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RESEARCH ARTICLE

A Novel Approach of Handwritten Character Recognition using Positional Feature Extraction

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Abstract— In this paper, we have presented a method of feature extraction for handwritten character recognition. We showed that our method, despite its simplicity, yields good classification results on handwritten characters. Normalization and binarization are the pre-processing techniques used for getting accurate results of classification process in handwritten character recognition. This method is based on positional properties of each pixel present in character image. First of all, add all the sample character image matrices and divide the resultant matrix by total number of matrices added, called as Avg_matrix. Then subtract it from each sample character image matrix, which results in unique features because of their positional properties of pixels present in that image. We used singular value decomposition technique to get projection vector matrix which is beneficial for more accuracy in results. Finally, we used generalized regression neural network for resulting feature vectors and obtain classification performance in the character recognition task. The proposed recognition scheme provided 82.89 percent and 85.62 percent accuracies on Devnagari and Kannada character databases respectively.

Key Terms: - Handwritten character recognition; Artificial neural network; Positional property; Feature extraction

I. INTRODUCTION

Character recognition has always been an active field of research for computer scientists worldwide due to its useful real life applications such as automatic data entry, mail processing, form processing and many other similar situations. 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: the data acquisition process (on-line or off-line) and the text type (machine-printed or hand written) as shown in figure 1. As compared with printed character recognition, handwritten character recognition (HCR) is still a challenging task due to the following factors:

- individual styles of writing,
- speed of writing,
- size of letters,
- physical and mental condition of the writer,
- overlap of letters etc.

Again the physical devices those are used during recognition also affect the recognition rate such as the acquisition devices, pen width, pen ink colour, etc.

In online OCR, two-dimensional coordinates of point sequences of the writing as a function of time are available. While in the offline OCR, only the completed writing is available as an image. So as compare to online recognition system offline recognition system is more difficult to implement. Normally character

recognition system can be divided into three steps namely pre-processing, feature extraction and classification. Pre-processing is subjected to a number of preliminary processing steps such as noise reduction, normalization, compression, etc. to make it usable in the descriptive stages of character analysis. The main aim of this step is to produce data that are easy for the character recognition (CR) systems to operate accurately. Feature extraction stage is most important stage which is used to remove redundancy from data and capture useful information. Fundamental component of characters, on the basis of which character can be differentiated, called features. And lastly, classification stage is to recognize characters or words on the basis of features.

In the literature, a number of approaches are available for pre-processing, segmentation, feature extraction, classification, and post-processing. However, two critical issues of developing a handwriting recognition system are:

- selection of a feature set and
- designing a classifier.

But as compared to the human recognition ability and requirements of applications, the current recognition accuracy by computers is still insufficient.

The rest of this paper is organized as follows. Section 2 reviews previous work on character recognition. This is followed by the introduction of the proposed algorithm in Section 3. Different databases used for this recognition system and how they are created are explained in Section 4. In Section 5, experimental results are reported and discussed. Finally, conclusions are drawn in Section 6.

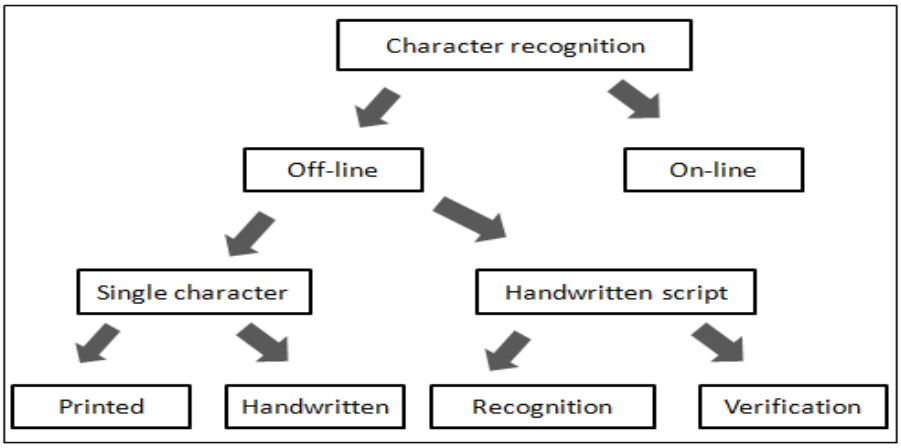

Fig. 1 Different areas of character recognition

II. RELATED WORK

In this section, we review previous work on character recognition of machine-printed and handwritten character images. All this work is categorized using four basic steps used for recognition of character. The limitations of different methods used for both handwritten and printed character recognition are also mentioned here.

