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Multistage Recognition Approach for Offline Handwritten Marathi Script Recognition

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Abstract

Handwriting is the most effective way by which civilized people speaks. Devanagari is the basic Script widely used all over India. Many Indian languages like Hindi, Marathi, Rajasthani are based on Devanagari Script. In the proposed work multistage approach i.e. an artificial neural network based classifier and statistical and structural method based feature extraction method has been employed for the recognition of the script. Optical isolated Marathi words are taken as an input image from the scanner. An input image is preprocessed and segmented. The key step is feature extraction, features are extracted in terms of various structural and statistical features like End points, middle bar, loop, end bar, aspect ratio etc. Feature vector is applied to Self organizing map (SOM) which is one of the classifier of an artificial neural Network.SOM is trained for such 3000 different characters collected from 500 persons. The characters are classified into three different classes. The proposed classifier attains 98% - 99% accuracy except special characters.

Keywords: *Image Preprocessing, Feature Extraction, Network Neighborhood, Self Organizing Map, Learning Vector Quantization*

1. Introduction

Many efforts has been taken by the researchers for the recognition of handwritten scripts. Due to variety of human writing offline word recognition is the challenging problem. A person’s handwriting is unique just like fingerprint. Offline handwriting script recognition is having its potential applications in bank automation, Cheque reading etc. Six different scripts popularly used all over the world are [1] Arabic, Roman, Cyrillic, Han, Hebrew, and Devanagari .Different script may follow the same writing method. Script may be defined as a graphical form of a system. Script is written from left to right (few exceptions like Gujarati,Oriya).Bhojpuri,Gujari,Pahari(Garhwali,Kumaoni),Konkani,Magahi,Maithili,Marwari,Bhili,Newari,Santhali,Tharu and sometimes Sindhi, Dongari, Sherpa and Kashmiri. For writing different local Indian languages Devanagari script is used .There are many region specific variations in terms of shape of numerals and characters. An interesting and surprising thing in Indian handwritten document is either the word or the numeral is **written in terms of English.** It may have the reason like English is India's Official language. According to survey of Indian languages conducted by Badoda Language centre there are 970 languages in which Indian people communicates. In Maharashtra there are 60 languages and sub languages out of which only two languages are having their own script(Marathi, Gond). This paper has been focused on recognition of Marathi script which is purely based on Devanagari script. Complexity in the patterns, large number of classes and subclasses involved in basic characters, different writing styles and sizes of the characters and words leads handwritten

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Marathi character recognition as one of the most difficult problem in pattern recognition. Three significant stages of recognition module are preprocessing, feature extraction and classification. Devanagari script consist of 49 characters and 10 numerals, out of which 13 are vowels and 36 are consonants. There are 5 upper modifiers and 3 lower modifiers with side modifiers .Vowels can be written as independent letters, or by using a variety of diacritical marks which are written above, below, before or after the consonant, they belong to. When vowels are written in this way they are known as modifiers and the characters so formed are called conjuncts. Sometimes two or more consonants can combine and take new shapes. These new shape clusters are known as compound characters. All the characters have a horizontal line at the upper part, known as Shirorekha or headline. In continuous handwriting, from left to right direction, the Shirorekha of one character joins with the Shirorekha of the previous or next of the same word. In this fashion, multiple characters and modified shapes in a word appear as a single connected component joined through the common Shirorekha as shown in Figure 1.

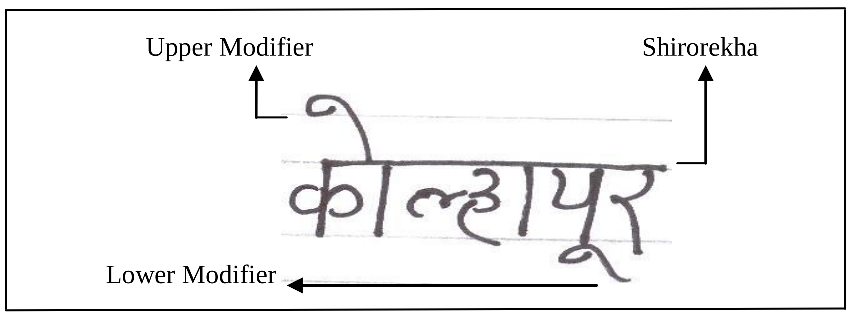


Figure 1. Devanagari Word," Kolhapur"

