A Review on Handwritten Devanagari Character Recognition

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Abstract— **Because of the vast variation in writing styles, the handwritten text recognition is takes into account to be challenging task. So, the handwritten character recognition is now an active field of research. In India, a large number of people use Devanagari Script to write their documents, but due to large complexity, research work done on this script is very less compared to English script. Hence, handwritten recognition of Devanagari Script is one of the most demanding research area in the field of pattern recognition. Feature extraction and classification are important steps of OCR which affects the overall accuracy of the character recognition system. This paper gives a detailed review on different techniques used for feature extraction and classification by the researchers over the last few years.**

Keywords— OCR, Devanagari, Artificial Neural Network, CNN, K-NN, SVM.

I. INTRODUCTION

Optical character recognition is a technique for converting the scanned images of handwritten or machine-printed text into a digital form. Handwritten character recognition is one of the active field of research having a great importance in digital image processing. It has many applications like automation of organizations like post office, government and private offices, cheques processing in banks, searching or extracting data from documents and books. OCR is categorized into two parts known as handwritten character recognition and printed character recognition [1]. Nowadays the recognition accuracy of printed text is almost a resolved problem. However, because of the vast variation in writing styles, the handwritten text recognition is takes into account to be a hard task [2]. So, the handwritten character recognition is presently an active field of research.

The main objective of Recognizer is to recognize an image document with the help of split-up the document into lines and then further broken these lines into words and in the end into characters [3]. Features are extracted from these individual characters and compared with the image patterns in order to recognize characters. The recognition of the characters can be carried out either from printed or handwritten papers. The recognition of handwritten characters can be carried out either online or offline. In case of online, the current information is available like coordinates of pens tip as a function of time however, in case of offline recognition [4], the image of handwritten paper is required in digital form as shown in figure 1.
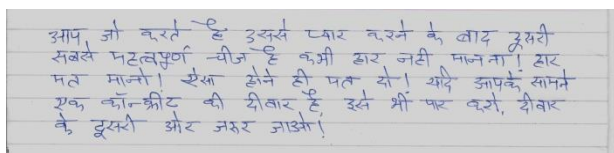

Figure 1. Example of Contemporary handwriting in Devanagari Script.

Character Recognition of other languages, such as, English, Korean, Chinese, German, Japanese, etc. are almost resolved problem as compared to Indian scripts like Devanagari, Bangla, Tamil, Oriya, Gurmukhi, etc. Due to gradually progressive growth handwritten Devanagari character recognition is a new and challenging area nowadays, which is developed with the concepts of artificial intelligence, machine learning, pattern recognition, and data mining. Although many handwritten Devanagari character recognition methods have already been introduced till date, but it is still a big task to process its documents because of large character set, linguistic based criticalities, and use of shirorekha[12].

Majority of the classification techniques in OCR deal with a numerous number of classes and finding discrimination between classes. There are numerous classification and recognition techniques available for the problem of pattern recognition. These techniques include, SVM, BPNN, ANN, KNN, CNN and Hybrid Classifier [17][18][19].

The objective of this paper is to find most accurate feature extraction and classification techniques used by the researchers over the past few years, for recognition of Devanagari script. The intention of this review paper is to serve as a guide for the researchers, working in the similar field.

The paper is managed in the following way: In Section II illustrates some information about Devanagari script,

Section III illustrates complexity of Devanagari script. In Section IV we discuss about four different phases in Devanagari OCR system, namely: preprocessing, segmentation, feature extraction and character recognition phase. Section V shows the literature survey on Devanagari script. Section VI narrates the recent work done on Devanagari script. Section VII we discuss conclusion and future scope of the research. Finally, last section illustrates the major challenges and issues.

II. INTRODUCTION TO THE DEVANAGARI SCRIPT

Every Indian language is derived from ancient Brahmi script and have phonetic base. India has 10 major scripts namely, Devanagari, Kannada, Bangla, Telugu, Gurumukhi, Tamil, Oriya, Malayalam, Urdu and Gujarati. From these scripts, many official languages are derived. Approximately half of the Indian people use Devanagari script and adopted more than 100 languages like, Hindi, Nepali, Marathi, Haryanvi, Rajasthani, Gujarati, Kashmiri, Bhojpuri, and Sanskrit, etc [20]. "Shirorekha" or "Matra" is also present in Devanagari script. Devanagari characters are divided into 3 parts: a core strip that contains main characters, a lower modifier symbol strip, and an upper modifier symbol strip. It has 47 primary characters from which 13 are vowels, 34 are consonants and 14 are modifiers as shown in figure 2 [13].

