DOI: 10.21917/ijivp.2015.0158

MODIFIED VIEW BASED APPROACHES FOR HANDWRITTEN TAMIL CHARACTER RECOGNITION

S. Sobhana Mari[1] and G. Raju[2]

[1] *School of Computer Sciences, Mahatma Gandhi University, Kottayam, India*
E-mail: mari.sobhana@gmail.com

[2] *School of Information Science and Technology, Department of Information Technology, Kannur University, India*
E-mail: kurupgraju@gmail.com

Abstract

Finding simple and efficient features for offline hand written character recognition is still an active area of research. In this work, we propose modified view based feature extraction approaches for the recognition of handwritten Tamil characters. In the first approach, the five views of a normalized and binarized character image viz, top, bottom, left, right and front are extracted. Each view is then divided into 16 equal zones and the total numbers of background pixel in each zone are counted. The 80 values so obtained form a feature vector. In the second approach, the normalized and binaraized character images are divided into 16 equal zones. Five views are extracted from each zone and the total number of background pixel in each view is counted, resulting in 80 feature values. Further the above two approaches are modified by employing thinned images instead of the whole image. The extracted features are classified using SVM, MLP and ELM classifier. The discriminative powers of the proposed approaches are compared with that of four popular feature extraction approaches in character recognition. The feature extraction time and classification performances are also compared. The proposed modified approaches results in high classification performance (95.26%) with comparatively less feature extraction time.

Keywords:

HCR, Tamil Character, View Based Feature, SVM

1. INTRODUCTION

High accuracy Handwritten Character Recognition (HCR) is a challenging task for Indian languages script. Offline handwriting recognition has become an active research area in image processing and pattern recognition since last few decades. In HCR, the characters in a digital image are segmented, and then submitted for a number of preprocessing steps that aims at reducing the variability in the appearance of the handwritten patterns. Algorithms are used to extract features from the preprocessed images and to assign the observed character to appropriate class. Recognition of handwritten character is a challenging area in image processing and pattern recognition. HCR system is developed with an objective to recognize handwritten characters from a digital image of handwritten documents. An HCR system includes steps such as character segmentation, pre-processing of character image, feature extraction and recognition of character class with the extracted features. The major challenges, as in the case of any handwritten character recognition problem, is the large variation in the writing styles of individual at different times and among different individuals such as size shape, speed of writing and thickness of characters etc. The problem of printed character recognition is relatively well understood and solved with little constraints and the available system yield as good as 99% recognition accuracy. But handwritten character recognition systems have still limited capabilities. The issues faced by the HCR systems are the similarities of some characters with each other, infinite variety of character shapes and deformed and illegible characters. Intelligent system which can identify handwritten scripts is still an open problem for the researchers.

Offline HCR systems are matured only in few languages like English and Chinese [1-3]. Effective handwritten character recognition systems have been developed by researchers during the past decades. A brief report of, some of the recent works done in various Indian languages are as follows.

Raju et al. proposed a novel handwritten Malayalam character recognition system using a combination of gradient based features and run length count. Classification was carried out with SQDF and MLP. The feature vector is augmented by including aspect ratio, position of centroid and ratio of pixels on the vertical halve of a character image. The recognition accuracy of 99.78% was achieved with minimum computational and storage requirements [4]. A method for recognition of printed and handwritten mixed Kannada numerals is presented using multi-class SVM for recognition yielding a recognition accuracy of 97.76% [5]. Ragha & Sasikumar describes system for Kannada characters. In this paper, the moment features are extracted from the Gabor wavelets of preprocessed images of 49 characters. The comparison of moments features of 4 directional images with original images are tested on Multi Layer Perceptron with Back Propagation Neural Network. The average performance of the system with these two features together is 92% [6]. Dhandra presents a handwritten Kannada and English character recognition system based on spatial features. Directional spatial features VIZ stroke density, stroke length and the number of stokes are employed as potential features to characterize the handwritten Kannada numerals/vowels and English uppercase alphabets. KNN classifier is used to classify the characters based on these features with four fold cross validation. The proposed system achieves the recognition accuracy as 96.2%, 90.1% and 91.04% for handwritten Kannada numerals, vowels and English uppercase alphabets respectively [7].

A system for recognition of handwritten Kannada vowels by extracting invariant moment feature from zoned images is

proposed [8]. A Euclidian distance criterion and KNN classifier is used to classify the handwritten Kannada vowels. A total 1625 images are considered for experimentation and overall accuracy is found to be 85.53%. Rajashekararadhya and Vanaja proposed an offline handwritten numeral recognition technique for four south Indian languages like Kannada, Telugu, Tamil and Malayalam. In this work, they suggested a feature extraction technique, based on zone and image centroid. They used two different classifiers nearest neighbor and back propagation neural network to achieve 99% accuracy for Kannada and Telugu, 96% for Tamil and 95% for Malayalam [9]. The work of Pal et al with gradient features and a classifier combination of SVM and MQDF have achieved a recognition rate of 95.13% for Devanagari character recognition [10]. Another work by Pal et al has turned up an accuracy of 95.19% with curvature features and mirror image learning [11]. Patil et al describes a complete system for the recognition of isolated handwritten Devanagari character using Fourier Descriptor and Hidden-Markov Model (HMM)[12]. Before extracting the features, the images are normalized using image isometrics such as translation, rotation and scaling. After normalization, the Fourier features are extracted using Fourier Descriptor. An automatic system trained 400 images of image database and character model form with multivariate Gaussian state conditional distribution. A separate set of 100 characters was used to test the system. The recognition accuracy for individual character varies from 90% to 100%.Siddarth et al. have worked with features like zonal density, projection histogram, distance profile and background direction distribution (BDD), and classifiers SVM, KNN and probabilistic neural networks. SVM gave the highest recognition accuracy of 95.04% with zonal density and BDD features [13].

