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Review of Devnagari Handwritten Word Recognition

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ABSTRACT
Devnagari is the most popular script in India it is usedby over 400 million people all over world. Recognitionof Devnagari handwritten word has been a popularresearch area for many years because of its various applications. This paper describes different techniques for pre-processing, segmentation, feature extraction and classification which play an important role for recognition of word.
Keywords:Preprocessing,Featureextraction, Segmentation

1. Introduction

India is multilingual/multiscript country withvarious languages namely Gujarati, Marathi, Konkani,Bengali, Tamil, Telugu, Punjabi, Sanskrit, Urdu.Handwritten recognition is classified into two types asoffline and online. In offline recognition document isscanned and complete writing is available as an image.Due to the availability of several computing devicessuch as Tablet PC, PDA and Smartphone in the marketand affordable by common Indian, online handwrittenword recognition gain enough attention. In onlinerecognition input is given by Tablet PC, PDA andSmartphone which is equipped with pen based inputtechnology. Input data to such as online handwritingrecognition consist of (x, y) coordinates along withtrajectory of the pen together with a few other possibleinformation such as pen-up, pen-down etc.

1.1. Features of Devnagari Script

Devnagari is used in manylanguages like Marathi, Hindi, Konkani and Sanskritwhich is used by approximately 400 million people innorthern India and it is most widely used Indic script.Devnagari is written from left to right and it does notcontain any lower and upper case letters. It consists of11 vowels and 33 consonants.

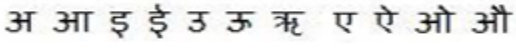

Figure 1. Set of vowels

Figure 2. Set of Consonants

Shirorekha or headline is the horizontal line at theupper part of the character or word. It does not containany useful information so it should detect and thendiscarded. N. Joshi [14] describes a Shirorekha detection algorithm in the context of online Devnagaricharacter recognition.

2. RECOGNITION OF DEVNAGARI HANDWRITTENWORD

The schematic block diagram consists of variousstages in Devnagari handwritten word recognition as
shown in figure 3.

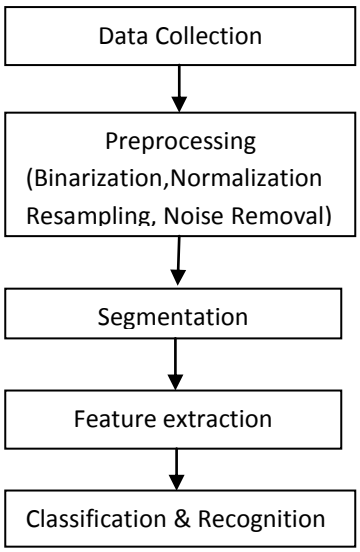

Figure 3. Stages in Handwritten word recognition

2.1. Pre-processing

For online recognition variations ofhandwriting occur due to various writers. For this preprocessingis required which involves elimination ofnoise, binarization of images, Size normalization, skewcorrection, thresholding and skeletonization techniques [5] [6].While inputting data through a pen on the digitizer tablets, there may be certain noise and distortions present in the input text due to some limitations, which may make the recognition of input difficult. Irregular size, missing points due to fast movement of the pen, uneven distances of points from neighboring positions are various forms of noise and distortions. These noise and distortions present in the input text are removed in the second phase of online handwriting recognition i.e. pre-processing phase. The pre-processing phase includes five common steps [5] namely:

- Size normalization and centering
- Interpolating missing points
- Smoothing
- Slant correction
- Resampling of points

2.1.1. Binarization.
It is a method of transforming agray scale image into a black and white image.

2.1.2. Size Normalization.

It is required so eachsegmented character is normalized to fit within suitablematrix so that all characters have same data size.

2.1.3. Thresholding.
Thresholding is the process ofreducing a gray scale image or colour image to a binaryimage.

2.1.4. Noise Removal**.**
It is necessary to eliminateimperfection like disconnected lines, gap of lines, etc.Median Filtering, Wiener filtering method andmorphological operations can be performed to removenoise.Sobel technique is used to detect edges in binarizedimage [10].

2.2. Segmentation

Segmentation is the phase in which data is represented as character or stroke level so that nature of each character or stroke can be studied individually. The preprocessing stage yields a "clean" document in the sense that a sufficient amount of shape information, high compression, and low noise on a normalized image is obtained.
The next stage is segmenting the document into its subcomponents. Segmentation is an important stage because the extent one can reach in separation of words, lines, or characters directly affects the recognition rate of the script. There are two types of segmentation: external segmentation, which is the isolation of various writing units, such as paragraphs, sentences, or words, andinternal segmentation, which is the isolation of letters, especially in cursively written words.
In segmentation, pre-processed image is segmented into lines, words and characters. Segmentation processinvolves three steps namely line segmentation, wordsegmentation and character segmentation. Marathiword can be split into character by removingShirorekha and then recognize [4].