Figure 2. Vowels (Swar), Consonants (Vyanjan) and modifiers of Devanagari script.

III. COMPLEXITY OF DEVANAGARI SCRIPT

Following are some major points about the complexity of Devanagari script [5].

A. Shirorekha

In a word, multiple characters and modifiers appear as a single component connected through the common Shirorekha. Along with numerals, component characters, consonants, vowels, and vowel modifiers there are many similar shaped characters existing in devanagari script. All these make the handwritten character recognition, a difficult task.

B. Compound Characters

Compound character joins two or more characters in various ways, forming a new character. Due to structural complexity, recognition of compound characters is a challenging task. Optical Character Recognition for Devanagari script is highly complex due to its rich set of conjuncts. There are about 280 compound characters in Devanagari script.

C. Size, shape and style variation

Although a number of good recognition algorithms have been proposed for handwritten character recognition, the achieved performance is still far from human beings in context to free handwritten character recognition. The major obstacles have been the changeable writing conditions and different handwriting styles. There is wide variety of size, shape and style of each character written by writer.

IV. STEPS IN THE RECOGNITION PROCESS

Number of factors like various font sizes, noise introduced at the time of scanning, broken lines, broken words, or broken characters, etc affect the results of recognition system. The four different phases in OCR are: pre-processing, segmentation, feature extraction and character recognition as shown in figure 3.

Figure 3. Different phases in optical character recognition system

A. Preprocessing

For good recognition rate preprocessing stage is very important. In this stage, smoothing, enhancing, and filtering techniques are applied in order to improve readability of digital image. Subsequent algorithms of OCR software, uses this digital image. The various preprocessing stages is shown in figure 4.

1) *Binarization:* Binarization is the process of converting a gray scale image into binary image by using thresholding. Two intensity values are obtained as Black & White through this process [21]. The two methods used for conversion of gray level image to binary form are local or adaptive threshold and global threshold. Local or adaptive threshold uses different values for each pixel according to the information from local area. Global threshold selects single threshold value based on estimation of the background value from the intensity histogram of the image. The binarization process is used to identify the extent of objects and also to concentrate on the shape analysis [22].

2) *Noise elimination:* In scanned image there may be possibility of noise. Distortion, incomplete corners and gap in the lines are called noise in the image. The accuracy in recognition system can reduce due to

presence of noise. Many morphological and filtering techniques can be used to remove noise from image [21].

3) *Skew Correction:* Skew may decreases the accuracy of the succeeding processes, such as segmentation and classification. Hence, it is necessary to made skewed lines horizontal by calculating skew angle and making systematic correction in the scanned image [46][47][48].
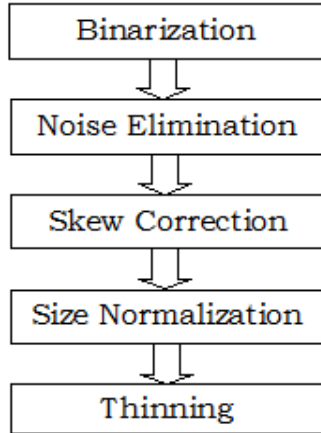

Figure 4. preprocessing stages

4) *Size normalization:* The handwritten characters of different writers are not uniform in size. To make characters in uniform size the segmented character is normalized into matrix like 16 x 16, 32 x 32, etc. Generally, input to the recognition system is an array of definite size. So, to make the image appropriate for recognition system, size normalization is necessary. Normalization decreases the size of the image without getting changed the structure of the image [21].

5) *Thinning:* A morphological operation called as thinning is applied to remove the selected foreground pixels from binary images. This process extracts a skeleton of the objects in image. The thinning algorithm consists of both connectivity analysis and boundary pixel analysis [22].

