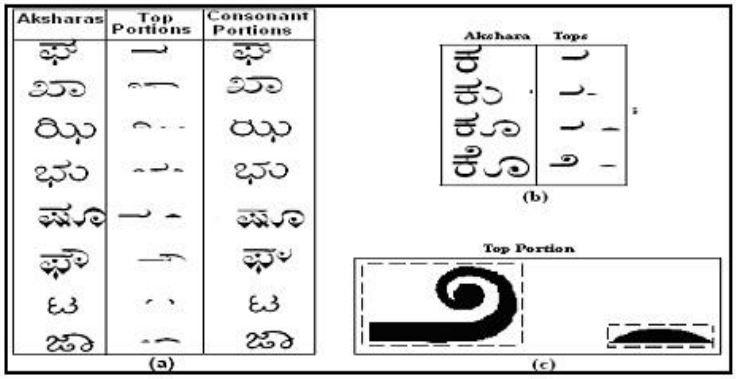

Fig. 3 (a)Examples for top segmentation. (b) Top portions having unwanted objects. (c) Rectangles formed around the objects of top portions.

Boundary based descriptors namely Fourier descriptors and chain codes are also used for extracting the features [1]. Once the boundary of the character is extracted, then these features can be computed in parallel. Fourier transformation is widely used for shape analysis [24]. The lower frequency descriptors contain information about the general features of the shape and the higher frequency descriptors contain information about finer details of the shape. Freeman chain codes[15] are generated by locating a boundary pixel, also called as starting pixel and then moving along the boundary either clockwise or anticlockwise, finding next boundary pixel and assign this new pixel a code depending upon its location from the previous pixel. The codes may be 4-directional or 8-directional depending upon 4-connectivity or 8-connectivity of a pixel to its neighbouring contour pixel. Deskewing is then performed using the Hough transformation algorithm to calculate skew angles using reference lines [1].

In [26], Mamatha H.R. et al. used the run length count (RLC) method for feature extraction. First of all image is divided into zones and for each zone apply RLC to get features. In RLC whenever there is change in pixel value i.e. from 0 to 1 or vice versa count is taken for each horizontal and vertical columns as shown in figure 4.

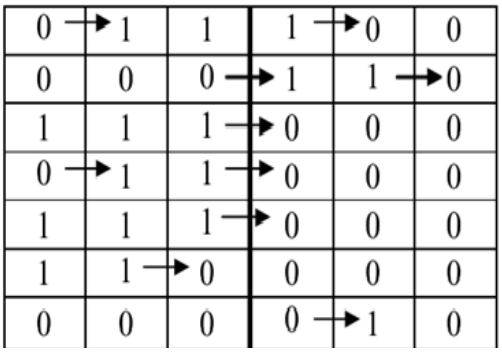

Fig. 4 Illustration of horizontal RLC

Rajashekararadhya et al. described new method for feature extraction based on vertical projection distance metric and zoning [7]. In this method, the image is divided into twenty five equal parts. Hence for each box/zone/grid, there will be 10 columns and 10 rows. For each grid column they compute the pixel distance i.e. vertical projection distance metric. If there is more than one pixel then compute average pixel distance to get feature vector of that grid column. Repeat this for rest of the columns in that grid. In [19] Zone and distance metric based feature extraction system is presented. For each zone column average pixel distance is computed in Vertical Downward Direction (VDD).This procedure is sequentially repeated for entire zone/grid/box columns present in the zone. Similarly this procedure is repeated for each zone from all the direction say Vertical Upward Direction (VUD), Horizontal Right Direction (HRD) and Horizontal Left Direction (HLD) to extract 10 features for each direction. Hence 40 features are extracted. Finally 1000 such features are extracted for classification and recognition. In [20], direction chain code for each contour point is noted then the frequency of the direction codes is computed and those frequency values are used as feature. Vishwaas M. et al. in [24] used the direction of the stroke, density of the stroke and no. of clicks for the character for the features that are used to form a signature. Here a stroke is defined as any line greater than a predefined length drawn in a particular direction. The density is calculated based on number of points obtained in each stroke during data collection.

