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Article

HHBCR: A novel approach for Hand-written Hindi Barakhadi Characters Recognition

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Abstract: The process that enables identification and classification of text characters from the image is termed as character recognition. This recognition is further categorized into two categories: (1) recognition of printed characters, and (2) recognition of hand-written characters. Hand-written Hindi character recognition is the process of recognizing Hindi characters from the image containing hand-written text. The work discussed in literature, related to hand-written Hindi character recognition, focuses on recognition of an individual vowel character or consonant character. As per our observations, this existing work possesses two limitations: (1) It does not focus on the recognition of characters formed by the combination of vowels and consonants known as Barakhadi characters, and (2) It recognizes individual characters less accurately because of similarity in the shapes of various characters. Hence, with an aim to overcome these limitations, in this paper, we propose a novel approach HHBCR for recognition of hand-written Hindi Barakhadi characters. Experimental results affirm recognition of characters with an acceptable accuracy.
Keywords: Optical Character Recognition; Hindi Barakhadi characters; Hand-written character recognition; Convolutional Neural Network; Feature extraction

1. Introduction

The technique used to recognize characters from digital images containing either printed or hand-written characters is termed as Optical Character Recognition (OCR) [1-5]. As discussed in [6-12], this technique is categorized into: (1) Online character recognition wherein characters are identified immediately after taking them as an input through various digital input devices such as digitizer, pad, mobile, etc. (2) Offline character recognition wherein first digital characters are generated from either machine-printed or hand-written characters and then characters are identified.

Recognition of characters from hand-written characters is complex as compared to recognition of the same from machine-printed characters because of variety in individuals' handwriting. Moreover, recognition of Hindi Barakhadi characters is a challenging task. In our work, we concentrate on the recognition of hand-written Hindi Barakhadi characters.

1.1 Hindi Barakhadi characters

Hindi Barakhadi characters are the characters formed by the combination of vowels and consonants. In Table 1 and Table 2, 12 vowels and 36 consonants of Hindi script are shown, respectively [1, 13-17]. Each consonant character (of Table 2) can be combined with 12 vowels (of Table 1) to generate 12 derived forms of that consonant character known as Barakhadi characters. As an illustrative example, Barakhadi characters for the Hindi character 'म' are shown in Table 3.

Furthermore, many printed as well as Hand-written Hindi characters, such as (ब, व), (घा, धा), (भी, मी), (पै, षै),

Table 1. Vowel characters

अ	आ	इ	ई	उ	ऊ	ए	ऐ	ओ	औ	अं	अः

Table 2. Consonant characters

क	ख	ग	घ	ङ	च
छ	ज	झ	ञ	ट	ठ
ड	ढ	ण	त	थ	द
ध	न	प	फ	ब	भ
म	य	र	ल	व	श
ष	स	ह	क्ष	त्र	ज्ञ

Table 3. Barakhadi characters for the Hindi character 'म'

म	मा	मि	मी	मु	मू	मे	मै	मो	मौ	मं	मः

Table 4. Examples of characters having similarity

	ब		ट		घा		भी		फि		पै		पै
	व		ढ		धा		मी		कि		षै		यै

etc. have similarity in their shapes. In Table 4, we illustrate few examples of similar shaped characters. The task to recognize such characters is also challenging. Consequently, the motive of this paper is recognition of hand-written Hindi Barakhadi characters including similar shaped characters with an acceptable accuracy.

1.2 Organization

The organization of the residual paper is as follows: In Section II, related work, along with parametric evaluation of existing approaches, is discussed. In Section III, proposed approach is discussed. In Section IV, experimental analysis of the proposed approach is discussed. In Section V, we conclude our paper. Moreover, future directions are also discussed in Section V.

2. Related Work

In [1], for feature extraction, authors utilize region-based k-means clustering. They apply binarization [18] on the image to convert it from RGB to grayscale. Characters are separated during the pre-processing phase. The authors use a database containing 430 samples of Hindi characters from 33 different classes. For classification, they use Support Vector Machine (SVM).

In [15], authors prepare and consider Devanagari hand-written character dataset of Devanagari script. This dataset contains 92,000 images of characters in Devanagari script from 46 distinct classes. The authors perform image scaling, padding, and grayscale conversion during pre-processing phase. For character recognition, they employ Convolutional Neural Network (CNN) classifier.