In this work, we present two modified view based approaches for the recognition of handwritten Tamil characters. In the first approach top, bottom, left, right and front views are extracted from normalized and binarized character image. Each view is divided into 16 equal zones and from each zone the total number of background pixel is counted as feature values. In the second approach the normalized and binary images are divided into 16 equal zones. From each zone the five views are extracted and from each view the total number of background pixel is counted. Further the same features are extracted using the above two approaches by employing thinned images. The extracted features are classified using SVM, MLP and ELM classifier. The experiments conducted with a large database consisting of handwritten Tamil character establish the merit of the proposed features in terms of classification accuracy and feature extraction time.

The rest of the paper is organized as follows: Section 2 discusses about Tamil HCR. Section 3 explains the proposed view based features extraction procedure. Section 4 discusses the classifier and data collection for the experiment and the experimental results are discussed in section 5. Finally conclusion is given in section 6.

2. STUDIES IN TAMIL HCR

There are a number of language families in the world. Tamil belongs to the Dravidian language family. This classical language is considered the earliest of the Dravidian languages and is spoken by more than eighty million people worldwide. Tamil is regarded as one of the four major literary languages of the Dravidian family and, in spoken form, is predominant form of communication in Tamil Nadu in south India. The literary heritage of this south Asian language is very rich. The Tamil language reflects the cultural traditions in Tamil Nadu. Tamil is widely used in mass media, the judicial system, the sciences and areas of technology. In addition to reflecting the cultural and traditional milieu, Tamil is the language used in the state administration and is recognized as one of the classical languages of India. There are thirty characters in the Tamil ethnographic system. There are twelve vowels and eighteen consonants and one special character (aayutha ezhuthu). Vowels and consonants are combined to form composite letters (216), making total of 247 different characters. A review of literature related to HCR system in Tamil scripts is given below.

Suresh et al attempts to use the fuzzy concept on handwritten Tamil characters to classify them as one among the prototype characters using a feature called distance from the frame and a suitable 46 membership function [14]. The prototype characters are categorized into two classes: one was considered as line characters/patterns and the other was arc patterns. The unknown input character was classified into one of these two classes first and then recognized to be one of the characters in that class. Suresh et al proposed a system to recognize printed characters, numerals and handwritten Tamil characters using Fuzzy approach [15].

Hewavitharana & Fernando described a system to recognize handwritten Tamil characters using a two stage classification approach, for a subset of the Tamil alphabet [16]. In the first stage, an unknown character was pre-classified into one of the three groups: core, ascending and descending characters. Then, in the second stage, members of the pre-classified group are further analyzed using a statistical classifier for final recognition. A complete Optical Character Recognition system for Tamil magazine documents or news print was described [17]. Aparna et al proposed a method to construct a handwritten Tamil character by executing a sequence of strokes. A structure or shape-based representation of a stroke was used in which a stroke was represented as a string of shape features. Using this string representation, an unknown stroke was identified by comparing it with a database of strokes using a flexible string matching procedure [18].

Patil and Sontakke proposed an approach to use the fuzzy concept to recognize handwritten Tamil characters and numerals [19]. The handwritten characters (numerals) are preprocessed and segmented into primitives. These primitives are measured and labeled using fuzzy logic. Strings of a character are formed from these labeled primitives. To recognize the handwritten characters, conventional string matching was performed.

However, the problem in this string matching had been avoided using the membership value of the string. Bhattacharya et al proposed a two stage approach. In the first stage, an unsupervised clustering method was applied to create a smaller number of groups of handwritten Tamil character classes [20]. In the second stage, a supervised classification technique was considered in each of these smaller groups for final recognition. The training samples are first grouped using K-means clustering using a count of transition from one pixel position into other. During the second stage MLP is used to classify each group using chain code histogram features of samples. The recognition accuracy obtained is 92.77% and 89.66% for training and testing sets. Sutha and Ramaraj proposed a system to recognize handwritten Tamil characters using Neural Network [21]. Fourier Descriptor was 47 used as the feature to recognize the characters. The system was trained using several different forms of handwriting provided by both male and female participants of different age groups.

Indra Gandhi and Iyakutti present a new approach of Kohonen neural network based Self Organizing Map (SOM) algorithm for Tamil Character Recognition, which provides much higher performance than the traditional neural network [22]. First, it describes how a system is used to recognize a hand written Tamil characters using a classification approach. The aim of the pre-classification is to reduce the number of possible candidates of unknown character, to a subset of the total character set. This is otherwise known as cluster, so the algorithm will try to group similar characters together. Second, members of pre-classified group are further analyzed using a statistical classifier for final recognition. A recognition rate of around 79.9% was achieved for the first choice and more than 98.5% for the top three choices. The result shows that the proposed Kohonen SOM algorithm yields promising output and feasible with other existing techniques. Sureshkumar & Ravichandran, spatial space detection technique is used [23] in which paragraphs are segmented into lines using vertical histogram, lines into words using horizontal histogram, and words into character image glyphs using horizontal histogram. The extracted features considered for recognition are given to Neural Network for classification. Selvakumar Raja and Mala John presents an efficient method for recognizing Tamil characters based on extracted features like horizontal lines, vertical lines, loops, and curves [24]. The extracted features are fed to Back Propagation based Neural Network (BPNN) classifier system, Support Vector Machine (SVM) classifier, and Decision Tree (DT) classifier. The DT classifier system has achieved very good recognition rate on the Tamil character database and shows improved performance as compared to BPNN classifier and SVM classifiers.