B. *Segmentation*

Segmentation is one of the most important stage, that affects the accuracy of the character recognition. Segmentation is the process of division of a character image into different regions [8]. Segmentation is obtained by finding the boundaries between characters. There are several techniques for finding the boundaries between characters. [6][7][45].

C. *Feature Extraction*

In this process most relevant information from the raw data is extracted. For each class, a set of features are extracted that helps reduces the pattern variation within class while maximizing between different classes [23] [9][24]. Some feature extraction methods are as follows:

1) Fourier Transforms
2) Gabor Transform
3) Wavelets
4) Moments
5) Zoning
6) Crossings and Distances
7) Projections
8) Coding
9) Graphs and Trees

D. *Character Recognition*

Features from input images are extracted and given as an input to the trained classifier like SVM and ANN. Trained Classifiers find out the best matching class by comparing the stored pattern with input features. Various methods and comparative study of Devanagari OCR can be found in [1] [10]. Character Recognition techniques can be classified as follows:

1. Artificial Neural Network
2. Support Vector Machine
3. K-nearest neighbors
4. Convolution Neural Networks
5. Hybrid Network

V. LITERATURE SURVEY

This section discusses literature survey on Devanagari script.

The errors in segmentation spread to recognition. Hence, suggested new segmentation techniques on the basis of structure technique for Handwritten Hindi text, in [40]. In which handwritten text is divided into lines then the lines into words and words into characters. The evaluation of performance on handwritten data of 1380 words of 200 lines written by 15 different writers. The overall results of segmentation are very capable.

Authors discussed feature extraction techniques for Euclidean distance based KNN, which achieved higher recognition rate than SVM [41]. In [34], curvatures and gradient features are extracted and applied on nearest-neighbor classifier. Results were analyzed on KNN, Nearest Neighbor, and Euclidean distance Neighbor based Kohonen NN and achieved accuracy of 94.98 percent.

In [27], features like chain code, shadow, histogram, longest run and view based are extracted and fed to NN and in SVM for classification. They achieved 82.89 percent accuracies on Devnagari character databases. The method proposed in [39] uses 16D rotation invariant Ring and

Zernike features for recognition of Devanagari handwritten numerals.

In [35] [36] using constellation diagram and chords structural features of characters are computed. In [38], statistical features was evaluated on different sub bands of Haar wavelet transform for recognition of Devanagari characters.

A method to recognize handwritten numerals and obtained 91.28 percent accuracy with MLP classifier [32]. In [33] proposed recognition of handwritten Hindi numerals and characters by fuzzy technique and obtained 92.67 percent accuracy for handwritten Devnagari numerals and 90.65 percent accuracy for handwritten Devnagri characters. In [44] presents a new approach in which features are extracted for handwritten Marathi numeral and fed to ANN for classification. The overall accuracy of recognition of handwritten Devanagari numerals is 99.67% with SVM, 99% with MLP and 98.13 with GFF classifier. In [43], Hindi OCR is developed in which shirorekha removal, feature extracted through K - means clustering and linear kernel based classification is accomplished in preprocessing, feature extraction, and classification stages respectively.

Hindi OCR survey in [42] illustrates recognition by using ANN, SVM, KNN, Fuzzy Logic, HMM, etc. In [37], discussed the state of the art of handwritten and machine printed Devanagari OCR techniques from 1970s. An effort is made to address the most important results reported so far and it is also tried to bring to light the advantageous directions of the research. A comparative study of handwritten character recognition for Devanagari script with respect to features and classifiers was presented in [10].

VI. PROPOSED WORK

In this section we discuss the recent work and detailed review on feature extraction and classification techniques used for Devanagari script:

Pankaj kale et. al.[11] proposed a ANN based recognition system for handwritten Marathi characters and experiments are applied on 500 characters from ten different peoples. The accuracy obtained is 92%.

Shalini Puri et. al.[12] presents OCR system, which identified Shirorekha-Less and modified Shirorekha-Less characters of handwritten Sanskrit, Hindi and Marathi image documents using support vector machine. The system was developed on various datasets of these languages and achieved better result 98.35%.