1.1. Pattern Recognition System

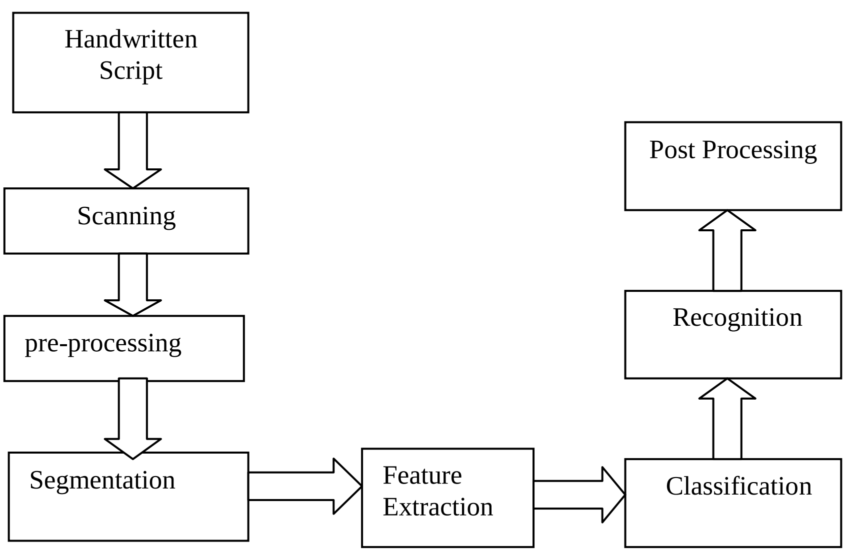


Figure 2. Pattern Recognition System

General block diagram for pattern recognition scheme has been shown in Figure 2. The classifier utilizes the extracted features to assign an input character into a predefined class.

Fine tuning and other parameters like cost of errors are considered for the final decision in post processing.

2. Past Review

Jenowa Park Proposed offline handwritten word recognition(HWR)[9].The key ideas are actively and successfully select a subset of features for each word image which provides the minimum required classification accuracy to get a valid answer and to derive a consistent decision metric which works in multi resolution feature space and considers the interrelationship of lexicon at the same time .A recursive architecture based on interaction between flexible character classification and deductive decision making is developed. The recognition process starts from the initial coarse level using a minimum number of features, then increase the discrimination power by adding other features adaptively and recursively until the result is adapted by the decision maker .For the computational aspect of a feasible solution ,unified decision metric ,recognition confidence ,is derived from two measurements: pattern confidence, evalution of absolute confidence using shape features and lexical confidence evaluation of the relative string dissimilarity in the lexicon He has implemented the same for the **US MAIL** Address component.

A. K.Jain [1] automatic identification of handwritten script facilities many important applications such as automatic transcription of multilingual documents and search for documents on the web containing a particular script. The increase in usage of handheld devices which accept handwritten input has created a growing demand for algorithms that can efficiently analyze and retrieve handwritten data. This paper proposes a method to classify words and lines in an online handwritten document in to one of the six major scripts: Arabic, Devanagari, Cyrillic, Han, Hebrew, or Roman. The classification is based on 11 different spatial and temporal features extracted from the strokes of the words. The proposed system attains an overall accuracy of 87.1%at world level with 5 fold cross validation on data set containing 13,379 words. The classification accuracy improves to 95% as the number of words in the test sample is increased to five and to 95.5 %for complete text lines consisting of an average of seven words.

Ujjawal Bhattacharya[2] had proposed a system that concerns the problem of isolated handwritten numeral recognition of major Indian scripts the main contribution that he has stated multistage recognition scheme and pioneering development for the database of Indian numerals. He has used three MLP classifier. If require one classifier may be added .The system has been developed for mixed numerals .He also stated that no standard database is available for Indian scripts. He has simulated the proposed recognition scheme on handwritten numeral database of three major scripts *i.e.*, Devanagari, Bangla *etc*. For Devanagari and Bangla he has created his own database but for English he has taken **MNIST** database he has tried the system for Devanagari English, Bangala **-**English as this type of manuscripts appears in various forms and mail pieces .PIN code is also written sometimes in mixed manner.

