# Handwritten Marathi Consonants Recognition using Multilevel Classification

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## ABSTRACT
This paper presents approach for the recognition of handwritten Marathi consonants. In order to recognize handwritten Marathi consonants, a database of handwritten Marathi consonants is developed to carry recognition experiments. Problem of handwritten Marathi consonant recognition is simplified using multilevel classificationwhich improves recognition rate. Total 36 Marathi consonants are transformed using instance simplification technique into six sub classesdepending on special property of consonants. Suitable features are extracted from different sub classes and further classification is carried out using SVM and k-NN classifiers.We have used database of 7920 characters for testing and found recognition accuracy 78.27% using SVM classifier and 73.29% using k-NN classifier.

## Keywords
Marathi consonents, multilevel classification, svm, knn, pattern recognition.

## 1. INTRODUCTION
Devanagari alphabet developed from eastern variants of the Gupta script called Nagari, which first emerged during the 8th century. Devanagari is written from left to right direction in horizontal lines.Devanagari script is used to writeAwadhi, Bhojpuri, Hindi, Kashmiri, Konkani,Kurukh,Maithili,Marath**i**,Marwari,Mundari,Nepal BhasaNewari,Nepali,Pali,Rajasthani,Sanskrit,Saraiki,Sindhi,Sunuwar,Sylhetiand many other languages.All of the Indo-Aryan languages originated from Sanskrit. Three Prakrit languages, simpler in structure, emerged fromSanskrit.These were Saurseni, Magadhi and Maharashtri. Marathi is said to be a descendent of Maharashtri which was the Prakrit spoken by people residing in the region of Maharashtra. Marathi is one of the 23 official languages of India and is the official language of Maharashtra. There are around 100million speakers of Marathi language which is fourth largest number of native speakers in India.Marathi language consist of 49 characters out of which 12 are vowelsas shown in Fig. 1(a)and 37 are consonantsas shown in Fig.1(b), one consonant ङ is rarely used in Marathi, so in this part of work only 36 consonants are considered. Handwriting recognition is the ability of a computer to receive and interpret intelligible handwritten input from source like paper documents. Recognition of handwritten Marathi character is a challenging task. Different writers have different writing styles, pens, papers. Every character has a horizontal line at the top known as the header line. The header line joins all the characters in a word.Marathi also has a complex system of compound characters in which two or more consonants are combined forming a new special symbol. There are few reasons that create problems in Marathi handwritten character recognition. (i)Some characters are similar in shape क and(ii)Total number of characters is more with different strokes as compare to English language. (iii) Different users or same user can write same characters differently at different times, depending on the pen or pencil, the width of the line, the rotation of the paper, the type of paper and the mood and stress level of the person. (iv)The character can be written at different location on paper. (v)Sometimes characters are overlapped and slanted. (vi) Handwritten Marathi characters could be of various shapes andsize. Because of the above mentioned reasons the recognition of handwritten Marathi character process needs to be more efficient and accurate.This has

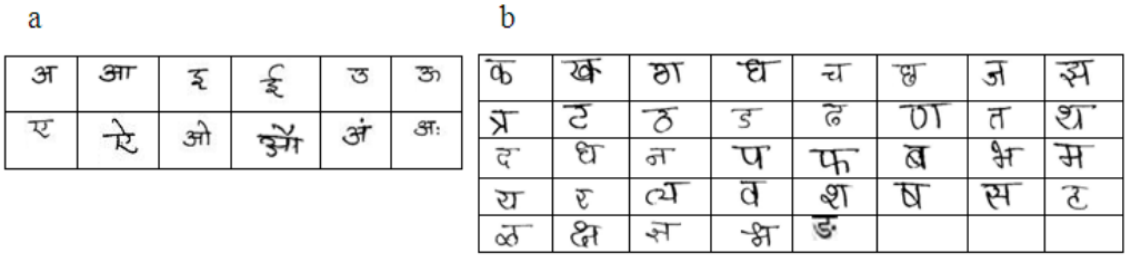


**Fig 1: Handwritten Marathi Vowels and Consonents**

motivated us to undertake problem of handwritten Marathi character recognition.Handwriting recognition is popular research area in academicians and researcher since 1870 [4]. Researchers have reported some work on Devanagri [1-3, 5,7,8,9,11,12,15,20,23-26,28-31,33-35 ], Marathi [4,6,10,13-14,18,22,27,32 ], Hindi [19] languages. Ajmire P.E. et. al [4] achieved 62% recognition for Marathi vowels. Archana Jain et. al. [6] used smoothing and feature set to improve recognition rate of similar shaped Marathi characters. K.V. Kale et. al. [18] used Zernike moment features set to reported 98.37% for compound Marathi characters. Vinaya Tapkir et. al. [22] used pixel density feature and Euclidean minimum distance classifier to recognize Marathi characters and reported 92.77% recognition rate. Sushma Shelke et. al. [32] reported multistage handwritten Marathi compound character recognition using neural networks and achieved 97.95%