V. CLASSIFICATION

The extracted features are given as the input to the classification process. A bag of key points extracted from the feature extraction approaches are used for classification. There are some approaches that are used to classify the character features in the existing systems such as K-nearest Neighbour approach(NN), Fuzzy system, neural network, discriminate classifier, unsupervised classifier and so on.

Multi-layer perceptrons are being used as classifiers because of their universal approximation property and good generalization ability [21]. Two stage classification methodology is used for classification. The consonant-vowel composite characters of a consonant are all grouped together as a single class of character in the first instance of classification. Later, a character belonging to such a group is further classified within its group by a separate small network meant for classifying that consonant group of characters. This is the second stage of classification [21]. Multilayer feed forward neural networks with a single hidden layer are used as classifiers in the present work [4].

In [6], Leena Ragha and M. Sasikumar used neural network multi-layer perceptron (MLP) with back-propagation (BP) for classification. For classification of the numerals, G. G. Rajput and Rajeswari Horakeri used the famous and efficient Support Vector Machines (SVM) [1, 17]. For the DTW classifie Rituraj Kunwar et al. in [22] found thatsmoothed first derivatives as features enhanced the performance to 89% as compared to pre-processed coordinates which gave 85%, but was too inefficient in terms of time. To overcomethisthey usedStatistical Dynamic Time Warping (SDTW)and achieved 46 times faster classification with comparable accuracy i.e. 88%, making it fast enough for practical applications. With SDTW, it can possible to overcome the limitations of NN with DTW at the same time retaining the quality to consider local temporal information in data.

Another method for classification is by using statistical dynamic space warping (SDSW) classifier [2] which uses X, Y coordinates and their first derivatives as features.Rajashekararadhya S. V. et al. used method for classification is based on nearest neighbor classifier (NNC) [7]. In [20], eigen values and their respective eigen vectors are used for the classifica-

tion. Vishwaas M. et al. used Kohonen neural network (KNN) for classification of online handwritten character recognition (HCR) [24].

VI. POST-PROCESSING

The post processing performs spell checking of the recognized Kannada characters. Technique uses a dictionary that stores valid Kannada words in large number and compares the words in output with the stored words. If the word does not match then few suggestions are listed to select appropriate word. Post Processing is done using Ternary Search Tree (TST) data structure. All the valid Kannada suggestions are stored in dictionary using TST data structure [23]as shown in figure 5.

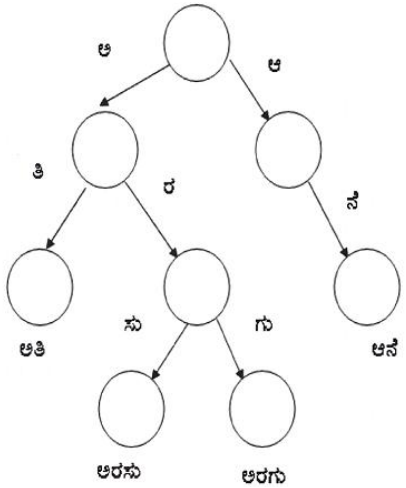

Fig. 5 Storage of character in TST

VII. COMPREHENSIVE STUDY

The TABLE Ishow the comprehensive study of which has been made on the different OCR's available for Kannada character recognition with their accuracy.

VIII. CONCLUSIONS

A comprehensive study of pre-processing, segmentation, feature-extraction and classification techniques for character recognition is explored. In addition a novel idea and its efficacy for Kannada natural writer independent handwritten character recognition are explored. Various methods have been used in each phase of the recognition process, whereas each approach provides solution only for few character sets. Challenges still prevails in the recognition of normal as well as abnormal writing, slanting characters, similar shaped characters, joined characters, curves and so on during recognition process.

In this paper, we have projected various aspects of each phase of the Kannada character as well as numeral recognition process. Researchers have used minimal character set. Coverage is not given for different writing styles and font size issues.