3. VIEW BASED FEATURES

Feature extraction is the most important steps in the success of handwritten recognition system. The selection of feature extraction method is an important factor in achieving high recognition performance. Numerous methods are used for feature extraction such as directional features, gradient features, and statistical features structural features and so on. A good number of feature extraction methods are discussed in [26-27]. Sumana Barman et al proposed a new system is based on the view based approach [27]. The system does not need thinning of analyzed character. The characteristic vectors taken from both top and bottom views. Here we are considering only two views that is top and bottom among four. Two "views" of each character are examined to extract from them a characteristic vector, which describes the given character. The view is a set of points that plot one of two projections of the object (top or bottom) – it consists of pixels belonging to the contour of a character and having extreme values of y coordinate – maximal for top, and minimal for bottom view. Till now we have seen that view based methods handle with the whole images and take feature as the characteristics vector for word recognition. Khalid Saeed and Marek Tabedzki uses a view based approach for capital Latin letter classification and recognition [28]. It examines four "views" of every letter and gathers nine uniformly distributed characteristic points of each view

In this work, we carried out feature extraction using modified view based approach of original and thinned images and sub images of original and thinned images for handwritten Tamil character recognition and also using fixed meshing type is described below

3.1 FIXED MESHING

In mesh type the character images are partitioned into different region with imaginary grids. The original image and thinned images are divided vertically and horizontally into N-sub images. We divided each character image of size 72×72 into 16 sub images, with size 18×18.

3.2 MODIFIED VIEW BASED APPROACH

The view based approach is based on the fact that for correct character recognition a human usually needs only partial information about it, which is its shape. In this feature extraction method, we used original and thinned binary images. For feature extraction two approaches are used. The first approach is to find the five views viz, top, bottom, left, right and front of original and thinned images and then each view is divided into 16 equal blocks. Thus, in each block, P, the sum of background pixels (SBP) is calculated as SBPp. In the second approach, the original and thinned images are divided into 16 equal blocks and from each block, five views are computed. Then for each view, the sum of back ground pixels is calculated as SBPv. The four different view based features are explained below.

3.2.1 View Mesh Original Image (VMOI):

Here, first find the five views of the original image, divide each view in to 16 equal blocks or zones and for each zone compute SBPp. The Fig.1 shows the five views of the original image and 16 equal blocks of left views.

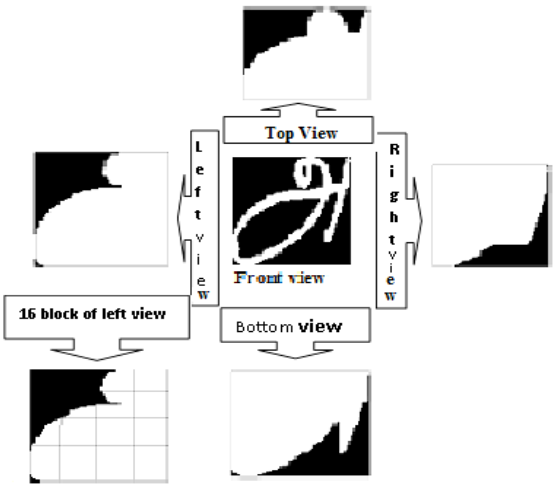


Fig.1. Five views of the binary image of character 'Aa' and 16 equal blocks of left view

3.2.2 View Mesh Thinned Image (VMOI):

Here, first find the five views of thinned images, divide each view into 16 equal zones and for each zone compute SBPp. The Fig.2 shows the five views of Thinned image and 16 sub images of left views.

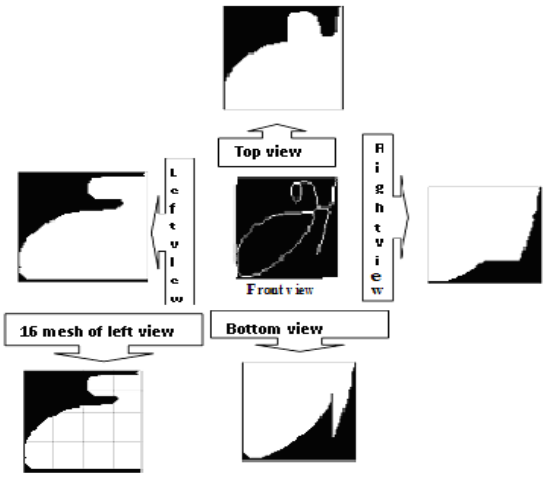
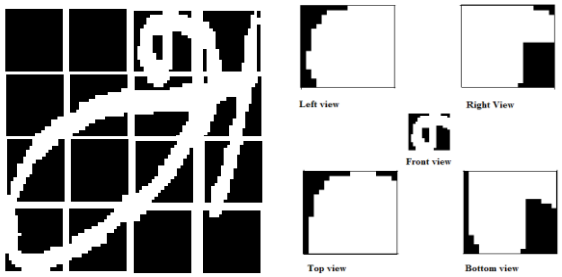


Fig.2. The five views of thinned image of character 'Aa' and 16 equal blocks of left view

3.2.3 Mesh View Original Image (MVOI):

Here, first the original image is divided into 16 equal blocks and the five views of each block are created. Then for each view, sum of background pixels is computed as SBPv. Fig.3(a) Shows the original image of character 'Aa' is divided into 16 equal zones and Fig.3(b) Shows five views of zone 3.