result. Handwritten Marathi character recognition has wide range of applications like bank cheque processing, postal automation, handwritten form processing and historical document preservation. Due to wide range of applications and complexity in recognition of Marathi character is point of attraction for researchers and academicians from long time. We have used analytical approach in which word is segmented into indivisible characters and these characters aretreated as input for recognition system.

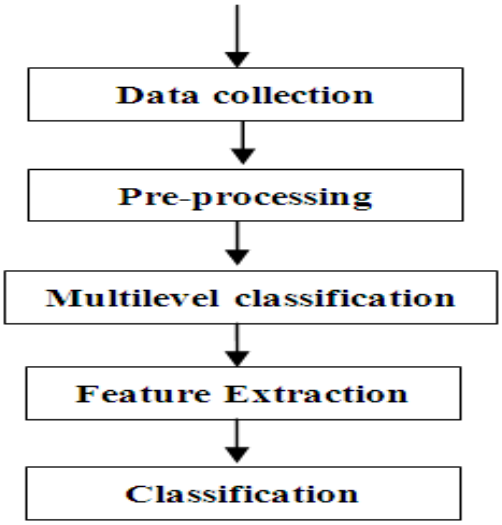


**Fig 2:Phases in handwritten Marathi character recognition**

Phases for handwritten Marathi character recognition are shown in the Fig. 2. Different phases are discussed as follows: Section II explains data collection phase, section III elaborates pre-processing, section IV focuses on multilevel classification, section V explains feature extraction techniques, section VI focusing on classification phase, in section VII results are discussed and section VIII concludes the research paper.

## 2. DATA COLLECTION

Literature review indicates that benchmark database for handwritten Marathi consonant is not available to carryexperiments. Since a benchmark database is not available our first attempt was to developsufficient database for handwritten Marathi consonants. Two A4 size sheets were designed for data collection and distributed to 20 writers which includestudents, teachers, and clerks. Every writer has to write consonants in square provided and no other constraint was imposed on writers. Specially designed sample handwritten datasheets are shown in Fig. 3.

**Fig 3:Sample data sheets for handwritten Marathi consonants**

The data sheets were scanned using a flat bed scanner at a resolution of 1200 dpi and stored as gray scale images. From the scanned gray scale image, the character images were cropped manually and stored in respective class folders. For each consonant approximately 220 samples were stored in respective class folders. Finally database of 7920 consonants images are ready to carry experiments. Fig. 4 shows some gray scale characters cropped from the scanned image of a datasheet.

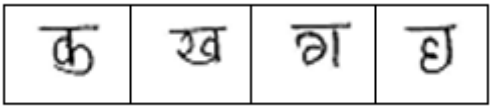

**Fig 4: Sample handwritten Marathi consonants**

## 3. PRE PROCESSING

Image preprocessing techniques enhancesquality of data images prior to extracting features for recognition. Also pre-processing is the technique used to reduce noise introduced in the image by various reasons like scanner, ink, paper etc.Firstly,threshold of input image is computed by using Ostu's method, which chooses the threshold to minimize the intra-class variance of the threshold black and white pixels. Using computed threshold value intensity imageconverted to black and white. Morphological thinning operation is performed to remove pixels so that an object without holes shrinks to a minimally connected stroke, and an object with holes shrinks to a ring halfway between the hold and outer boundary.The binarized character image is mapped onto a standard plane so as to give a representation of fixed dimensionality for classification. Character normalization is used to reduce the inter-class variation of the shapes of the characters in order to facilitate feature extraction process and improve their recognition accuracy. Linear normalization method used to standardize the character images. The standard plane is considered as a square of size 60 x 60. The aspect ratio of the character image is not disturbed due to normalization. Thinned image of each character contains header cap known as '*shirorekha'* placed above every character, this cap is identified and removed from the character images.To remove header cap we have computed horizontal projection for each character. In this methodwe have identified a row which contains maximum black pixels in top 33% rows of the character. All pixels values in the identified row are set to zero which will remove the '*shirorekha'* from the character.

