Recognition of Isolated Handwritten Marathi Vowels using Symmetric Density and Moment Invariant Features

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ABSTRACT
In this paper, combination of zone based symmetric density feature and moment invariant feature is proposed for recognition of isolated handwritten Marathi vowels. Recognition of handwritten Marathi vowels is a challenging task due to their interclass structural similarities. Since a standard database does not exist for handwritten Marathi vowels, as a part of this work database of 2294 handwritten Marathi vowels was developed. Pre-processing techniques are applied to remove noise and there zone based symmetric density features are extracted. In addition to zone based symmetric density feature, moment invariants for each image is extracted. Proposed methodology is tested using fivefold cross validation technique; maximum 92.98 percent recognition accuracy was noted for fold III using SVM classifier. The recognition accuracy was compared using k-NN and SVM classifiers. Average recognition rate achieved 88.17 percent and 86.93 percent using k-NN classifier and SVM classifier respectively.

Keywords
Handwritten Marathi Vowel Recognition; OCR; Zoning; symmetric density; fivefold; Invariant moment;

1. INTRODUCTION
Marathi is an official language of Maharashtra and Marathi is written in devanagari script [2-8, 13, 19, 27]. Marathi is 15th most spoken language in the world. Marathi language consists of 12 vowels and 36 consonants making a total of 48 characters [1, 11, 16, 24]. Recognizing handwritten Marathi characters is important because of its application in various fields like bank cheque automation, postal automation, form processing, historical document preservation, etc [1-5, 16]. Recognition of Handwritten Marathi vowel is a difficult and challenging task due to interclass and intra class similarities.

Vowels are used as characters in the formation of Marathi words as well as are combined with consonants as modifiers. Modifier comes above header line, or at the bottom of character or in line [1, 24].

Data collection, Pre-processing, Feature Extraction and Classification which are the major steps [20] in OCR are shown in Fig. 1.

2. DATA COLLECTION
Since a standard database does not exist for handwritten Marathi vowels, an attempt was made to create a database of isolated Marathi handwritten vowels to enable experiments to be carried out [1, 11, 16, 24]. Specially designed A4 sheets are used for data collection. Twenty writers from different professions include students, clerks, teachers were chosen to write the Marathi vowels on the datasheets provided. No constraints were imposed on the use of ink or pen except that

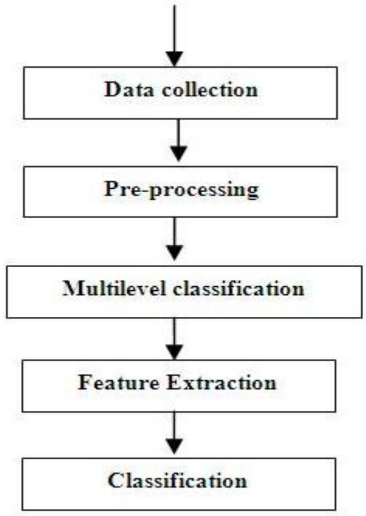


Fig 1: Steps in isolated handwritten character recognition

they have to write the characters in the boxes of the sheets provided. A sample sheet of handwritten Marathi vowels is shown in Fig. 2.

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. Fig. 3 shows some characters cropped from the scanned image of a datasheet in gray scale.

Fig 2: Sample Sheet for Handwritten vowel

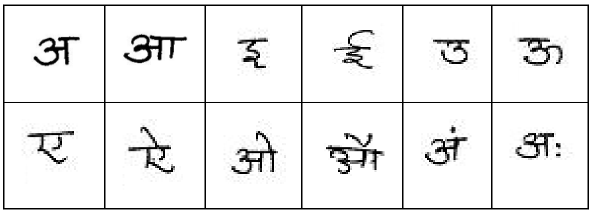


Fig 3: Handwritten Marathi Vowels

3. PRE-PROCESSING

Pre-processing commonly involves normalizing the intensity of the individual particles images by removing low frequency background noise reflections and masking portions of the images [1-4, 7, 13, 19, 27]. Pre-processing enhances recognition rate of the images prior to feature extraction.