In [19], authors employ the digital curvelet transform and the K-Nearest Neighbour (KNN) classifier for Hindi characters recognition. After segmenting input images, using the curvelet transform, curvelet features are retrieved by calculating thick and thin images. They consider the dataset containing 200 images of the characters from 49 distinct classes.

Table 5. Existing approaches utilized for recognition of Hand-written characters - parametric evaluation

Approach	Technique(s) used for pre-processing	Technique(s) used for feature extraction	Language(s) considered	Considered types of characters	No. of classes considered	No. of samples used for experiments	Technique(s) used for classification	Performance measure
Gaur A. et al. [1]	Noise removal, Binarization	k-means clustering	Hindi	Consonants	33	430	SVM	Accuracy
Yadav M. et al. [6]	Thinning, Noise removal	HOG, Profile projection histogram	Hindi	Vowels and consonants	41	4,428	SVM, KNN, Bagged trees	Accuracy
Narang S. R. et al. [13]	Noise removal, Resize of image	DCT zigzag features	Devanagari	Consonants	33	5,484	Decision tree, Naive Bayes, SVM	Accuracy
Acharya S. et al. [15]	Resize of image	CNN	Hindi	Consonants and numbers	46	92,000	CNN	Accuracy
Verma G. K. et al. [19]	Normalization, Noise removal, Gray Scale conversion	Curvelet features	Hindi	Consonants and vowels	49	200	KNN	Accuracy
Singh N. [20]	Resize of image, Binarization	HOG	Hindi	Vowels	12	400	ANN	Accuracy
Tushar et al. [21]	-	CNN	Hindi, Urdu, Bangla	Numbers	10	12,000	CNN	Accuracy
Narang S. R. et al. [22]	Noise removal, Resize of image	DCT, HOG	Devanagari	Consonants	33	5,484	Naive Bayes, SVM	Accuracy
HHBCR (Proposed Approach)	Resize of image, Gray Scale conversion	CNN	Hindi Barakhadi	Hindi Barakhadi characters	408	81,600	CNN	Accuracy

In [6], the database of hand-written Hindi characters is considered by authors. To assure diverse orientations and sizes, the database contains a total of 4,428 samples with 108 samples for each character. They use profile projection histogram and Histogram of Oriented Gradients (HOG) for feature extraction. Classifiers including

quadratic SVM, KNN, weighted KNN, Ensemble Subspace Discriminant, and bagged trees are employed by the authors.

In [20], the author employs the collection of images containing ten samples of each 62 hand-written Devanagari characters. The size of each image is of 80×40 pixels. The author employs a Histogram of Oriented Gradients for feature extraction. For classification of characters, the author uses an Artificial Neural Network (ANN).

In [21], a model for hand-written numerical character recognition of Indian scripts is proposed by authors. The model uses CNN with backpropagation for error reduction. It employs dropout for data overfitting. They consider hand-written numerical datasets in three different languages: Hindi, Urdu, and Bangla. The authors utilize Bangla, Urdu, and Hindi hand-written numerical datasets with 3,000, 6,000, and 3,000 samples, respectively.

In [13, 22], the dataset of existing Devanagari manuscripts from various libraries and museums is employed by authors. A Hindi character's database with 5,484 samples from 33 distinct classes is used by them. They use the K-Nearest Neighbour interpolation approach to normalize the characters into 64×64 pixel sized characters. Using a zigzag Discrete Cosine Transform (DCT), the authors of [22] extract features. Character from manuscripts is recognized using Support Vector Machine (SVM), Naive Bayes, and decision tree classifiers. In addition, with the base classifier, bagging ensemble and the Ada boost techniques are used with an aim to increase an accuracy of character recognition. The highest accuracy is achieved by Adaptive boosting using Radial Basis Function (RBF) kernel SVM. With the help of various performance assessment metrics, results of the ensemble process are evaluated by the authors. In [13], authors extract features with the help of a Discrete Cosine Transform (DCT) zigzag and a Histogram of Oriented Gradients. For character recognition from archaic Devanagari manuscripts, Support Vector Machine (SVM), Naive Bayes, and decision tree classifiers are utilized.

Parametric evaluation of existing approaches for hand-written characters recognition is discussed in Table 5. As per our observations, these approaches exhibit following limitations:

1. Existing approaches do not focus on recognition of the Barakhadi characters - characters formed by the combination of consonants and vowels.
2. Because of similarity in the shape of various characters, such as (ब, व), (घा, धा), (भी, मी), (पै, षै), etc., existing approaches recognize the characters less accurately.