## 4. MULTILEVEL CLASSIFICATION

Total numbers of Marathi consonants are 36 and in these consonants interclass similarities are more. By experiment it has been observed that single feature is not sufficientfor classification because recognition rate using single feature is very low. Also classifying and recognizing 36 consonants is time consuming, hence to solve the problem of classification well known approach of problem solving based on transformation is used. Instance simplification is type of transformation which solves a problem by first transforming into simple instance of the same problem with some special property that makes the problem easier to solve. In phase I to phase IV problem is simplified by classifying 36 consonants into six sub classes according to their characteristics as shown in the Fig. 5. Following is the discussion on phase I to phase IV sub classification where 36 consonants are classified into six classes:

### 4.1.Phase I Sub classification:

This sub classification is based on bar characters and no bar characters. Marathi consonants are broadly classified into two major categories bar characters and no bar characters. Bar character are those characters having presence of vertical bar. In order to verify whether a bar is present in the character, vertical projection of imagewas taken and if any column contains more than 70% of black pixels, then label it as bar character otherwise label as no bar character. As shown in the Fig. 6(a) column number 57 contains 86% black pixels hence labeled as bar character and as shown in the Fig.6(b) all columns contains less than 70% black pixels hence labeled as no bar character Thus 36 consonants are classified into two subclasses,first contains 27 bar characters and second contains nine no bar characters as shown in phase I of fig 5.