3.1 Noise Removal

The raw input of the digitizer typically contains noise due to erratic hand movements and inaccuracies in digitization of the actual input. In order to reduce the blurring of character edges and suppress noise, the median filter is used. In median filtering, the idea is to replace the current point in the image by the median of the brightness in its neighborhood. A 3×3 square neighborhood is used to remove noise from the gray scale images [2, 7, 13, 16, 19, 27].

3.2 Binarization

Image binarization is performed on input image. Histogram-shape based image thresholding suggested by Otsu is used for converting gray scale image to binary image. The algorithm assumes that the image contains two classes of pixels (foreground and background) prior to thresholding and it calculates the optimum threshold separating those two classes so that their combined spread (intra-class variance) is minimal.

3.3 Normalization

The binarized character image is mapped onto a standard plane (with predefined size) so as to give a representation of fixed dimensionality for classification. The goal of character normalization is to reduce the inter-class variation of the shapes of the characters in order to facilitate feature extraction process and improve their classification accuracy. Linear normalization method was used to standardize the character images. A square of size 60 x 60 is considered as the standard plane. The width and height ratio of the character image is not disturbed due to normalization.

3.4 Thinning

The goal of character thinning is 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.

4. FEATURE EXTRACTION

4.1 Density Symmetric

In the proposed method, the binary image representing the handwritten character is pre-processed in order to identify the important features as shown in the Section 3 and is normalized to a size of 60 x 60 pixels. The size-normalized image is divided into n equal zones. Recognition rates were computed for n=4, 9, 16, 25, 36, 49 and 100. It is observed that a no significant improvement in recognition rate where n=49. Therefore only features identified for n=4, 9, 16, 25, 36 were considered.

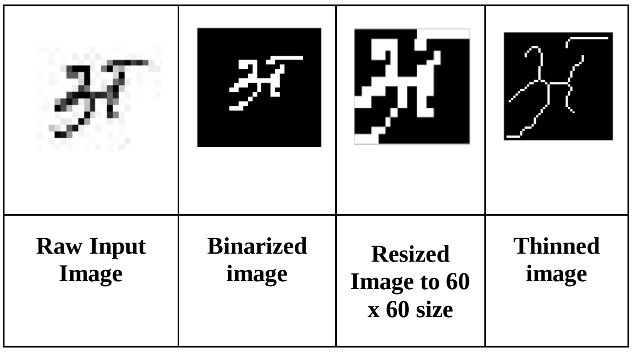


Fig 4: Pre-processed Handwritten Marathi Vowels

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 where n=4, 9, 16, 25, 36 are shown in fig. 5(a) - 5(e).

$$Density(Z)=\frac{\text{number of object pixels in the zone Z}}{\text{total number of pixels in this zone Z}}$$

4.2 Moment Invariant

In addition to zone based symmetric density moment invariants features are extracted for the image which contributes to improve the overall recognition accuracy.

The 2 Dimensional moment of order (p+q) of a image is calculated as follows

$$m_{pq} = \sum_{x=0}^{m-1}\sum_{y=0}^{n-1} x^p y^q f(x,y)$$

Where p=0,1,2,… and q=0,1,2….

Using 2D moments central moment of order (p+q) can be calculated as follows

$$\mu_{pq} = \sum_{x=0}^{m-1}\sum_{y=0}^{n-1} (x-\bar{x})^p (y-\bar{y})^q f(x,y)$$

For p=0,1,2,… and q=0,1,2…. Where $\bar{x} = \frac{m_{10}}{m_{00}}$ and $\bar{y} = \frac{m_{01}}{m_{00}}$

Normalized central moments can be derived by using above central moments as follows

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\gamma}}$$

Where

$$\gamma = \frac{p+q}{2} + 1$$

For p+q=2,3…

Set of seven invariant moments can be derived from second and third moments

$$\phi_1 = \eta_{20} + \eta_{02}$$

$$\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2$$

$$\phi_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2$$

$$\phi_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2$$

$$\phi_5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2]$$

$$\phi_6 = (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03})]$$

$$\phi_7 = (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (3\eta_{12} - \eta_{30})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2]$$

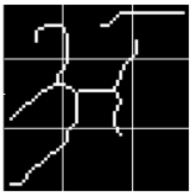
4.3 Algorithm to Calculate Feature vector