Reena Bajaj and Lipika Day [3] describes an efficient and reliable technique for recognition of handwritten numerals. Three different types of features have been used for classification of numerals. In this paper a new approach for recognition of handwritten Devanagari numerals using multiple neural classifiers hence tried to exploit information about stylistic variations, similarity between numerals and style invariant features. The overview of the scheme presents, the set of first type of features provide coarse shape description of the numerals and are relatively insensitive to minor changes in character shapes. But these features are not expected to remain unchanged for different writing styles.

3. Recognition of Handwritten Devanagari OCR System

The scanned Image is preprocessed. Significant steps involved in recognition of handwritten characters are

Image Acquisition.

Image Pre-processing.

RGB To Gray conversion

Noise Removal

Segmentation.

Feature Extraction.

SOFM Based Character Classification.

Post-processing.

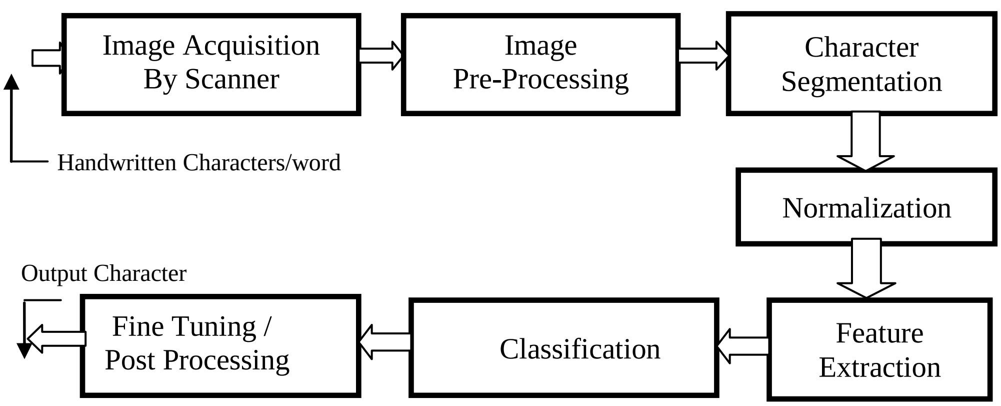


Figure 3. Recognition of Handwritten Devanagari Characters

3.1. Image Acquisition

By using 300 dpi flat bed scanner handwritten Devanagari words are captured and are converted into digital images. Size variant Devanagari words are taken from different 500 persons which makes database of 3000.

3.2. Image Pre-processing

Preprocessing relates to image preparation for the later analysis and use. The main aim of preprocessing is to make the image ready for segmentation and for feature extraction.

3.3. RGB to Gray Conversion

Color image can be converted into grey scale image by using the formula [10]

GRAY = 0.299*R + 0.587*G + 0.114*B

3.4. Noise Removal

There are many methods to remove the noise from an image but Median filter with 3*3 matrix is used for noise removal. Median Filtering has been employed, to remove irregularities such as ‘’speckle noise”, “salt and pepper noise” in the digital image introduced in the scanning process .Each pixel has been replaced by the median of the neighbouring pixels. [9]

f (x, y) = median {g(s, t)}.

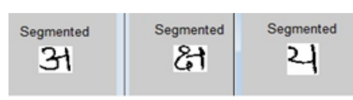
3.5. Segmentation

Segmentation is the key element of recognition system. Devanagari character segmentation process has been depicted in Figure 4. The pre-processed image has been taken as an input image .The upper part of the word is called Shirorekha[1], connects all the alphabets together. Initially remove the Shirorekha from the word to reduce the complexity in the recognition process. Extract the sub images that are separated from the adjacent letters. The sub image may contain more than one component called as modifier. Separate the modifiers. Segmented image is sent for feature extraction [8]. (Compound characters are having separate algorithm for segmentation).

a)Marathi word AKSHAY with Shirorekha after pre-processing.

b)Pre-processed Marathi word AKSHAY after removing Shirorekha

c) Character Separation in the Marathi word AKSHAY



d)Segmentation of Marathi word AKSHAY

Figure 4. Segmentation Process of Marathi Word, "AKSHAY"

3.6. Feature Extraction

Feature extraction is the key step in the recognition process. Based on shape the core characters are classified into three main classes, These classes also decides coverage of core stripe and bar present or absent.