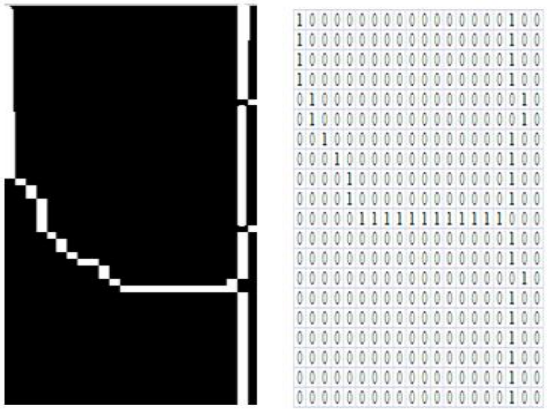

**Fig 6(a):Bar character**

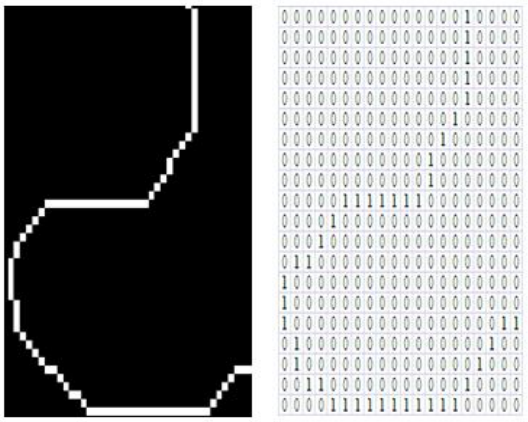

**Fig 6(b): No Bar character**

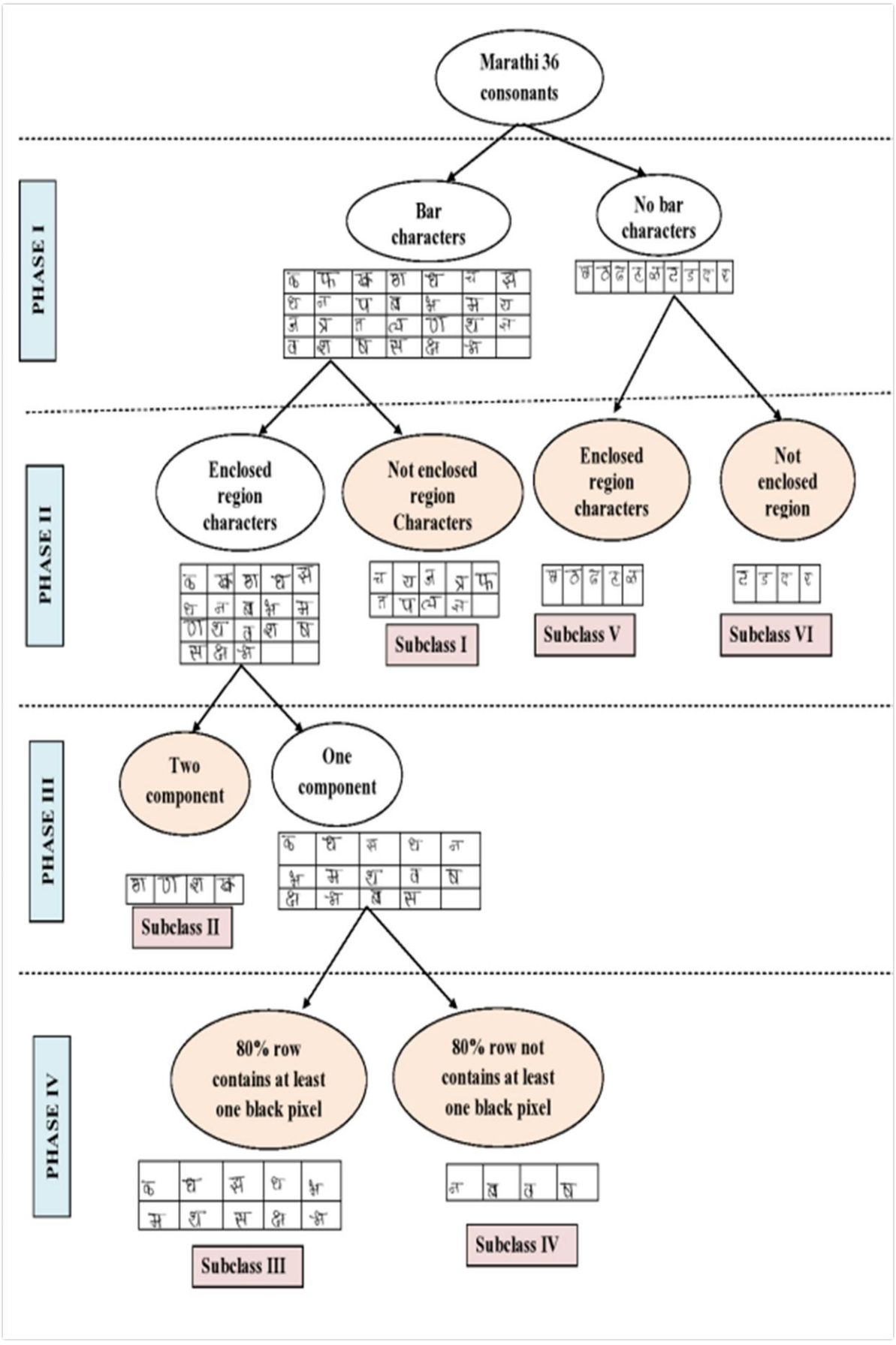


**Fig. 5:Phases in Multilevel classification**

## 4.2.Phase II sub classification:

This sub classification is based on enclosed region. In phase II, 27 bar characters are broadly classified into two major categories having enclosed region or not. To verify whether enclosed region is present, the numbers of holes are counted in the character using eight connectivity as shown in the Fig. 7(a). If one or more than one enclosed region exists in the character then label it as enclosed region character otherwise not enclosed region character. Now 27 bar characters are sub classified into 18 enclosed region bar characters and nine not enclosed region bar characters as shown in phase II of Fig. 5. Similarly nine no bar characters are classified into five enclosed region no bar characters and four not enclosed region no bar characters as shown in phase II of Fig. 5.

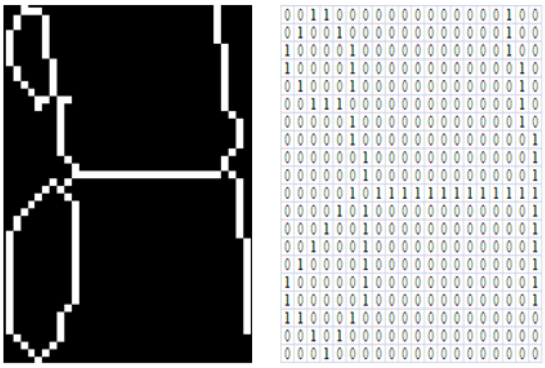

**Fig 7(a): Enclosed Region character**

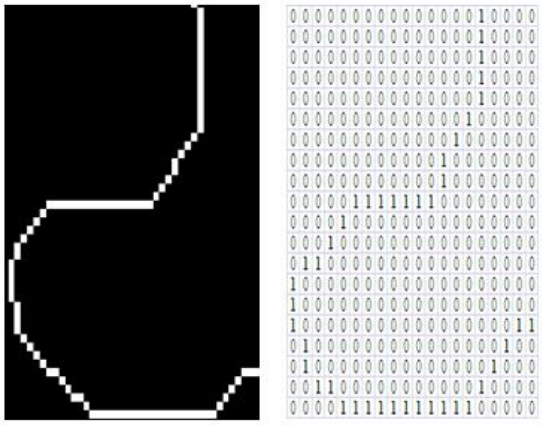

**Fig 7(b): Not enclosed region character**

## 4.3. Phase III sub classification:

This sub classification is based on number of components. In phase III 21 bar enclosed region characters are classified into two subclasses, depending on whether number of component is one or more. Presence of a component can be verified using region properties for each labeled region. In all 18 bar enclosed Region characters are sub classified into 14 characters having a component and four characters having two component.