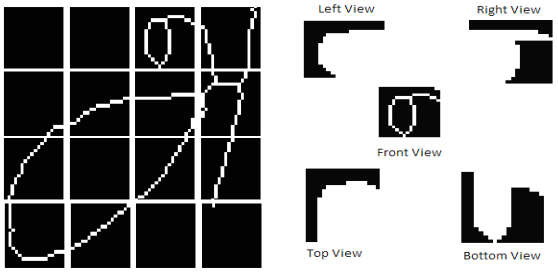


(a) (b)

Fig.3. (a) Character 'Aa' is divied into 16 equal zone (b) Five view of zone 3

3.2.4 Mesh View Thinned Image (MVTI):

Here, first the thinned image is divided into 16 equal blocks and the five views of each block are computed. Then for each view, compute sum of background pixels as SBPv. The Fig.4(a) shows the thinned image of character 'Aa' divided into 16 equal zones and Fig.4(b) shows five views of zone 3.



(a) (b)

Fig.4. (a) Character 'Aa' is divied into 16 equal zone (b) Five view of zone 3

3.3 FEATURE EXTRACTION ALGORITHM

Repeat steps I and II for all original and thinned images stored in the data base:

Step I

1. Top, bottom, left, right and front views are computed on original images.
2. For each view is divided into 16 equal blocks and each block compute SBPp and store the SBP values of the character and class-id into a file.
3. Same as step I (1) and (2) in thinned images

Step II

1. The original image is divided into 16 equal blocks and each block compute the top, bottom, left, right and front views.
2. For each view compute SBPv and store the SBP values of the character and class-id into a file.
3. Same as step II (1) and (2) in thinned images

The output of the algorithm contains a set of four files, each containing 80 features together with class id of the 21600 images.

4. EXPERIMENTAL ANALYSIS

If the goal of feature extraction is to map input patterns onto points in a feature space, the purpose of classification is to assign each point in the space with a class id or membership scores to the defined classes. Hence, once a pattern is mapped the problem becomes one of the classical classification to which a variety of classification methods can be applied. In this work, the SVM [29] and MLP classifier in WEKA Tool and ELM classifier [30] are used for classification. The experiment consists of database creation, preprocessing, feature extraction and training and testing.

4.1 DATASET

We conducted our experiments using a database of 21600 handwritten Tamil character samples collected from three hundred different persons. In the present study we considered only isolated characters of vowels, consonants and Grantha scripts. Three hundred handwritten pages, containing the selected 72 characters are collected from different persons belonging to different age groups, qualification and professions. The collected documents are scanned at 300 DPI which is usually a low noise and good quality image. Characters are segmented using projection histogram method, cropped and stored as bmp images. The resultant database consists of 21600 characters of the 72 selected character classes.

In order to analyze the quality of dataset, we introduce the concept of class representative images through linear combination of samples [36]. We analyzed the properties of the image in the database based on aspect ratio, normalized distance from character centroid (NDCO), and mean and standard deviation of aspect ratio and NDCO. Further, we have analyzed the dataset with class average images and deviations from standard samples. It is established that the samples posses sufficient variations to pose challenges in the machine recognition. Hence a well structured and standard database is created to facilitate a comprehensive study of handwritten Tamil character recognition [36].

4.2 PREPROCESSING

The preliminary step for recognizing handwritten character is the pre-processing, which involves operation on the digitized image intended to reduce noise and to simplify extraction of structural and statistical features. Preprocessing stage involves a set of operations to produce a modified image which is less complex, so that it can be used directly and efficiently by the feature extraction stage. In this work focus is given to size normalization, binarization and thinning. Each character image is normalized to size 72 × 72 pixels using nearest neighbor interpolation method. The normalized image is further converted in to binary image using Otsu's threshold selection technique [33]. Finally each character is thinned using a standard thinning algorithm. The Fig.5 shows the steps involved in preprocessing of input characters.

(a) (b) (c) (d)

Fig.5. Different steps involved in preprocessing: (a) Original image (b) Normalized image (c) Binarized image (d) Thinned image

4.3 FEATURE EXTRACTION

For each image in the database, the different feature extraction methods are applied. The normalized and binarized thinned images are used for finding the chain code, gradient, zero cross and division point features. For view based feature extraction, two approaches are used. In the first approach, normalized and binarized original character images are used. In the second approach, normalized and binarized thinned character images are used. The Fig.6 shows the feature extraction steps used in this work.

4.4 TRAINING AND TESTING

In the experiment, the 80 features are given as input to the SVM, MLP and ELM classifier. The eight methods are tagged as View Mesh Original Image (VMOI), View Mesh Thinned Image (VMTI), Mesh View Original Image (MVOI), Mesh View Thinned Image (MVTI), chain code (CH), gradient (GD), zero cross(ZC) and division point(DP).