Consequently, we aim to overcome these limitations. In this paper, our contributions are as follows:

1. We create dataset of hand-written Hindi Barakhadi characters. This dataset also contains similar shaped characters.
2. A novel approach HHBCR is proposed for the recognition of hand-written Hindi Barakhadi characters including similar shaped characters.
3. We evaluate performance of the proposed approach.

3. Proposed Approach

The working of our approach is divided into three steps (Figure 1): (1) Data collection and pre-processing step, (2) Feature extraction step, and (3) Classification step.

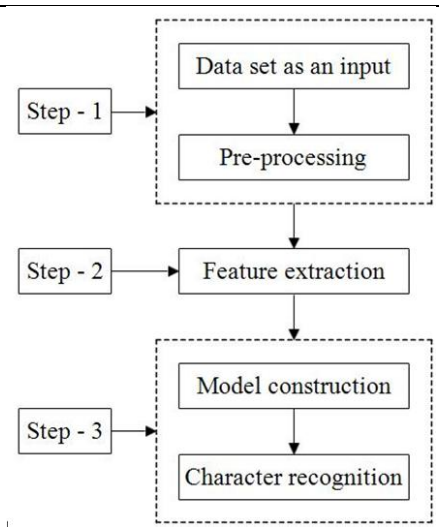

Figure 1. HHBCR - workflow diagram

1.3 Data collection and pre-processing step

Data collection step: Dataset of hand-written Hindi Barakhadi characters is created by us. For the purpose, we collect hand-written Hindi Barakhadi characters from more than 200 random persons. Few samples of collected characters are shown in Figure 2(a)-2(d).

Figure 2(a). Sample of hand-written Hindi Barakhadi characters collected from Person 1

Figure 2(b). Sample of hand-written Hindi Barakhadi characters collected from Person 2

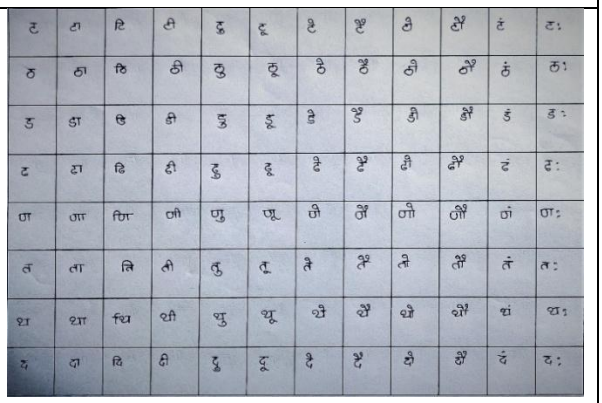

Figure 2(c). Sample of hand-written Hindi Barakhadi characters collected from Person 3

Figure 3(a). Scanned image taken as an input

Figure 2(d). Sample of hand-written Hindi Barakhadi characters collected from Person 4

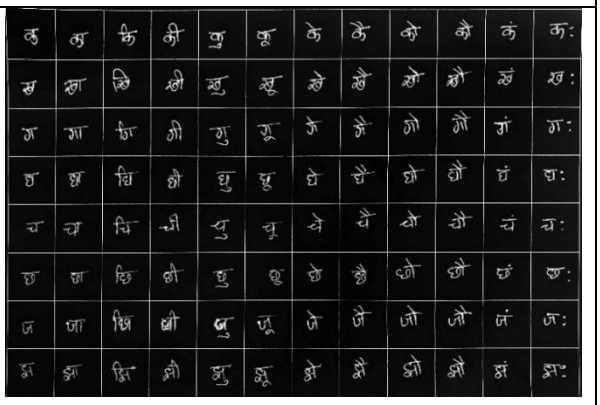

Figure 3(b). Conversion of an Input image (Figure 3(a)) into grayscale image

Figure 3(c). Slicing of the image of the Figure 3(b)

Figure 3(d). Sample individual images after Slicing Operation

Figure 3(e). Final images after cropping and normalization

Data pre-processing step: The collected samples are digitized using scanner in colour and stored in JPEG format (Figure 3(a)). Subsequently, scanned images from RGB are converted to grayscale images and stored in JPEG format (Figure 3(b)). After conversion of images, slicing of images is done (Figure 3(c)). The sliced images (Figure 3(d)) are then manually cropped and normalized (Figure 3(e)). The whole process is depicted in Figure 3(a)-3(e) with the help of the collected sample of Figure 2(a). Then, final images are stored in 408 different classes of Barakhadi characters. Thus, our dataset is consisting of 81,600 images from 408 classes, each class consisting of 200 images of Barakhadi characters.