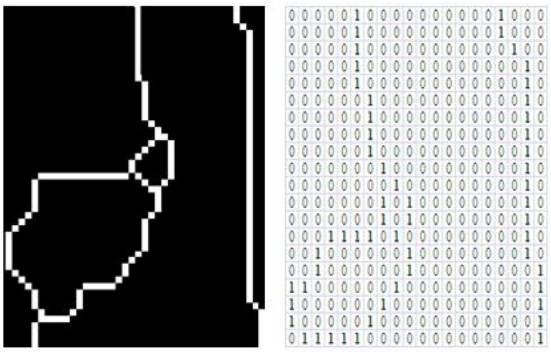

**Fig 8(a): Two component character.**

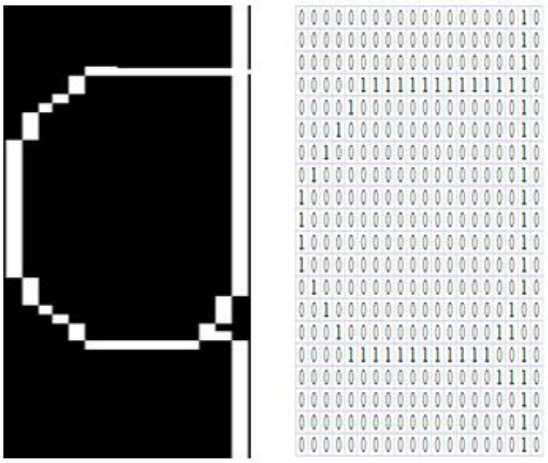

**Fig. 8(b): One component character**

## 4.4.Phase IV sub classification:

This sub classification is based on number of rows containing at least one black pixel. We have 14 bar enclosed region characters having one component and further classified into two subclasses, depending on whether character's 80% rows contains at least one black pixel in first 75% columns. Out of 18 bar enclosed region characters having one component we get 10 characters satisfying above condition and four characters does not satisfy the condition.

**Fig. 9 (a): 80% row contains at least one black pixels character**

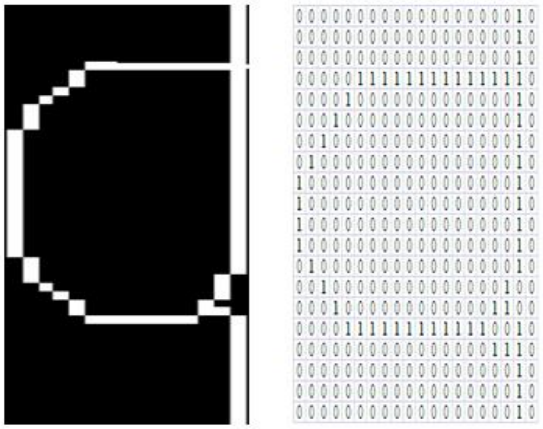

**Fig 9 (b): less than 80% row contains at least one black pixels character.**

Using above sub classification method problem of handwritten Marathi consonant recognition is simplified into six sub classes as follows:

**Sub class I.** Barnot enclosed region (**9 characters)**

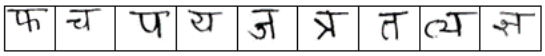

**Fig. 10(a): Consonants having bar and enclosed region.**

**Sub class II**: Barenclosed region with two components (**4 characters).**

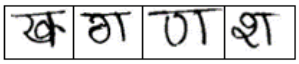

**Fig. 10(b): Consonants having bar, enclosed region and having two components**.

**Sub class III.** Sub class III: Barenclosed region with one componentand having 80% rows contains at least one black pixel in first 75% columns (**10 characters)**

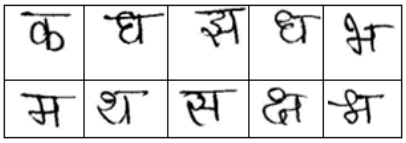

**Fig. 10(c): Consonants having bar, enclosed region, one component and black pixels**

**Sub class IV**: Barenclosed region with one component and less than 80% rows contains at least one black pixel in first 75% columns (**4 characters).**