1) Pre-processing

There are numerous tasks to be completed before performing character recognition. 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 such as binarization, noise removal, normalization, skew correction, thinning and slant removal.

Binarization is a method of transforming a gray scale image into a black and white image, which is used by [1, 7, 10, 15, 17] to get accurate features. The most commonly used method is Otsu's method [22, 30]. 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 [27]. 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.

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 [37]. Wiener Filtering method [29] and morphological operations can be performed to remove noise. There are number of Morphological operation, which is used for connecting broken strokes, eliminating small breaks and holes, reducing the width of the line to some extent [15, 17, 20].

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 [12, 15] and the element is cropped and then resized to fit into 32x64 window [7]. In [37], the cropped element is normalized to a size of 36x36 pixels without disturbing the aspect ratio using bilinear standard transformation. There is another method for resampling which is based on equiarc length [42]. Java Image Class [31] normalization techniques could be used for standard sized images.

Thinning is a pre-process which results in single pixel width image to recognize the handwritten character easily. The detailed information about the thinning algorithm is available in [7, 33]. Slant removal is used in [20] to get better results. Projection profile method can be used for skew detection and correction of image [22].

2) 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 of lines and words are done using the horizontal and vertical projection profiles of the scanned document image [36].

A two stage segmentation technique has been adopted in [32, 36]. Yungang Zhang and Changshui proposed a new algorithm for character segmentation. They use Hough transformation for a Character Segmentation of License plate [34]. In [28], B. Vijay Kumar et al. used a method based on the analysing the vertical projection of a character is developed to find column index (break point). With the help of these column indexes, segmentation is carried out.

3) 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. In [36], Discrete Wavelet Transform is applied on the contour points to get wavelet descriptors which serve as features for the character. Sarveswaran K. et al. divide character image into 15x15 grids i.e. 225 parts [1]. If the region is coloured black then corresponding region is represented by 1 otherwise 0. All written characters are converted into binary numbers and these entries are written onto a text file, where each character consists of 225 binary numbers. Each 15x15 binary matrix is further divided into 5 x 5 small matrices. Number of 1's present in each region considered as feature. Jarernsri L. Mitrpanont extracts features which are totally based on analysis of contour characteristics [2]. In [3], image is firstly divided into number of zones and then chain code is used for each zone as a feature. Fourier transform is used to extract features called as Fourier descriptor in [4]. G. Vamvakas et al. [5] used features which are based on horizontal and vertical zones, the projections of the character profiles, distances from the character boundaries and profiles from the character edges. Mamatha H. R. et al. used the run length count (RLC) method for feature extraction [24]. In [27], zone and distance metric based feature extraction system is presented. De Cao Tran et al. proposed an analytic method in which the accented character is segmented into two parts: the root character and the accent part that are recognized separately and SVM classifier is used, which is the one implemented in the LibSVM software package, as classifier [21].

In [8], Tian-Fu Gao et al. proposed linear discriminant analysis (LDA) based compound distance measure for discriminating similar characters in handwritten Chinese character recognition. Four sided projections of alphabets can be used for feature extraction [9]. In [10], offline recognition of segmented handwritten characters based on the fuzzy-zoning and normalized vector distance measures. Roberts filter is applied on the normalized image to obtain gradient image and curvature feature are computed using biquadratic interpolation method [13]. A successful feature extraction method, Scale Invariant Feature Transform (SIFT), has been proposed by D. G. Lowe [38]. Lian-Wen Jin et al considered five different decompositional algorithms that work on either skeleton or contour of an image [39, 40]. In [17], the information of character's outline structure is used as the feature and takes the boundary chain code which is extracted based on regional projection as the feature of classifiers. Characters are grouped in to different classes based on their HLH intensity patterns and then extraction of features takes place [22]. Seiichi Uchida et al. [23] used two steps for character recognition that is, a training step and a recognition step. Firstly key points are detected from each training pattern by using the speeded up robust features (SURF) [41] key point detector. Secondly, a square area around each key point is described as a 128-dimensional SURF feature vector. Euclidean 1-nearest-neighbor (1NN) is used in recognition step.