For these methods, training and testing data sets are formed as follows:

The training and testing was carried out with 5 different data sets. In all the experiments, 60% of the samples are selected randomly for training and the remaining 40% for testing. Among the 21600 samples in the database, 12960 samples are used in the training phase and the remaining 8640 in the testing phase. For the creation of next data set, another combination of the same character samples (21600) are considered, and the selected 60% (12960) training data and 40% (8640) testing data will be different from the first. The formation of the five different data sets ensures the distribution of all variations of characters across training and testing phases.

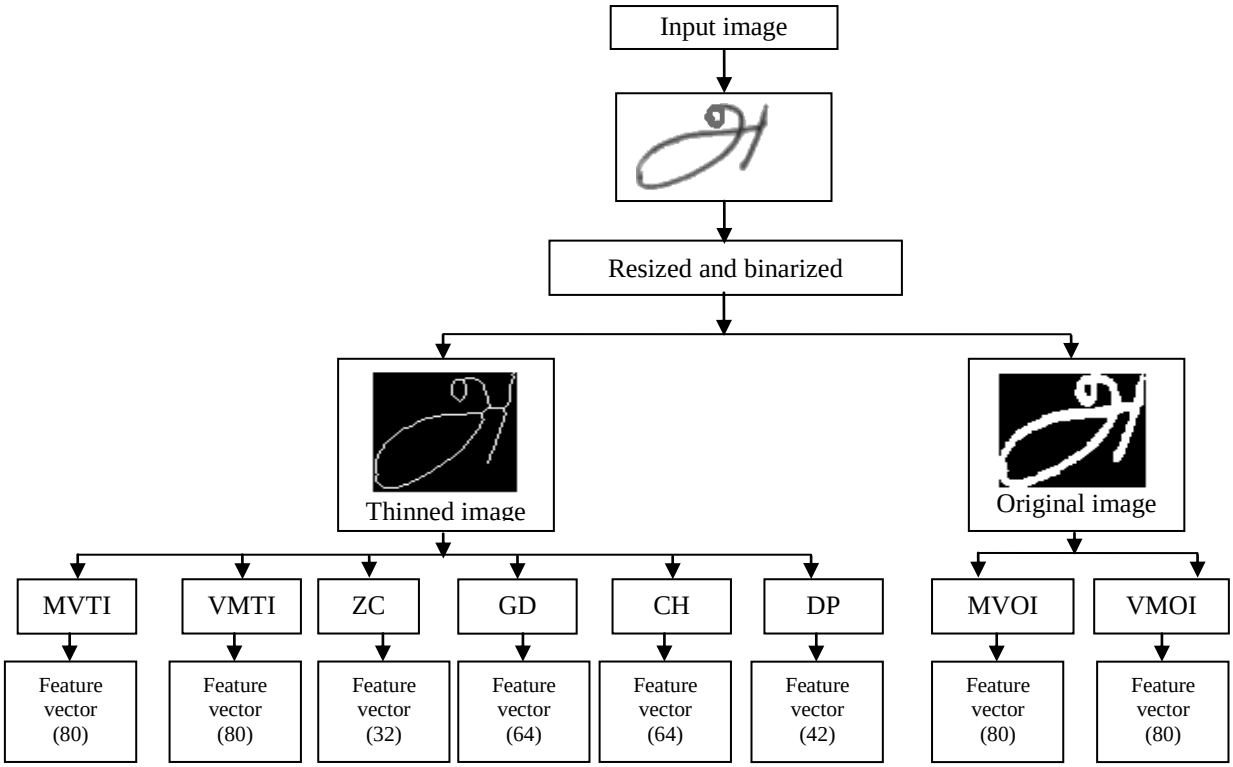


Fig.6. Feature extraction steps

4.5 RESULT AND DISCUSSION

The proposed modified view based feature extraction methods are implemented using MatLab. The performance of the proposed modified feature extraction approaches in terms of feature extraction time and classification accuracy is compared with four other feature extraction methods. All feature extraction method compared are listed in Table.1.

Table.1. All feature extraction, including view based method that are being compared

ZC	Zero crossing method [31-32]	
CH	Chain code method [34]	
DP	Division point method [30]	
GD	Gradient method [35]	
VMOI	View mesh original image	Proposed Methods
VMTI	View mesh Thinned image	
MVOI	Mesh view original image	
MVTI	Mesh view Thinned image	

The recognition experiments are carried out with SVM, MLP and ELM classifiers. The classification performance of view based feature extraction methods is given in Table.2. In each experiment a viewing strategy-classifier pair is chosen and the recognition accuracy for the five training-testing set is found. From the results, the view features extracted from thinned images are more discriminative than the view based feature extracted from original image. The highest accuracy is given by MVTI-SVM pair (95.26%). Here SVM is the best classifier where as ELM gives poor performance. Out of the four view based features MVTI is found to be superior. A comparison of the average recognition accuracy, total and average time of different feature extraction methods is given in Table.3.