1) Without Bar Characters.
2) End Bar
3)Middle Bar

Two structural and one statistical parameter which includes twenty one features are extracted and applied to the classifier (neural network). End points, No. of Junctions, loops are structural features and aspect ratio is statistical feature. Suppose the Character is अ

Then 3*3 matrix are

1	0	1
0	0	0
1	0	1

0	1	1
0	1	0
0	0	0

Figure 5. a)End Points b) Junction Points c) Loop is Present with Shirorekha

And the aspect ratio is [1 0 0] So the total code feature vector is

1 0 1 0 0 0 1 0 1 01 1 0 1 0 0 0 0 1 0 0

If the character is क्ष Then the matrix 3*3 are

0	0	1
0	0	0
1	0	1

0	0	0
1	0	1
0	0	0

Figure 6. a)End Points b) Junction Points c) Loop is Present with Shirorekha

And the aspect ratio is [1 0 0] So the total code feature vector is [7, 9, 10]

0 0 1 0 0 0 1 0 1 0 0 0 1 0 1 0 0 0 1 0 0

If the character is य Then the matrix is

1	0	1
0	0	0
0	0	1

0	0	0
0	0	1
0	0	0

Figure 7. a)End Points b) Junction Points c) Loop is Absent with Shirorekha

Aspect ratio is 110

1 0 1 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 1 1 0

In this way the feature(code) vector for all Devanagari characters has been calculated [12]. These features are applied as an input vector to the classifier *i.e.*, self organizing map.

3.6. Classification

Self Organizing map has been employed as a classifier. It is Topology preserving Map. It uses the concept of closet cluster wins(minimum Euclidean distance) and efficiently clusters the data .Generalization is the unique property of the said classifier.

3.6.1. Basic Structure

The first layer of the network is an input layer. Figure 8 shows connections between input vector and a single unit in the competitive layer. Typically the second layer is organized as a two dimensional grid [4]. All the connections are from the first layer to the second layer. Two layers are fully interconnected [31].

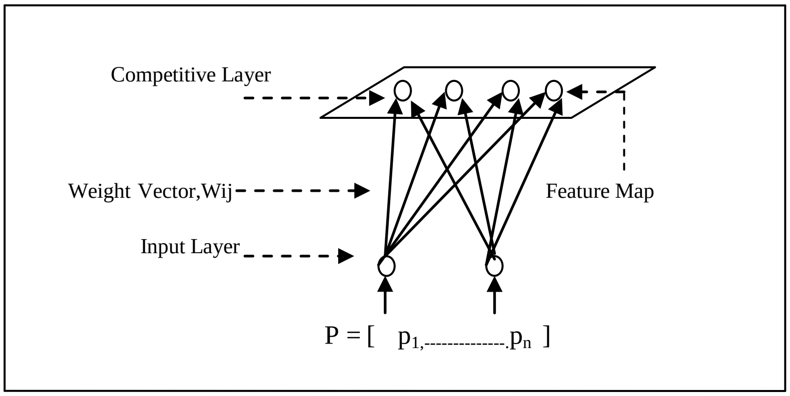


Figure 8. Self Organizing Maps

When an input pattern is presented [31], each unit in the first layer takes the values of the corresponding entry, from an input pattern. The second layer units then sums the inputs and compute to find a single winning unit. Every unit is associated with its weight value which is initially random. The overall operation of the Kohonen's network is similar to the competitive learning paradigm [4]. Each input pattern vector is uniformly distributed between 0 and 1.We can apply input pattern vector with n entries. As a result the input pattern is uniformly spread over d dimensional hypercube. If n = 2,then an input pattern is uniformly spread over a square [4].