2.3. FEATURE EXTRACTION

Feature extraction is a very crucial step as the success of a recognition system is often attributed to a good feature extraction method. The feature extractor determines which properties of the preprocessed data are most meaningful and should be used in further stages. For online recognition Vertical position of a point, curvature, PenUp/PenDown, writing direction, aspect, and slope are amongst the various features extracted in [2]. 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 [4]. In [9] zoning method is used in which Diagonal feature extraction scheme is used to extract features from each zone. Features can extract using Freeman's direction code in which the change in directions while moving from one point to the next one of the sample are computed and quantized into one of the 8 possible values, via 1, 2… 8. Histograms of these direction codes are computed. In [15], global features are extracted from word which is useful to recognize the word.
The objective of feature extraction is to capture theessential information from data. This is an important
stage as its effective functioning improves the recognition rate and reduces the misclassification. In [10] Diagonal feature extraction scheme is used forrecognizing offline handwritten character. For onlinerecognition NPen++ recognition system [1] is used forfeature extraction. Some feature extraction methods areMoments, Zoning and Projection Histogram.

2.4. CLASSIFICATION AND RECOGNITION

Recognition is the most important phase of the online recognition system and uses the features extracted in the previous stage to identify theinput characteraccording to preset rules. In many of the emerging new applications, it hasbecome clear that no one method for recognition can be considered as optimal and usually a combination of multiple methods yield better recognition results. Combination of two or more recognition methods is a common practice now-a-days and is referred to as hybrid methods for recognition. The four best known approaches for pattern recognition are: 1) template matching, 2) syntactic or structural matching, 3) neural networks and 4) statistical classification.
The decision making stage of a recognition stage is classification stage and it use the features extracted from previous stage. A number of classificationmethods were proposed by different researchers some
of these are template matching, SVM classifiers and artificial neural network.

2.4.1. Template Matching.
This is the simplestapproach of pattern recognition. Given pattern that is tobe recognized is compared with stored patterns.

2.4.2. SVM Classifiers**.**
Support vector machines(SVM), when applied to text classification provideexcellent precision, but poor recall. SVM haveachieved excellent recognition results in various patternrecognition applications. Different types of kernelfunctions of SVM are: Linear kernel, Polynomialkernel, Gaussian Radial Basis Function and Sigmoid.

2.4.3. Artificial Neural Network**.**
Neural network isa computing architecture that consists of a massivelyparallel interconnection of adaptive "neural"processors. Because of its parallel nature, it canperform computations at a higher rate compared to theclassical techniques. Neural network architectures canbe classified as, feed forward and feedback (recurrent)networks. The most common neural networks used inthe OCR systems are the multilayer perceptron (MLP)of the feed forward networks and the Kohonen's SelfOrganizing Map (SOM) of the feedback networks.

3. COMPREHENSIVE STUDY OF PREVIOUS RECOGNITION TECHNIQUES:

Shailendra Kumar (2013)[1] proposed method Real Time Recognition of Handwritten Devnagari Signatures without Segmentation Using Artificial Neural Network in this data collection is done by digital tablet. Various features of signature such as height, length, slant, Hu's moments etc are extracted and used for training of the NN. The highest accuracy rate achieved by for Devnagari handwritten signature recognition system was 96.12 %.
Swapnil A. Vaidya et.al(2013) [2] proposed method in which add all the sample character image matrices and divide the resultant matrix by total number of matrices added, called as average 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. They used singular value decomposition technique to get projection vector matrix then 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 and85.62 percent accuracies on Devnagari and Kannada character databases respectively.
Bharat et.al (2012) [3] proposed method based on HMM for lexicon driven and lexicon free word recognition for online handwritten for feature extraction they used NPen++ feature [29] for curliness, linearity and slop. The two different techniques for recognition of word written in Devanagari Text based on Hidden Markov Models (HMM): lexicon driven and lexicon free. The lexicon-driven technique models each word in the lexicon as a sequence of symbol HMMs according to a standard symbol writing order derived from the phonetic representation. The lexicon-free technique uses a novel Bag-of-Symbols representation of the handwritten word that is independent of symbol order and allows rapid pruning of the lexicon. In combination with the lexicon-driven and lexicon free approach, high recognition accuracy 93.38 percent can be achieved.
Naveen S. et.al (2012) [4] proposed a method of detecting Devanagari text of a printed document by mapping word directly to Unicode sequence. Printed text is different than handwritten text because it does not vary with users. Here they consider Unicode as the main recognition unit and use a sequence transcription module to map the words features to corresponding Unicode. A variant of RNN known as BLSTM (Bidirectional long Short term memory) was used for the task. The total time taken to test a word image is approximately 0.25 seconds.
VedAgnihotri (2012) [5] proposed a new technique of Chromosomes function generation and fitness function for classification by extracting diagonal features from zones of an image. Handwritten Devanagari script recognition system using neural network is presented in this paper. For diagonal