1.4 Feature extraction and Classification steps

We use CNN for feature extraction and classification. The architecture of CNN model, we utilize, is discussed in the subsequent subsection (Section 4.1, Table 6).

4. Experimental Analysis

1.5 Experimental Setup

The system, used for the experimental analysis of our approach, has 16 Gigabytes of memory, Intel i7 10th generation CPU running at 2.60GHz with turbo boost up to 5 GHz clock speed, and 4 Gigabytes of GPU memory (NVIDIA GeForce GTX 16100).

Table 6. Architecture of CNN

Layer (Type)	Input Shape	Output Shape
Input	[(None, 64, 64, 3)]	[(None, 64, 64, 3)]
Conv2d_1	[(None, 64, 64, 3)]	[(None, 64, 64, 32)]
MaxPooling2D	[(None, 64, 64, 32)]	[(None, 32, 32, 32)]
Conv2d_2	[(None, 32, 32, 32)]	[(None, 32, 32, 64)]
MaxPooling2D	[(None, 32, 32, 64)]	[(None, 16, 16, 64)]
Conv2d_3	[(None, 16, 16, 64)]	[(None, 16, 16, 96)]
MaxPooling2D	[(None, 16, 16, 96)]	[(None, 8, 8, 96)]
Conv2d_4	[(None, 8, 8, 96)]	[(None, 8, 8, 96)]
MaxPooling2D	[(None,8, 8, 96)]	[(None, 4, 4, 96)]
Flatten	[(None, 4, 4, 96)]	[(None, 1536)]
Dense	[(None, 1536)]	[(None, 512)]
Activation	[(None, 512)]	[(None, 512)]
Output	[(None, 512)]	[(None, 12)]

The proposed approach is implemented in Python. Specifically, it is implemented using Keras [23] with TensorFlow [24] as backend. Among different types of the neural networks, CNN is preferable over other fully connected networks for classification of the image data [25-31]. Hence, in our work, we use CNN. The overall architecture of CNN utilized for the experimental analysis of our proposed approach is summarized in Table 6.

For experimental analysis of our approach, we collect hand-written Hindi Barakhadi characters from more than 200 persons. Subsequently, we pre-process these collected data as discussed in Section 3.1 (Figure 3(a)-3(e)).

1.6 Experimental Configurations

For evaluating performance of the proposed approach, we consider two cases (Table 7). In Case-I, same number of epochs (100) and different split ratio of training and testing data are taken into consideration. In Case-II, different number of epochs and same split ratio of training and testing data (70:30) are considered. Experimental configurations are summarized in Table 7.

Table 7. Experimental Configurations

Configurations	Cases	Image Size
Configuration-I (for Hindi Barakhadi characters recognition)	Case-I (Same number of epochs (100) and different split ratio of training and testing data)	32×32 pixels
		64×64 pixels

	Case-II (Different number of epochs and same split ratio of training and testing data (70:30))	32×32 pixels
		64×64 pixels
Configuration-II (for similar shaped Hindi Barakhadi characters recognition)	Case-I (Same number of epochs (100) and different split ratio of training and testing data)	32×32 pixels
		64×64 pixels
	Case-II (Different number of epochs and same split ratio of training and testing data (70:30))	32×32 pixels
		64×64 pixels

For experimental Configuration-I, we take total 12 Barakhadi characters of individual Hindi letter. For experimental analysis of our approach, in this configuration, we consider letters "व", "ज", "क्ष", "ख", "म", "झ", and "ण" as candidate letters.

For experimental Configuration-II, we take similar shaped Barakhadi characters of Hindi letter. For experimental analysis, in this configuration, we consider (भ, म), (प, ष), (ट, ढ), (क, फ), and (व, ब) as candidate similar shaped Barakhadi characters.

In both configurations, we resize the image into 32×32 pixels as discussed by the authors in [15, 21, 32, 33] and 64×64 pixels as discussed in [6, 22, 34, 35]. We use CNN [36] machine learning algorithm for training our model.

1.7 Experimental Results

In this section, experimental results we obtain through our approach proposed in this paper are demonstrated (Figure 4-11).

1.8 Experimental Findings

From experimental results we obtain, in both cases of both configurations (Figure 4-11), we observe that our approach recognizes Hindi Barakhadi characters with an acceptable accuracy despite of having variations in hand-written characters. The variations in collected characters are caused through variations in, (1) individuals' handwriting styles, and (2) shapes of different Hindi Barakhadi characters.