Parul sahare et. al.[13] proposed robust algorithms for character segmentation and recognition for Latin and Devanagari scripts. Primary segmentation paths are obtained by using structural property, whereas overlapped and joined characters are segmented using graph distance theory. SVM classifier validated the segmentation results and KNN classifier is used for recognizing the handwritten and printed input character. The recognition rates 97.05% for Devanagari script and 97.10% for Latin script respectively.

S. P. Deore et. al.[14] presents the system which recognizes the handwritten Devanagari isolated characters using ensembling of classifiers. In this paper HWCR system to recognize the Devanagari character using ensembling of classifiers is proposed. The recognition of Devanagari character is done in three main steps. The first step is pre-processing of the character image in which binarization and complementary of an image are performed. The second important step is feature extraction, in which it uses histogram of oriented gradient as a feature. Third step is classification in which three different classifiers SVM, K-NN and NN are used and their performance is measured. Results of these classifiers are combined together and given to the ensembler who classifies the class label based on maximum voting method. The average recognition rate is achieved by the proposed HWCR system is 88.13% using ensembling.

Bappaditya Chakraborty et al [15] have studied recognition of handwritten Devanagari characters using deep neural networks. In this study, handwriting recognition task using deep architectures of a wide variety of sizes is the first of its kind. Also, the highest recognition accuracy of 96.09% provided by a CNN network consisting of 7 convolution layers and 2 fully connected layers improves the existing state-of-the-art accuracy of handwritten offline Devanagari characters. However, the performance of a hybrid network of the same depth consisting of 5 convolutional layers, 2 BLSTM layers and 2 fully connected layers is poorer.

Naveen Malik et. al.[16] proposed Devanagari OCR using ANN, at the beginning lines, words and characters are segmented. For line and word 100% whereas for character 84% segmentation accuracy is achieved so it needs more attempt for character segmentation as it is complicated for Devanagari script. The performance of an OCR system hinges on to a great amount on the extracted features. They used 3 sets of features Chain code histograms, Projection histograms, and Histogram of aligned Gradients for comparing the performance of the character recognition system and obtained accuracy 91.11%.

S. No	Work	Feature Extraction	Classifier	Accuracy %	Research Gap
1	Shalini Puri et. al.[12]	geometric based features	SVM	98.35%	The accuracy will be improved for a large set database.
2	Parul sahare et. al.[13]	fixed center distance based feature, fixed center cut based feature, neighborhood counts based feature	KNN	97.05%	This technique gives 2.7-12.4% more accuracy on numerals then alphabets. There is large recognition gap between numerals and alphabets.
3	Bappaditya Chakraborty et al [15]	Histogram of Oriented Gradient	CNN	96.09%	The recognition accuracy can be improved, by increasing the size of the training set. Even larger the training set drops the recognition accuracy due to further, increasing the number of convolutional layers.
4	Pankaj kale et. al.[11]	Array based feature extraction	ANN	92%	Recognition rate are less.
5	Naveen Malik et. al.[16]	Chain code histograms, Projection histograms, and Histogram of aligned Gradients	ANN	91.11%	The character rank segmentation accuracy is 84%, which is very less.
6	S. P. Deore et. al.[14]	Histogram of Oriented Gradient (HOG) features	Hybrid Classifier (SVM, K-NN and NN)	88.13%	Recognition rate are less.

VII. CONCLUSION AND FUTURE SCOPE

In this survey paper we present a detailed study on work done in handwritten Devanagari character recognition and comparison between different techniques used. The comparison is shown in table 1. This study also discusses various feature extraction and character identification techniques used for the Devanagari handwritten characters. The survey concludes that SVM classifier provides better results which classified Shirorekha-Less characters and obtains recognition rates of 98.35%. This study points out that the work done on Devanagari scripts is still at its childhood stage, so this area still needs further consideration to solve many problems.

In future, the system can be improved in the following ways:

- By using the large set of database.
- Include various Indian and Latin scripts to make the generic system.

VIII. MAJOR CHALLENGES AND ISSUES

The ready availability of dataset is a huge problem in handwritten Devanagari character recognition system, more time and effort is required to generate them manually. Lack of the co-operation and co-ordination between researchers also affects the growth of handwritten Devanagari character recognition system.

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