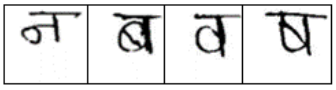

**Fig. 10(d): Consonants having bar, enclosed region, one component and not black pixels.**

**Sub class IV**: No bar enclosed region (**5 characters)**

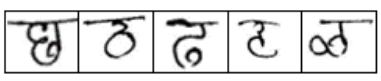

**Fig. 10(e): Consonants does not have bar and having enclosed region.**

**Sub class V**: No bar not enclosed region (**4 characters)**.

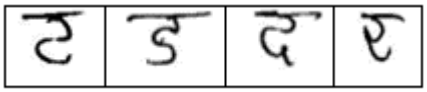

**Fig. 10(f): Consonants does not have bar and enclosed region.**

Now we have 36 consonants divided into 6 different sub classes as discuss above. Feature extraction methods suitable for different sub classes are discussed in the Section VI.

## 5. FEATURE EXTRACTION

Feature for any character is the distinguishable property of the character and is extracted such that it quantifies some significant characteristics of the character.

### 6.5.Symmetric Density

By experiment it is observed that symmetric density feature is more suitable for sub class III and sub class VI. In the proposed method, the binary image representing the handwritten character is pre-processed and is normalized to a size of 60 x 60 pixels. The size-normalized image is divided into n equal zones. As shown in Fig. 11(a-e) consonant image is divided into equal size 4 zones, 9 zones, 16 zones, 25 zones and 36 zones and density feature for every zone is calculated and is stored into feature vector.The density of each zone is computed by taking the ratio of total number of object pixels to total number of pixels in that zone. This is carried out for every zone in the image. Finally, 90 features are extracted from the image and feature vector stores there 90 features. Density features calculated by using the following equation.

$$\text{Density}(Z) = \frac{\text{numberofobjectpixelsinthezoneZ}}{\text{totalnumberofpixelsinthiszoneZ}}$$

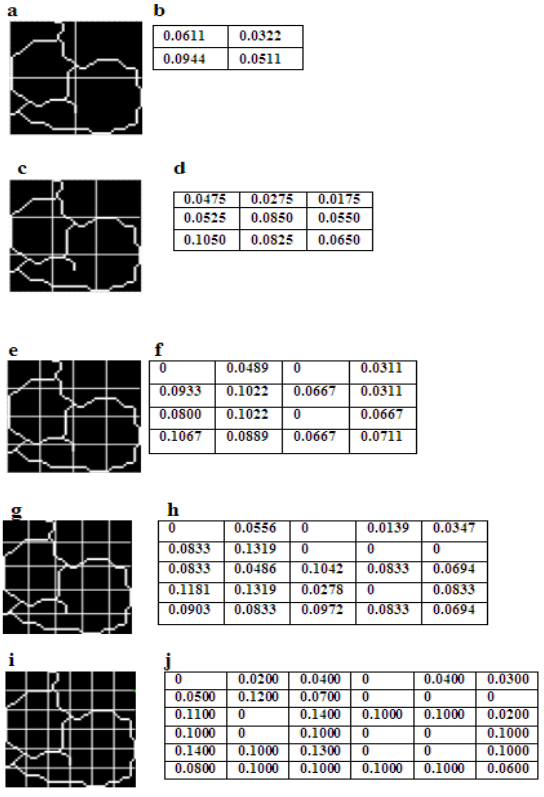


**Fig 11(a-e): consonant image is divided into equal size 4 zones, 9 zones, 16 zones, 25 zones and 36 zones**

## 6.6.Horizontal Features

By experiment it is observed that horizontal feature is more suitable for sub class I, subclass IV and sub class V.To extract horizontal feature of the binary image representing the handwritten character is first preprocessed and is normalized to size of 60 x 60 pixels. The size-normalized image is divided into 36 equal zones as shown in Fig. 12(a); each zone is of size 10 x 10 as shown in Fig. 12(b). Each zone has 10 horizontal lines, each horizontal line is summed to get a single sub feature and thus 10 sub-features are obtained from the each zone.These 10 sub-features values are averaged to form a single feature value and assigned as horizontal feature to the corresponding zone. This procedure is sequentially repeated for the all the zones. Finally, 36 features are extracted for 36 zones for each character.

By experiment it is observed that horizontal feature is more suitable for sub class 2.In the proposed method, the binary image representing the handwritten character is preprocessed and is normalized to a size of 60 x 60 pixels. The size-normalized image is divided into 36 equal zones each of size is 10 x 10. Each zone has 19 diagonal lines, each diagonal line is summed to get a single sub feature and thus 19 sub-features are obtained from the each zone.These 19 sub-features values are averaged to form a single feature value and placed in the corresponding zone. This procedure is sequentially repeated for the all the zones.Finally, 36 features are extracted for each character. In addition, 12 features are obtained by averaging the values placed in zones row wise and columnwise, respectively.As a result, for every character is 36 +12 features total 48 features are stored in feature vector.