4) 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.

Leena Ragha and M. Sasikumar used neural network multi-layer perceptron (MLP) with back-propagation (BP) for classification [3, 18, 35]. In [26], eigen values and their respective eigen vectors are used for the classification. Vishwaas M. et al. used Kohonen neural network (KNN) for classification of online handwritten

character recognition (HCR) [25]. Kohonen Self Organizing Map is also used for training data [1]. Quadratic classifier is used by U. Pal et al. for classification to get better results of recognition [6].

In [13], U. Pal et al. are using twelve different classifiers like projection distance, subspace method, linear discriminant function, support vector machines, modified quadratic discriminant function, mirror image learning, Euclidean distance, nearest neighbour, k-Nearest neighbour, modified projection distance, compound projection distance and compound modified quadratic discriminant function, for comparative study. Direct matching technique is also used in which dissimilarity correlation and similarity correlation is used for classification [15]. Bagging algorithm is used to carry on the integration based on the HMM classifier [17]. This technology may reduce the variance and improve the performance. A novel intelligent method is presented in [19], which uses the particle swarm optimization (PSO) algorithm with adaptive inertia weight to train the neural networks.

III. PROPOSED ALGORITHM

1. To get exact and unique features of every character image, first of all pre-processing is required. For pre-processing apply linear normalization to make resolution of 64x64. Then apply binarization technique to convert it into binary image.
2. Then take a complement of binary image, which means, zeros become ones and ones become zeros i.e. black and white are reversed.
3. After pre-processing step, add all training image matrices into single matrix of 64x64 and then divide it by total number of samples to get the average of all training images called as Avg_matrix. In Avg_matrix, if 1 is present then it means in each and every sample image that particular pixel is ON and for 0 values, it is vice versa. As values present in this matrix decreases from 1 to 0, possibility that the particular pixel is ON, is also decreases.
4. After creating Avg_matrix, subtract it from each and every sample character image matrix to get unique features, results in matrix *X*.
5. Then to calculate covariance matrix and to compute the projection vector distance matrix, apply singular value decomposition (SVD) technique as it is more convenient to avoid larger calculations.

Suppose order of matrix *X* is mxn. In SVD matrix *X* can be factored as:

$$X = U * S * V'$$

Where U and V are orthogonal matrices containing singular vectors, and S is the matrix of the form $\begin{bmatrix} D & 0 \\ 0 & 0 \end{bmatrix}$ where D is a diagonal matrix containing singular values of *X*. So, basically SVD breaks *X* into three components as shown in figure 2.

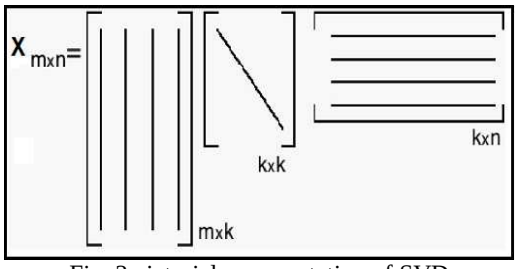

Fig. 2 pictorial representation of SVD

6. Consider first 100 columns i.e. first 100 vectors of matrix *U* and then take a transpose of matrix *U* to multiply it with matrix *X* to get final features for each sample.
7. Use Generalized Regression Neural Networks (GRNN) as a classifier. GRNN is a special case of Radial Basis Networks (RBN). Compared with its competitor, e.g. standard feed forward neural network, GRNN has several advantages. First of all, the structure of a GRNN is relatively simple and static with 2 layers, namely pattern and summation layers as shown in figure 3.