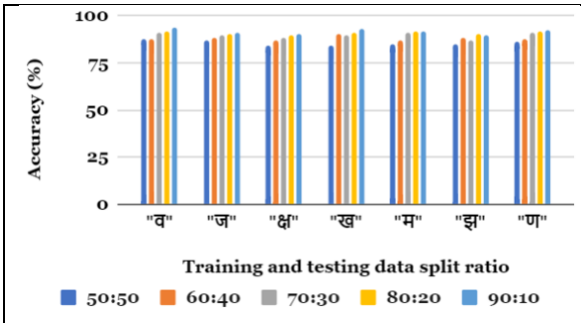

Figure 4. Accuracy Vs. Training and testing data split ratio (Configuration-I, Case-I, 32×32 pixels image size)

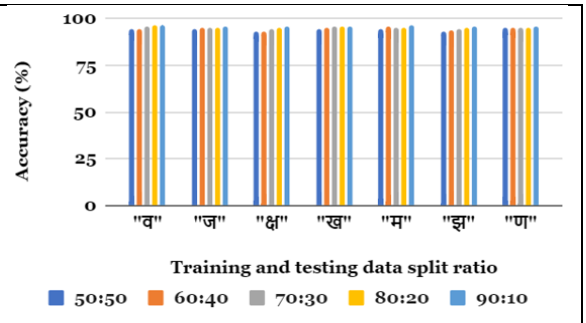

Figure 5. Accuracy Vs. Training and testing data split ratio (Configuration-I, Case-I, 64×64 pixels image size)

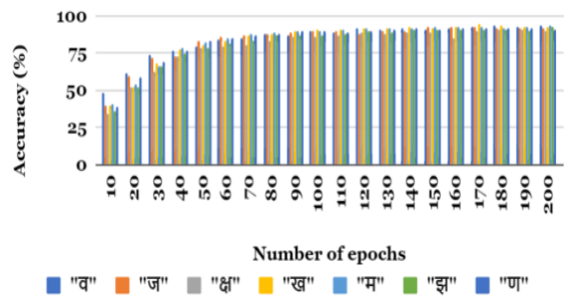

Figure 6. Accuracy Vs. Number of epochs (Configuration-I, Case-II, 32×32 pixels image size)

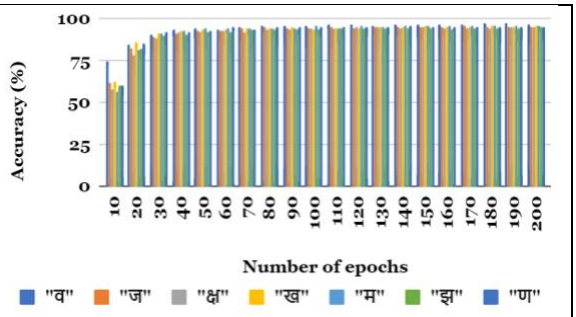

Figure 7. Accuracy Vs. Number of epochs (Configuration-I, Case-II, 64×64 pixels image size)

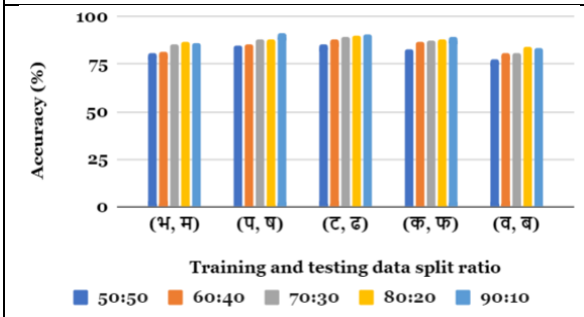

Figure 8. Accuracy Vs. Training and testing data split ratio (Configuration-II, Case-I, 32×32 pixels image size)

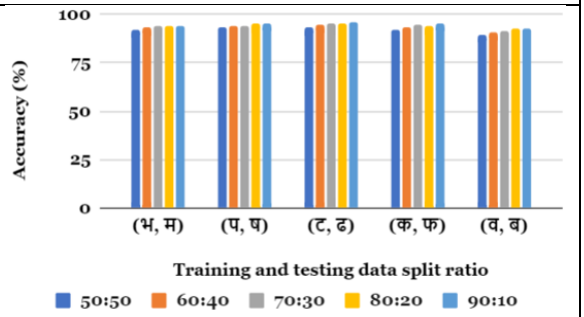

Figure 9. Accuracy Vs. Training and testing data split ratio (Configuration-II, Case-I, 64×64 pixels image size)