## 6.7.Diagonal Features

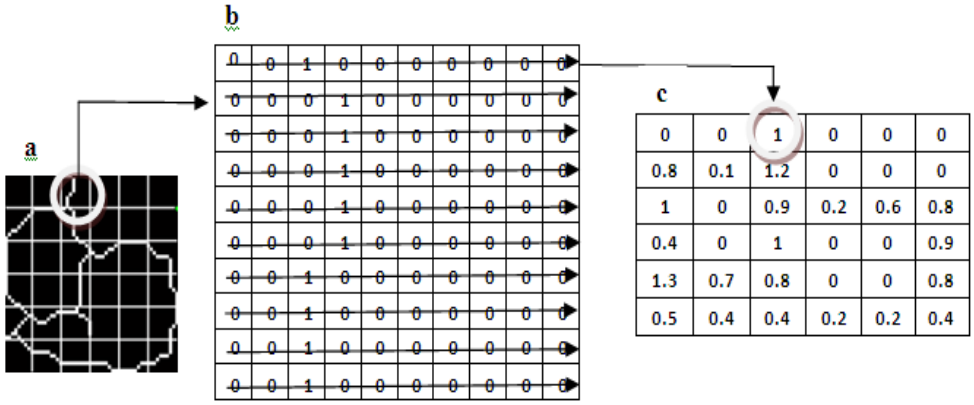


**Fig. 12 (a): Character divided into 36 zonesFig. 12 (b): Zone z3 of size 10x10. Fig. 12 (c): Total 36 zones average values**

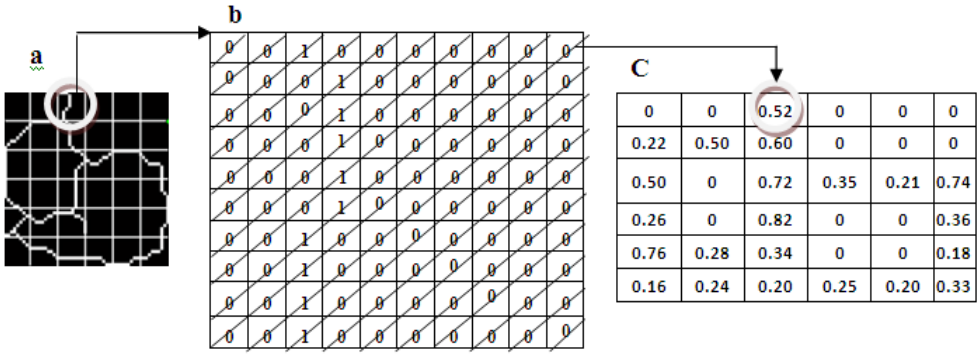


**Fig. 12 (a): Character divided into 36 zonesFig. 12 (b): Zone z3 of size 10x10. Fig. 12 (c): Total 36 zones average values**

## 6. CLASSFICATION

Pattern recognition from labeled 'training' data is called supervised learning, and when no labeled data is available it is called as unsupervised learning. Here we have used supervised learning approach in which 80% samples are used for training and 20% samples for testing. As discussed in section V feature vector is created for all images and k-NN as well as SVM classifiers are used to carry experiments. k-NN and SVM classifiers are discussed below:

## 6.1.K-NN

The k-Nearest Neighbor (k-NN) classifies an unknown sample based on the known classification of its neighbors [9, 11, 13, 16, 18, 24, and 25]. Suppose that a set of samples with known classification is available, the so-called training set. Intuitively, each sample should be classified similarly to its surrounding samples. Therefore, if the classification of asample is unknown, then it could be predicted by considering the classification of its nearest neighbor samples. Given an unknown sample and a training set, all the distances between the unknown sample and all the samples in the training set can be computed. The distance with the smallest value corresponds to the sample in the training set closest to the unknown sample. Therefore, the unknown sample may be classified based on the classification of this nearest neighbor. k- NN is an instance-based learning type classifier, or lazy learning where the

function is only approximated locally and all computation is deferred until classification. Euclidean distance is used.

## 6.2.SVM

Support vector machines (SVM) are supervised learning models with associated learning algorithms that analyze data and recognize patterns, used for classification [5, 7, 9, 13-15, 18, 20, 24-26]. SVM training algorithm builds a model that assigns new examples into one category or the other, making it a non-probabilistic binary linear classifier.