TABLE I

Sr/paperNo.	Preprocessing	Segmentation	Feature Extraction	Classification	Accuracy
1[4]	It involves elimination of noise in the document.	Horizontal and vertical projection profile used for line & wordsegmentation	Wavelets are used to extract the features.	Two-stage multi-network neural classifiers i.e. Multi-layer perceptrons are used.	The recognition rate of about 91% is got at character level.
2[6]	-	The original image is cut by some percentage from top, right and bottom directions.	Moment features from original and directional images.	Multi-layer perceptron with back propagation neural network is used.	The recognition results for vowels are average 85% and that of consonants are 59%.
3[1]	Median filter is used for removal of salt and pepper noise.Otsu's method is used for binarization.Bit plane method is used for gray to binary imageconversion.	-	Fourier descriptors and chain codes are used.	SVM approach is used for classification.	The recognition rate is 98.45% and 93.92%, for numeral characters and vowels, respectively.The mean recognition rate of 95% is obtained for both.

4[25]	RGB image is converted to gray scale and then gray scale image is further converted to a binary image.	Three classes, i.e. base characters, modifier Glyphs and subscripts which are recognized separately.	K-means clustering is used for extraction.	-	The recognition rate is 94.76% in K-means.
5[23]	Noise removaland conversion of gray scale image having 0 to 255 pixel values into binary image.	Segmentation algorithm by brute force approach, horizontal and vertical projection and dividing the individual character by 3 parts.	Post processing technique uses a dictionary based approach in order to increase the OCR output.	-	-
6[30]	-	-	-	DTW classifier and SDTW.	The recognition rate is 89% for DTWand 88% for SDTW but 46 times faster classification than DTW.
7[2]	-	Segmentation strategy can be used for grouping strokes into different recognizable symbols.	K-means algorithm is used.	Classification is performed by SDSW classifier.	Classification accuracies obtained are 88% at the akshara level and 80% at the word level.
8[7]	Size Normalization, thinning is involved.	Image is divided into 25 equal parts.	Feature extraction based on verticalprojection distance metric and zoning.	Classification is done based on NNC.	93% and 90% of recognition accuracy for Kannada and Tamil numerals respectively.
9[20]	Histogram based global binarizing algorithm is used to convert gray image to two-tone images.	Bounding box of a character is segmented into blocks.	Directional chain code information of the contour points of the characters is used.	Quadratic classifier based scheme.	97.87% and 98.45% recognition accuracyusing 64 dimensional and 100 dimensional featuresrespectively.
10[19]	The digitized images are stored as binary images in BMP format.Morphology based thinning algorithm for better symbol representation.	The character/numeral image (50x50) is divided in to 25 equal zones (10x10)	Zone and projection distance metric based feature extraction system.	NNC is used.	97.8% recognition rate for Kannada numerals.
11[26]	Binarise the image using a threshold value. Thethreshold value for an image is fixed using the Otsu's method.The image is resized to 72x72 pixels.	-	Run length count and directional chain code is used for the recognition ofHandwritten Kannada numeral, combine both the statistical and structural features.	K-nearest neighbor classifier is used.	The recognition rate is 94% and 87% for Directional and run length count resp.
12[27]	It involves noise reduction, slantcorrection, size normalization and thinning.	-	Zone and distance metric based feature extraction system.	Feed forward back propagation neural network is used.	98 % and 96 % recognition rate for Kannada and Telugu numerals respectively.
13[28]	Preprocessing stage involves noise reduction, slant	-	Zone and Distance metric based feature extraction system.	SVM is used for subsequent classification.	97.75% recognition rate for Kannada numerals.

	correction, size normalization and thinning				
14[5]	-	Gabor filters at higher frequency are proposed for top portion segmentation.MAS Sis used.	-	-	Overall accuracy of 96.87% for top row index and 95.49% for consonant row index is observed.
15[29]	-	Novel character segmentation method using Gaborfilters. Method based on the analyzing the verticalprojection of a character is developed to find column index.	-	-	Accuracy of 93.82%.
16[24]	-	-	The features that are used to form a signature are direction of the stroke, density of the stroke and number of clicks for the character.	KNN is used for classification.	Accuracy is of 94.4%.

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