Table.2. Recognition accuracy of all feature extraction method using SVM, MLP and ELM

Feature extraction Methods	**Average recognition accuracy (%)**		
	SVM	**MLP**	**ELM**
MVOI	90.6759	88.33	84.6
MVTI	95.2647	93.03	88.6
VMOI	87.7708	83.36	83
VMTI	92.3125	90.17	86.6
ZC	89.9861	88.75	93.8
DP	82.2477	80.77	86.2
CH	93.5509	92.76	93
GD	92.9907	91.85	92

Table.3. Total and average execution time

Feature extraction Methods	Total time	Average time	No. of characters Recognized with accuracy 95-100% (out of 72 characters)
MVOI	63.101	0.00278	23
MVTI	60.121	0.00292	46
VMOI	66.883	0.0031	25
VMTI	62. 819	0.00291	37
ZC	72.848	0.00337	23
DP	242.898	0.01125	10
CH	44723.57	2.0705	42
GD	87866.19	4.0679	32

Here, we present a comparative analysis of the performance of the feature extraction method is described. All the four view based features together with chain code, gradient; division point and zero crossing are selected for the study. We have considered only fixed meshing for extracting features. From the Table.3, it is clear that the view based feature extraction methods take less feature extraction time and highest recognition accuracy. Out of the four view based approaches MVTI gives the best performance (95.26%). It is to be noted that chain code method and gradient method are two well accepted feature extraction strategy in HCR.

The average recognition accuracy for each feature extraction method with the three different classifiers is given in Table.5. Here, SVM classifier is giving the best recognition accuracy of the features, MVTI is found to be the best feature out of the selected feature set. CH, GD and VMTI are relatively better. When we consider the time required for feature extraction, GD and CH are very expensive. All the view based features and the ZC approach require much less time. From this study, it is evident that as a single feature, view based features are the best option. In terms of recognition accuracy and the time required for feature extraction. MVTI is selected as the best feature among the set of features considered.

Though the overall accuracy given by MVTI is the highest in recognizing confusing character pairs, the other view based approaches are found to be better. This aspect needs further investigation.

The Table.4 shows the recognition accuracy of SVM classifier with respect to each character for the selected features. From the Table.4, 18 characters (highlighted) gives less than 95% recognition accuracy in all the feature extraction methods. The proposed method gives highest accuracy for all the characters except  ,  and  .

From the Table.4, the characters ஆ, நு, லு, ஹா, ணா, நா, ரு, ழு, றா, and னா have recognition rate of less than 75%. Again, the characters ரு, ஞ and ஞ have less than 60% in certain experiments. The Fig.7 and Fig.8 illustrate the average feature extraction time and classification performance of different feature extraction methods applied on handwritten Tamil character dataset.

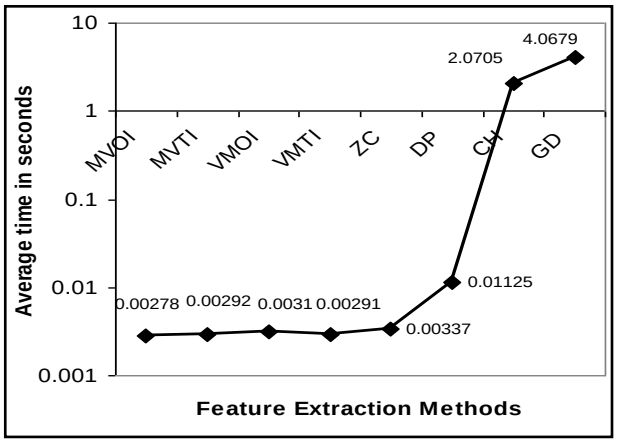


Fig.7. Average feature extraction time of different method applied on dataset

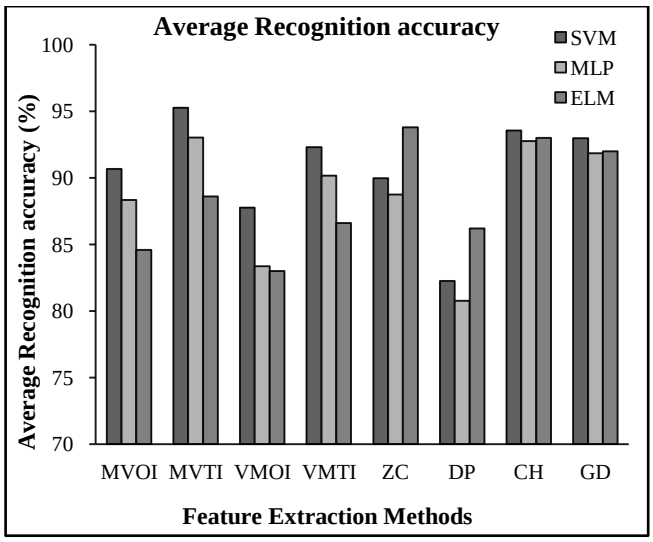


Fig.8. Performance comparison of classifiers on different feature extraction methods

5. CONCLUSION

In this work, we proposed two modified view based feature extraction approaches for the recognition of Tamil handwritten characters. The discriminative powers of the proposed approaches are compared with that of four popular feature extraction approaches in character recognition. The feature extraction time and classification performances are compared. The proposed approaches results in high classification performance with comparatively less feature extraction time. To improve the recognition accuracy, especially to deal with confusing character pairs, structural features can be added with view based features. Further other classifiers can be employed to evaluate the merit of the proposed features.