## 7. RESULTS

Database of 7920 samples are used to carry out the experiments out of which 80% samples are used for training and 20% samples are used for testing. Multilevel classification approach is introduced here to simplify the handwritten Marathi consonant recognition problem. Once consonants are classified into six sub classes horizontal, diagonal and symmetric density features are used. Recognition accuracy for subclass I is 74.17%, subclass II is 76.77%, subclass III is 60.63%, subclass IV is 67.92%, subclass V is 74.00% and subclass VI is 86.25% using k-NN classifier as shown in Table I. Recognition accuracy for subclass I is 79.58%, subclass II is 85.83%, subclass III is 64.17%, subclass IV is 77.92%, subclass V is 81.50% and subclass VI is 80.62% using SVM classifier as shown in Table I. Average recognition rate for all subclasses achieved is 73.29% and 78.27% using k-NN and SVM classifier as shown in Table I. Table II shows recognition accuracy for all 36 consonants separately by using k-NN and SVM classifier.

**Table I: Recognition Rate for sub class I to VI using k-NN and SVM Classifier**

| Sr. No. | Class | Character set | Feature used | No. of features | k-NN Classifier | SVM Classifier |
|---|---|---|---|---|---|---|
| 1 | Subclass I | 6 characters | Horizontal | 36 | 74.17 | 79.58 |
| 2 | Subclass II | 3 characters | Diagonal | 48 | 76.77 | 85.83 |
| 3 | Subclass III | 12 characters | Symmetric Density | 90 | 60.63 | 64.17 |
| 4 | Subclass IV | 6 characters | Horizontal | 36 | 67.92 | 77.92 |
| 5 | Subclass V | 5 characters | Horizontal | 36 | 74.00 | 81.50 |
| 6 | Subclass VI | 4 characters | Symmetric Density | 90 | 86.25 | 80.62 |
| **Average Recognition Rate** | | | | | **73.29** | **78.27** |

**Table II: Recognition accuracy for each consonant using k-NN and SVM Classifier**

| SR. NO. | SUB CLASS | CONSONANT | k-NN | SVM | SR. NO. | SUB CLASS | CONSONANT | k-NN | SVM |
|---|---|---|---|---|---|---|---|---|---|
| 1 | I |  | 75 | 65 | 19 | III |  | 47.5 | 47.5 |
| 2 | |  | 97.5 | 100 | 20 | |  | 55 | 47.5 |
| 3 | |  | 90 | 85 | 21 | |  | 72.5 | 57.5 |
| 4 | |  | 52.5 | 70 | 22 | |  | 47.5 | 45 |
| 5 | |  | 90 | 82.5 | 23 | |  | 65 | 47.5 |
| 6 | |  | 77.5 | 85 | 24 | IV |  | 72.5 | 90 |
| 7 | |  | 72.5 | 75 | 25 | |  | 67.5 | 90 |
| 8 | |  | 52.5 | 62.5 | 26 | |  | 75 | 70 |
| 9 | |  | 55 | 72.5 | 27 | |  | 50 | 62.5 |
| 10 | II |  | 47.5 | 92.5 | 28 | V |  | 57.5 | 67.5 |
| 11 | |  | 72.5 | 87.5 | 29 | |  | 77.5 | 82.5 |
| 12 | |  | 85 | 82.5 | 30 | |  | 85 | 90 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | |  | 72.5 | 87.5 | 31 | |  | 82.5 | 97.5 |
| 14 | |  | 95 | 82.5 | 32 | |  | 67.5 | 70 |
| 15 | |  | 85 | 62.5 | 33 | |  | 97.5 | 87.5 |
| 16 | **III** |  | 60 | 57.5 | 34 | **VI** |  | 100 | 97.5 |
| 17 | |  | 47.5 | 35 | 35 | |  | 50 | 57.5 |
| 18 | |  | 30 | 40 | 36 | |  | 97.5 | 80 |

## 8. CONCULSION

Single level classification is not sufficient for recognition of Marathi consonants. Hence, in this paper multilevel classification approach is introduced. Multilevel classification is depends on the structural feature like bar, region, number of component, black pixels. After multilevel classification suitable features are extracted from different sub classes and recognition is carried out using k-NN and SVM classifiers. Overall recognition rate for all subclasses achieved is 73.29% and 78.27% using k-NN and SVM classifier. SVM classifier is more suitable for consonants classification. In future recognition accuracy can be improved by extracting more suitable features and combining classifiers.

## 9. ACKNOWLEDGMENTS

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