The input pattern to the Kohonen's network is denoted as [4]

$$P = [\ p_1,\ p_2,\ p_3,\ p_4,\ ---p_n,\ ]^T \qquad (1)$$

The corresponding weight vector is given by

$$W_{ij} = [\ w_{1j},\ w_{2j},\ w_{3j},\ w_{4j},\ --\ w_{nj},\ ]^T \qquad (2)$$

W_{ij} is the weight vector.The first step in the operation of the Kohonen network is to compute a matching value for unit i is [4]

$$\| P - W_{ij} \| \qquad (3)$$

which is the distance between vector P and W_{ij}

$$\sum (P - W_{ij})2 \qquad (4)$$

The unit with the lowest matching value (the best match) wins the competition. Here we denote The unit with the best match as unit c_i and c is chosen such that

$$\| P - W_{ij} \| = \min \{ \| P - W_{ij} \| \} \qquad (5)$$

Where minimum is taken over all the units i in the competitive layer. If two units have same matching value then by convention, the unit with the lower index value i is chosen. After the winning unit is identified, the next step is to identify the neighborhood around it. The neighborhood in this case consists of the units that are within the square that is centered on the winning unit C.

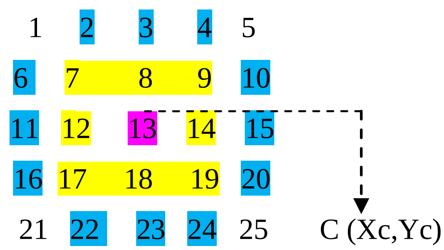


Figure 9. Network Neighborhood

The size of the neighborhood changes as shown by squares of different sizes in Figure 9. The neighborhood is denoted by set of units N_c.Weights are updated for all neurons that are in the neighborhood of the winning unit. The rectangular neighborhood as shown in Figure 9 is considered.

(By considering 13th neuron as centre C (winner)we can define the neighborhood as N1,N2)
N_1 = { 7 8 9 12 14 17 18 19}
N_2 = { 2 3 4 6 10 11 15 16 20 22 23 24 }
Squared Euclidean distance can be computed as

$$D(j) = \sum (W_{ij} - P_i)^2 \quad (6)$$

The updation of weight can be given by

$$W_{\mathbf{ij(new)}} = W_{ij(old)} + \alpha [P_i - W_{ij(old)}] \quad (7)$$

The adjustments results in the winning unit and its neighbors having their weights modified becomes more like the input pattern [4, 31]. The winner then becomes more likely to win the competition. Two parameters that must be specified are learning rate α and its initial value, which is specified as

$$\alpha = \alpha_0 \{1- (t/T)\} \quad (8)$$

Where t = the current training iteration
T = Total no. of training iterations to be done.

Thus α_0 is decreased until it reaches 0.The decrease is linear with number of training iterations completed. The size of neighborhood is second parameter to be specified. Typically the initial neighborhood width is relatively large and the width is decreased over many training iterations. Consider the neighborhood as shown in Figure 9 which is centered on winning unit c, at position (x_c, y_c). Let D be the distance from C to the edge of the neighborhood. The neighborhood is then all (X,Y) Such that

$$C-D < X < C+D \text{ And } C-D < Y < C+D \quad (9)$$

This defines a square neighborhood about c. Since the width of the neighborhood decreases over the training iterations, the value of d decreases. Initially d is set at a chosen value denoted by d_0 may be chosen at a half or a third of the width of the competitive layer of the processing units[2][4]. The value of d is then made to decrease according to the equation [4].

$$d = d_0 \{1- (t/T)\} \quad (10)$$

Where t = the current training iteration
T = Total no. of training iterations to be done. This process assures a gradual linear decrease in d, starting with d_0 and going down to 1. The same amount of time is spend at each value.