extraction image is divided into some zones. Diagonal based feature extraction is used for extracting features of the handwritten Devanagari script. After that these feature of each character image is converted into chromosome bit string of length 378. In the recognition phase and classification Genetic Algorithm is used. The precision of offline Devanagari system is 85.78% match, 13.35% mismatch.

Gunjan Singh et.al (2012) [6] proposed an offline handwritten Hindi character recognition system using neural network. Neural networks are good at recognizing handwritten characters as these networks are insensitive to the missing data. In this paper proposed approach is to recognize Hindi characters this is done in four stages—1) Scanning, 2) Preprocessing, 3) Feature Extraction and, 4) Recognition. The feature vector comprises of pixels values of normalized character image. A Back propagation neural network is used for classification. Experimental results show that back-propagation network yields recognition accuracy of 93%.

Mitrakshi B. Patil et.al (2012) [7] proposed method for recognition of offline handwritten Devanagari characters using segmentation and Artificial neural networks. In this input image is scan image so it can easily preprocess. The whole process of recognition includes two phases- segmentation of Characters into line, word and characters and then recognition through feed-forward neural network.

Jayadevan R. et.al (2011)[8] did a survey of the comparative study of recognition of printed as well as handwritten word recognition by different classification techniques like Artificial Neural Network, Hidden Markov Model, Support Vector Machine, MQDF. In this survey paper he compares all classifiers with their accuracy.

A handwritten character recognition system using multilayer feed forward neural network is proposed in (2010) [9]. Three different orientations, namely, horizontal, vertical and diagonal directions are used for extracting 54 features from each character. Trained neural network is used for recognition of character.

In [10] Shanti N.(2010) proposed system for Handwritten Tamil character recognition which is based on support vector Machine. In this system global features are extracted from the character on which SVM is applied.

In [11] Suresh Kumar (2010) proposed a system in which the scanned image is segmented into paragraphs using spatial space detection technique, paragraph into lines using vertical histogram. The extracted features are given to SVM, self-organizing Map, RCS, Fuzzy Neural network. Structure analysis suggested that the proposed system of RCS with back propagation network is given higher recognition rate. With the combination of RCS and back propagation network, a high accuracy recognition system is realized. The training set consists of the writing samples of 25 users selected at random from the 40, and the test set, of the remaining 15 users. A portion of the training data was also used to test the system. In the training set, a recognition rate of 100% was achieved and in the test set the recognized speed for each character is 0.1sec and accuracy is 97%.

In [12] SandhyaArora (2010) characters are collected in a systematic manner from printed pages scanned on a HP7670 Scanjet scanner. Documents were skew corrected and components were extracted. After dimensionality reduction (PCA), Telugu needs around 150 features for representation, while Hindi needs only 50. SVM and ANN are used for classification. SVM-based classifiers are found to perform better than KNN. Experimental results show that recognition accuracy of 93.31%.

M. C. Padma (2009) [13] proposes a method which uses distinct features extracted from the top and bottom profiles of the printed text lines. Using learning algorithm propose system learnt training data set. From the experimentations on the test data set, the overall accuracy of the system has turned out to be 99.67%. This algorithm is also tested on another test data set constructed from the scanned document images. The overall accuracy of the system reduces to 98.5%.

PrachiMukherji et.al (2009) [14] proposed method in which thinned character is segmented into segments (strokes), using basic structural features like endpoint, cross point, junction points and adaptive thinning algorithm. The segments of characters are coded using our Average Compressed Direction Code (ACDC) algorithm. The knowledge of script grammar is applied to identify the character using shapes of strokes, mean row and column co-ordinates, relative strength, straightness and circularity. Their location in the image frame is based on fuzzy classification. Characters are pre-classified using a tree classifier. Subsequently unordered stroke classification based on mean stroke features is used for final classification and recognition of characters. Recognition accuracy for characters with top modifier (matra) is 71.68 % and without top modifier (matra) is 88.33 %. Somaya Alma (2006) [15] presented system for offline Arabic handwritten word recognition using neural network. In this system preprocessing is done by edge detection and thinning of slant and slope is done. After preprocessing feature extraction is done by extracting global features from whole word using that neural network recognizes word. The achieved accuracy is 63%.