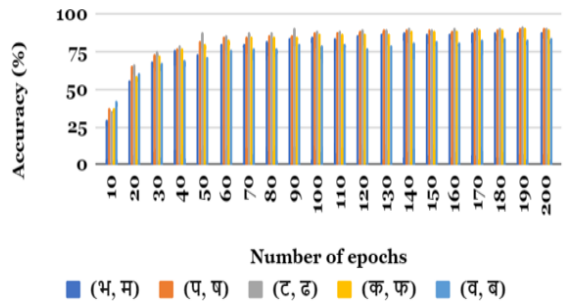

Figure 10. Accuracy Vs. Number of epochs (Configuration-II, Case-II, 32×32 pixels image size)

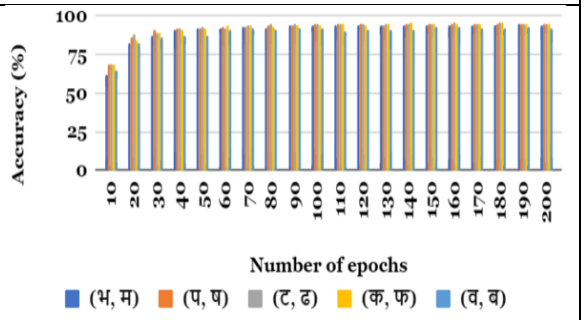

Figure 11. Accuracy Vs. Number of epochs (Configuration-II, Case-II, 64×64 pixels image size)

4.1 Experimental Findings (from results of Configuration-I)

From the results of case-I (Figure 4, Figure 5), we observe that, for 70:30 training and testing data split, our approach recognizes each Hindi Barakhadi character with an accuracy up to 90% and 95% having image size of 32×32 pixels and 64×64 pixels, respectively.

From the results of case-II, we observe that our approach recognizes the characters, with an accuracy up to 93% after 100 epochs in 32×32 pixels image size (Figure 6) and with an accuracy up to 97% after 40 epochs in 64×64 pixels image size (Figure 7).

4.2 Experimental Findings (from results of Configuration-II)

In this configuration, from the results we obtain for case-I (Figure 8, Figure 9), for 70:30 training and testing data split, we observe that similar shaped characters are recognized with an accuracy up to 89% and 95% having image size of 32×32 pixels and 64×64 pixels, respectively.

In this configuration, from the results we obtain for case-II, we observe that similar shaped characters are recognized after 70 epochs in 32×32 pixels image size (Figure 10) with an accuracy up to 91% whereas in 64×64 pixels image size such characters are recognized after 50 epochs (Figure 11) with an accuracy up to 95%.

5. Conclusion and Future Work

In this paper, we propose a novel approach HHBCR for recognition of hand-written Hindi Barakhadi characters. For experimental analysis, as we discuss, we create a dataset for hand-written Hindi Barakhadi characters.

Firstly, we measure an accuracy for recognition of total 12 Barakhadi characters of individual Hindi letters. In this paper, we demonstrate experimental results for "व", "ज", "क्ष", "ख", "म", "झ", and "ण" letters (Figure 4-7). From experimental results, we conclude that our approach recognizes 12 Hindi Barakhadi characters of individual letters with an acceptable accuracy (as discussed in Section 4.4). Though, in this paper, we demonstrate experimental results for candidate letters ("व", "ज", "क्ष", "ख", "म", "झ", and "ण"), our approach equally performs for Barakhadi characters of all Hindi letters.

Secondly, we measure the accuracy of recognition for similar shaped Barakhadi characters of Hin-di letters. We demonstrate the experimental results for (भ, म), (प, ष), (ट, ढ), (क, फ), and (व, ब) (Figure 8-11). From experimental results, we conclude that our approach recognizes similar shaped Barakhadi characters of Hindi letters with an acceptable accuracy (as discussed in Section 4.4). Though, in this paper, we demonstrate experimental results for candidate similar shaped Barakhadi characters of Hindi letters ((भ, म), (प, ष), (ट, ढ), (क, फ), and (व, ब)), our approach performs alike for similar shaped Barakhadi characters of all Hindi letters.

The work presented in this paper can be extended for recognition of Barakhadi characters of languages other than Hindi language. Additionally, our work can be extended for recognition of hand-written words formed by Barakhadi characters of all languages.

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