3.7. Post Processing

By using Learning vector Quantization the classes are fine tuned .The closest weight vector W_{ij} to pattern P may be associated with node j, that has wrong class label for P. This follows because the initial node labels are based only on their most frequent class use and are therefore not always reliable. The updation of Wij is given by

$$\Delta W_{ij} \quad \begin{cases} \alpha\,(P - W_{ij}) & \text{: If P is classified correctly} \\ -\alpha\,(P - W_{ij}) & \text{: If P is classified incorrectly} \end{cases} \qquad (11)$$

4. Performance Analysis

The scheme is implemented and discussed as below. The database is prepared from 500 different persons. Each image is scanned and segmented . Feature vector is applied to the classifier. Accuracy has been calculated by using the formula.

$$\text{Accuracy} = \frac{T_P\text{ (True Positive)} + T_N\text{ (True Negative)}}{T_P\text{ (True Positive)}+ T_N\text{ (True Negative)}+ F_P\text{ (False Positive)}+ F_N\text{ (False Negative)}}$$

Table 1. Percentage Accuracy Table

Character	No. of Samples for Training	No. of Samples for Testing	Accuracy With SOM&LVQ Classifier.
अ	**1500**	**1000**	99
आ	**1500**	**1000**	99
इ	**1500**	**1000**	99
ई	**1500**	**1000**	83
उ	**1500**	**1000**	99
ऊ	**1500**	**1000**	86
ऋ	**1500**	**1000**	96
ए	**1500**	**1000**	99
ऐ	**1500**	**1000**	86
ओ	**1500**	**1000**	87
औ	**1500**	**1000**	88
अं	**1500**	**1000**	88
अः	**1500**	**1000**	82
क	**1500**	**1000**	99
ख	**1500**	**1000**	94
ग	**1500**	**1000**	90
घ	**1500**	**1000**	99
ङ	**1500**	**1000**	88
च	**1500**	**1000**	99
छ	**1500**	**1000**	94
ज	**1500**	**1000**	99
झ	**1500**	**1000**	99
ञ	**1500**	1000	99

ठ	**1500**	1000	99
ड	**1500**	1000	99
ढ	**1500**	1000	99
ण	**1500**	1000	99
त	**1500**	1000	99
थ	**1500**	1000	99
द	**1500**	1000	99
ध	**1500**	1000	99
न	**1500**	1000	99
प	**1500**	1000	99
फ	**1500**	1000	99
ब	**1500**	1000	99
भ	**1500**	1000	99
म	**1500**	1000	99
य	**1500**	1000	99
र	**1500**	1000	99
ल	**1500**	1000	99
व	**1500**	1000	99
श	**1500**	1000	80
ष	**1500**	1000	99
स	**1500**	1000	99
ह	**1500**	1000	99
ळ	**1500**	1000	99
क्ष	**1500**	1000	99
ज्ञ	**1500**	1000	99
श्र	**1500**	1000	99
०	**1500**	1000	99
१	**1500**	1000	99
२	**1500**	1000	99
३	**1500**	1000	99
४	**1500**	1000	99
५	**1500**	1000	99
६	**1500**	1000	99
७	**1500**	1000	99
८	**1500**	1000	99
९	**1500**	1000	99

Table 2. Final Classification of Marathi Characters

Classification of the characters	**Example**
Open header letter with End Bar	अ, थ, ध ,भ
One conjunction letter with End Bar	च ,ज ,त ,ञ ,न ,ज्ञ , व
More conjunction letter with End Bar	ख ,घ ,झ ,प ,म ,य ,ष ,स

Middle Bar	क ,फ , ऋ
No Bar	इ ,ठ ,र ,ळ ,ड ,ढ ,द , ए
Special Case	ग ,श , ण

5. Conclusion and Discussions

Self-organizing map groups the input data in clusters which is commonly used in unsupervised learning. The self-organizing map has topological structure property which is observed in the brain so it is used for pattern classification. The performance achieved by self- organizing map is better than back propagation algorithm. Generally back propagation algorithm is used for such tasks. The disadvantages associated with back propagation algorithm such as local minima and deciding number of hidden units and layer are not observed in the implemented system. Self organizing map is trained for different parameters such as no. of input and output layer nodes, learning rate, neighborhood size *etc*. The classification accuracy obtained is 87% to 99% for 200 nodes, except some special *characters*. The training time is proportional to the number of patterns used for training, number of output nodes and epochs. After fine tuning the accuracy is increased by 2%-5%. The data base from 1500 persons is taken for training and for testing 1000 samples are taken per character from different persons. In SOM initially as the training progresses observed winner index of different classes are either same or closer to the previous winner index. The characters are divided into three different classes based on whether the character is without any bar, Middle bar, end bar. The output is fine tuned for different classes by using learning Vector Quantization.

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