5. COMPREHENSIVE STUDY

Below table shows the comprehensive study of different techniques used for handwritten character, word and script recognition.

Reference Paper	Preprocessing	Segmentation	Feature Extraction	Classification /Recognition
[1]	Preprocessing is done to normalize the position andsize of the sample.	–	NPen++ features are used for curliness, linearityand slope.	Hidden Markov Model based lexicon free technique used.
[2]	Image Binarization Thinning of binarized image windowing	Character recognition by neural network	Replacing the recognized characters by Standard fonts.	Assembling all the Separatedcharacters in thesame order as theyappeared inthe input image to give final output.
[3]	Thresholding method used for Binarization	Lines are segmented by noting the valleys of projection profile	Vertical Feature Bar, HorizontalZero , Crossing,Moments	Tree Classifiers
[4]	Morphological operation are used to noise removal Thinning algorithm is used to remove the distortions Bicubic interpolation are used for standard sized image	Differential distance based technique used for identifying the Shirorekha and spine	Top, bottom, left, right or on a Combinationtechnique. A single or double vertical line called a Danda (Spine) was traditionally used to indicate the end of phrase or sentence	Preliminary classification is performed for better results.
[5]	Gaussian filter used to make input data strokesmoother Andreduce noise.	–	Sequential floating search method used for Indic script	K-nearest neighbor and Support Vector Machine (SVM) used forrecognition.
[6]	Edge Detection is done and thinning for slant and slope	–	features are extracted from whole word.	Artificial neural network
[7]	Noise removal	–	Five differentfeatures from avertical strip width, usinga sliding window.	Neural network classifier known as Bidirectional Long Short TermMemory
[8]	Smoothing, Resampling and computation the length of input stroke if it less than set a priori ignore it for next phases	Cursive stroke segmentation for line and word segmentation.	Histogram of the direction codes calculated for each sub-stroke. Obtain co-ordinates of centre of gravity and normalize	Modified Quadratic discriminate function (MQDF) classifier is used. It improves efficiency over QDF.

	this approach is for noise removal.		these value by width and height of Stroke	
[9]	Preprocessing isdone to Normalizethe position and size of the sampleand to Removelocal noise so that the extractedfeatures from the sample becomerobust.	Horizontal projection file method is used for segmentation	Images scaled into height and width using bilinear interpolation technique	feed forward algorithm
[10]	Detection of edges in the binarized image using sobel technique,	Preprocessed input image is segmented into isolated characters by assigning a number to each character using a labelling process.	Diagonal feature extraction scheme is used to extract features from each zone.	A feed forward back propagation neural network used for classification
[11]	Gabor Thresholding and Otsu Thresholding methods(global) are used for Binarization	Horizontal and vertical profile method is used for segmentation	Zone based approach is used for Feature Extraction.	Support vector machine (SVM) method is used for classification.
[12]	Detection of edges in binarized image is done by canny technique.	Preprocessed input image is segmented into isolated characters by assigning a number to each character using a labelling process.	Diagonal feature extraction scheme is used to extract features from each zone.	Chromosome function generation and Chromosome fitness function are used for classification.
[13]	Thresholdingmethod used ForBinarization. Thinning algorithm used to thin thecharacters	Histogram method used to convert the image to glyph	Character height, width, no. of horizontal and vertical lines.	Support Vector Machine(SVM) used for classification
[14]	Threshold technique used for preprocessing.	−	Encoding binary variation method used for extract the features. Then text and tested recognize thecharacters.	Support Vector Machine(SVM) used for classification
[15]	Global thresholding approach was used to binarized the scanned gray scale image	−	Top and bottom profile based features are used for feature extraction.	Learning Algorithm is used for classification.

4. CONCLUSION

In this paper we have represented a survey of preprocessing, segmentation, feature extraction, classification and recognition techniques for handwritten Devnagari word recognition. This survey research paper helps researches and developers to understand various techniques which were implemented for recognition .

There is lot of issues in
recognition such as variation of writer's style. It is becomes interesting and challenging field for researcher in image processing and pattern recognition.

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