Table.4. Recognition accuracy of different feature extraction methods applied on 72 handwritten Tamil characters

Recognition accuracy in SVM classifier (%)									
Sl. No	**Character/methods**	**ZC**	**GD**	**CH**	**DP**	**MVTI**	**VMTI**	**MVOI**	**VMOI**
1	அ	98.33	98.33	100	97.5	100	100	98.33	100
2	ஆ	95.83	96.67	95	90.83	96.67	96.67	94.17	95
3	இ	97.5	97.5	98.33	90.83	100	97.5	96.67	94.17
4	ஈ	98.33	98.33	98.33	95.83	98.33	99.17	98.33	98.33
5	உ	99.17	100	99.17	98.33	100	100	98.33	100
6	ஊ	86.67	94.17	95	75.83	95	91.67	95	92.5
7	எ	99.17	98.33	100	90.83	100	99.17	97.5	96.67
8	ஏ	97.5	94.17	100	89.17	97.5	95.83	95.83	94.17
9	ஐ	95	95	97.5	95	96.67	99.17	97.5	93.33
10	ஒ	87.5	90	90	88.33	91.67	89.17	90.83	89.17
11	ஓ	91.67	92.5	95	83.33	97.5	94.17	90.83	92.5
12	க	95.83	95.83	97.5	89.17	98.33	98.33	97.5	96.67
13	ங	93.33	97.5	96.67	78.33	96.67	96.67	93.33	87.5
14	ச	98.33	100	100	93.33	100	100	98.33	98.33
15	ஞ	84.17	89.17	90	95	92.5	83.33	80	84.17
16	ட	100	100	100	91.67	100	98.33	99.17	98.33
17	ண	97.5	95.83	96.67	83.33	97.5	96.67	97.5	91.67
18	த	84.17	89.17	95	93.33	94.17	93.33	92.5	86.67
19	ந	86.67	97.5	94.17	90.83	94.17	94.17	87.5	84.17
20	ப	98.33	100	100	100	100	98.33	100	100
21	ம	97.5	98.33	95.83	97.5	96.67	98.33	94.17	98.33
22	ய	100	97.5	99.17	91.67	98.33	98.33	96.67	100
23	ர	92.5	90.83	96.67	96.67	99.17	92.5	95	90
24	ல	85	94.17	96.67	82.5	91.67	96.67	92.5	92.5
25	வ	85.83	83.33	90.83	76.67	92.5	87.5	88.33	92.5
26	ழ	89.17	93.33	95.83	82.5	95	93.33	90.83	91.67
27	ள	98.33	95	99.17	80.83	97.5	96.67	95	91.67
28	ற	94.17	96.67	98.33	90.83	97.5	98.33	94.17	95
29	ன	97.5	100	99.17	85.83	100	98.33	94.17	83.33
30	ஸ	88.33	90	91.67	75.83	95.83	97.5	93.33	94.17
31	ஹ	87.5	93.33	91.67	77.5	94.17	90	91.67	85
32	ஜ	84.17	91.67	92.5	80.83	95	86.67	92.5	86.67
33	ஷ	89.17	92.5	95.83	85	94.17	93.33	92.5	94.17
34	க்ஷ	90.83	94.17	96.67	87.5	96.67	92.5	90.83	91.67
35	டி	91.67	94.17	96.67	85	95.83	96.67	90	90.83
36	டீ	97.5	98.33	98.33	92.5	95	100	97.5	96.67
37	கு	91.67	92.5	95	79.17	95.83	85.83	85.83	76.67
38	ங்	86.67	99.17	100	82.5	98.33	98.33	96.67	96.67
39	சு	94.17	95	95.83	82.5	98.33	99.17	93.33	96.67
40	ஙு	82.5	91.67	88.33	70.83	95	86.67	85.83	74.17
41	டு	84.17	89.17	94.17	78.33	95.83	91.67	93.33	80
42	ணு	87.5	93.33	94.17	81.67	90.83	95	87.5	80.83
43	து	93.33	95.83	95	90.83	97.5	95.83	95	89.17
44	நு	85.83	95	92.5	70	94.17	80.83	85	68.33
45	பு	96.67	97.5	95.83	93.33	100	92.5	95.83	95.83
46	மு	82.5	90.83	90	76.67	93.33	89.17	91.67	84.17

47	யு	92.5	96.67	98.33	92.5	96.67	96.67	95	97.5
48	ரு	72.5	76.67	83.33	55.83	88.33	74.17	72.5	60
49	லு	88.33	89.17	89.17	69.17	90.83	89.17	88.33	88.33
50	வு	95.83	95.83	94.17	83.33	97.5	98.33	94.17	95.83
51	ழு	83.33	88.33	88.33	80	90	83.33	88.33	79.17
52	ளு	72.5	76.67	81.67	55	82.5	77.5	77.5	73.33
53	று	90	96.67	95.83	80.83	95.83	91.67	85.83	80
54	னு	82.5	85.83	80.83	67.5	91.67	84.17	77.5	70
55	கூ	98.33	98.33	98.33	97.5	97.5	95.83	95.83	95.83
56	ஙூ	87.5	95.83	97.5	83.33	97.5	98.33	94.17	94.17
57	சூ	86.67	91.67	90	89.17	92.5	88.33	92.5	90
58	ஞூ	90.83	88.33	75.83	66.67	91.67	89.17	85	77.5
59	டூ	86.67	86.67	91.67	80.83	91.67	90	86.67	92.5
60	ணூ	90.83	95.83	98.33	70	97.5	95.83	86.67	80.83
61	தூ	87.5	92.5	94.17	87.5	92.5	87.5	92.5	84.17
62	நூ	84.17	85.83	89.17	81.67	87.5	77.5	76.67	71.67
63	பூ	95	93.33	93.33	85.83	95.83	95	92.5	95.83
64	மூ	75	86.67	91.67	75	90	92.5	88.33	86.67
65	யூ	92.5	95.83	96.67	77.5	98.33	95.83	94.17	95
66	ரூ	74.17	82.5	79.17	60	87.5	83.33	75	72.5
67	லூ	91.67	97.5	95.83	75	99.17	96.67	90.83	94.17
68	வூ	95	98.33	98.33	91.67	99.17	100	99.17	95.83
69	ழூ	85	90.83	85.83	81.67	88.33	90	88.33	67.5
70	ளூ	70	83.33	76.67	49.17	88.33	80	75.83	67.5
71	றூ	85.83	89.17	61.67	75	89.17	85.83	81.67	78.33
72	னூ	86.67	94.17	84.17	76.67	95.83	90	90.83	70