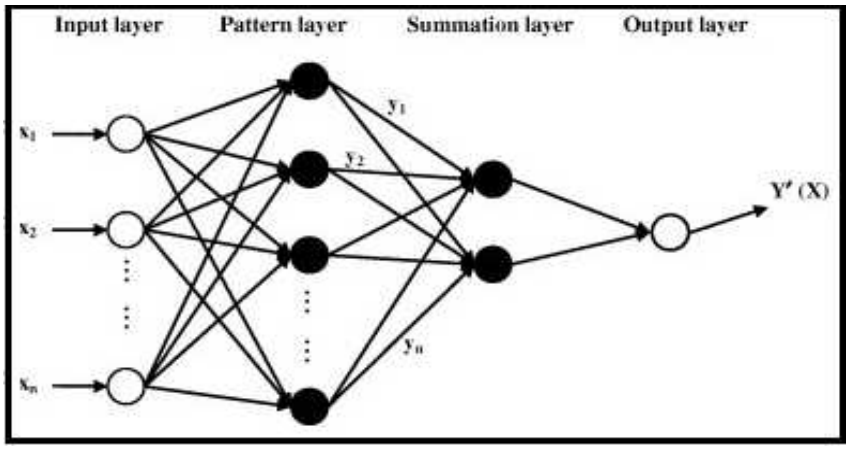

Fig. 3 Generalized Regression Neural Network

IV. DATABASE

We used two different databases of two languages i.e. Devnagari and Kannada. Few samples of both languages are as shown in figure 4. For specific purpose we are used these two language database. All the basic characters present in Devnagari having majority of straight lines than curves and in Kannada database majority basic characters are made up of curves than straight lines.

So our proposed system is generalized handwritten character recognition system. Data used for the present work were collected from different individuals of various professions. We considered 4500 samples (100 from each class) of Devnagari basic characters (vowels as well as consonants) and 7350 (150 from each class) samples of Kannada basic characters for the experiment of proposed work.

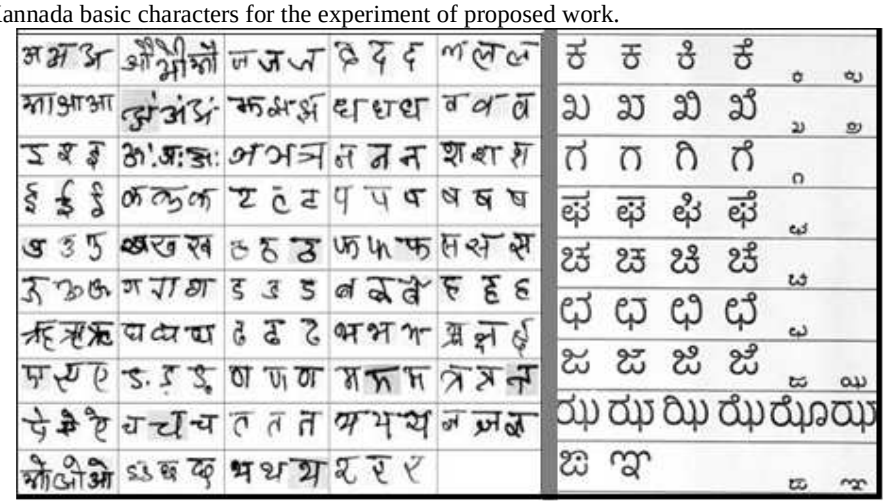

Fig. 4 Few samples of Devnagari and Kannada Character database

V. EXPERIMENTAL RESULTS

Matlab is the tool used for implementation. The proposed recognition scheme provided 82.89 percent and 85.62 percent accuracies on Devnagari and Kannada character databases respectively. To the best of our knowledge, the above recognition performance is better than other available recognition experiments on handwritten characters as shown in table 1.

For testing, 30% samples are taken from each class of both databases. In our recognition system, GRNN classifier is applied for classification.

TABLE I
Comparison of results

Sr.	Method proposed by	Data size	Accuracy
1	Kumar and Singh [43]	200	80 %
2	Sharma et al. [44]	11270	80.36 %
3	Deshpande et al. [45]	5000	82 %
4	Proposed method for		
	A. Devnagari Database	4500	82.89 %
	B. Kannada Database	7350	85.62 %

VI. CONCLUSIONS

In this paper we present a GRNN classifier based system towards the recognition of offline Devnagari and Kannada handwritten characters. To the best of our knowledge there is no published work on the Kannada characters. From the experiment of 49 classes of Kannada we obtain encouraging results from our system although shapes of characters are very complex. As basic character set of Devnagari language are made up of straight lines than curve and for Kannada language, it is vice versa, so this recognition system can be used for handwritten character recognition of Indian languages.

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