The steps for calculation of feature vector are given below

1. Pre-process the input Image and resize to 60 x 60.
2. Divide the input image into four equal zones; calculate density of each zone that will give four features.
3. Divide the input image into nine equal zones; calculate density of each zone that will give nine additional features.
4. Divide the input image into 16 equal zones; calculate density of each zone that will give 16 more features.
5. Divide the input image into 25 equal zones; calculate density of each zone that will give 25 extra features.
6. Divide the input image into 36 equal zones; calculate density of each zone that will give 36 additional features.
7. Calculate 7 moment invariants values.
8. Feature vector of total 97 features is prepared for individual image.

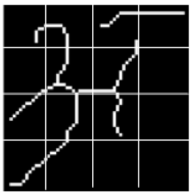
0.0567	0.0567
0.0456	0.0133

Fig 5(a): Four zone features



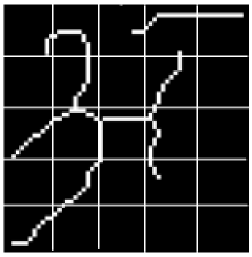
0.0375	0.0525	0.0625
0.0575	0.1150	0
0.0475	0.0150	0

Fig 5(b): Nine zone features



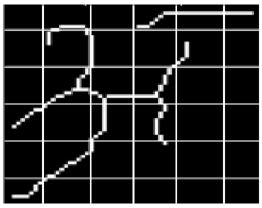
0.0356	0.0533	0.0800	0.0578
0.0222	0.1156	0.0889	0
0.0356	0.0667	0.0533	0
0.0622	0.0178	0	0

Fig 5(c): Sixteen zone features



0.0347	0.0833	0.0347	0.0903	0.0694
0	0.0833	0	0.0833	0
0.0625	0.1389	0.1042	0.0556	0
0.0069	0.0903	0.0208	0.0208	0
0.0764	0.0208	0	0	0

Fig 5(d): Twenty five zone features



0	0.12	0.01	0.09	0.10	0.08
0	0.03	0.09	0.02	0.07	0
0	0.15	0.11	0.15	0	0
0.08	0	0.10	0.10	0	0
0	0.07	0.04	0.02	0	0
0.09	0.03	0	0	0	0

Fig 5(e): Thirty six zone features

Invariant Moments for a Symbol:
1.3808 0.6823 0.3304 0.0080 -0.0004 -0.0064 -0.0002

5. CLASSIFICATION
As explained in section 4 feature vectors are created for every image. Using k-NN and SVM Classifiers experiments are carried out and class labels are assigned to images.

5.1 k-NN
The k-Nearest Neighbor (k-NN) classifies an unknown sample based on the known classification of its neighbors [13, 16, 20, 24]. 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 a sample 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.

5.2 SVM
Support vector machines (SVM) are supervised learning models with associated learning algorithms that analyze data and recognize patterns, used for classification [3, 4]. SVM training algorithm builds a model that assigns new examples into one category or the other, making it a non-probabilistic binary linear classifier.

6. RESULTS
Database of 2294 samples is used to carry out experiments 80% of the samples are used for training and the remaining for testing purpose. Fivefold cross validation technique is used to test recognition rate. Every fold contains different test samples to experiment deviation in recognition rate.

As shown in Table 1 average recognition accuracy for k-NN classifier is 88.17% and 86.93% using SVM classifier.

Table 1. Recognition Result using k-NN and SVM Classifier for 97 features

Fold Number	k-NN Classifier	SVM Classifier
Fold I	85.44	83.75
Fold II	89.79	87.92
Fold III	92.71	92.98
Fold IV	87.29	88.54
Fold V	85.63	81.46
Average Recognition Rate	**88.17**	**86.93**

7. CONCLUSION
This paper describes a simple and efficient method to extract combination of zone based symmetric density features and moment invariant features. Also pre-processing techniques are used to improved recognition rate. From experimental results it is evident that average recognition rate for k-NN classifier is more than SVM classifier. Reason for recognition errors are due to abnormal handwriting and inter class similarities. Future work need to be focused on reducing the pre-processing and the number of features used for recognition.

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