REFERENCES

[1] H. Bunke and P. S. P Wang, Eds., "*Hand Book of Character Recognition and Document Image Analysis*", world Scientific Publishing Company, 1997.

[2] Rakesh Kumar Mandal and N. R. Manna, "Hand Written English Character Recognition using Row-wise Segmentation Technique", *International Symposium on Devices MEMS, Intelligent Systems & Communication*, No. 2, pp. 5-9, *2011*.

[3] Rakesh Kumar Mandal and N. R. Manna, "Hand Written English Character Recognition using Column-wise Segmentation of Image Matrix (CSIM)", *WSEAS Transactions on Computers*, Vol. 11, No. 5, pp. 148-158, 2012.

[4] G. Raju, Bindu S. Moni and Madhu S. Nair, "A Novel Handwritten Character Recognition System using Gradient Based Features and Run Length Count", *Sadhan: Academy Proceedings in Engineering Sciences*, Vol. 39, No. 6, pp. 1333-1355, 2014.

[5] G G. Rajput, Rajeswari Horakeri and Sidramappa Chandrakant, "Printed and handwritten mixed Kannada numerals recognition using SVM", *International Journal on Computer Science and Engineering* Vol. 2, No. 5, pp. 1622-1626, 2010.

[6] Leena Ragha and Sasikumar Mukundan, "Using Moments Features from Gabor Directional Images for Kannada Handwriting Character Recognition", *Proceedings of International Conference and Workshop on Emerging Trends in Technology*, pp. 53-58, 2010.

[7] B. V. Dhandra, Mallikarjun Hangarge and Gururaj Mukarambi, "Spatial Features for Handwritten Kannada and English Character Recognition", *IJCA Special Issue on Recent Trends in Image Processing and Pattern Recognition*, No. 3, pp. 146-151, 2010.

[8] S. K. Sangame, R.J. Ramteke, Rajkumar Benne, "Recognition of isolated handwritten Kannada vowels", *Advances in Computational Research*, Vol. 1, No. 2, pp. 52-55, 2009.

[9] S.V. Rajashekararadhya and P. Vanaja Ranjan, "Zone-based hydrid feature extraction algorithm for handwritten numeral recognition of four Indian scripts", *IEEE International Conference on Systems, Man and Cybernetics*, pp. 5145-5150, 2009.

[10] Umapada Pal, Sukalpa Chanda, Tetsushi Wakabayashi and Fumitaka Kimura, "Accuracy improvement of Devanagari character recognition combining SVM and MQDF", *Proceedings of International Conference Frontiers in Handwriting Recognition*, pp. 367-372, 2008.

[11] U. Pal, T. Wakabayashi and F. Kimura, "Comparitive study of Devnagari handwritten character recognition using different features and classifiers", *10th International*

Conference on Document Analysis and Recognition, pp.1111-1115, 2009

[12] Sandeep B. Patil, G. R. Sinha and Kavita Thakur, "Isolated Handwritten Devnagri Character Recognition using Fourier Descriptor and HMM", *International Journal of Pure and Applied Sciences and Technology*, Vol. 8, No. 1, pp. 69-74, 2012.

[13] Kartar Singh Siddarth, Mahesh Jangid, Renu Dhir and Rajneesh Rani, "Handwritten Gurmukhi character recognition using statistical and background directional distribution features", *International Journal of Computer Science and Engineering*, Vol. 3, No. 6, pp. 2332-2345, 2011

[14] R. M. Suresh, S. Arumugam and L. Ganesan, "Fuzzy Approach to Recognize Handwritten Tamil Characters", *Third International Conference on Computational Intelligence and Multimedia Applications*, pp. 459-463, 1999.

[15] Sundaram Suresh, R. Venkatesh Babu and H. J. Kim, "No-reference image quality assessment using modified extreme learning machine classifier", *Applied Soft Computing Journal*, Vol. 9, No. 2, pp. 541-552, 2009.

[16] S Hewavitharana and H. C. Fernando, "A Two Stage Classification Approach to Tamil Handwritten Recognition", *Tamil Internet*, pp. 118-124, 2002.

[17] K. H. Aparna and V. S. Charavarthy, "A Complete OCR System Development of Tamil Magazine Documents", *Tamil Internet*, pp. 45-51, 2003.

[18] K. H. Aparna, Vidhya Subramanian, M. Kasirajan, G. Vijay Prakash, V. S. Chakravarthy and Sriganesh Madhvanath, "Online Handwriting Recognition for Tamil", *Proceedings of 9th International Workshop on Frontiers in Handwriting Recognition*, pp. 438-443, 2004.

[19] Pradeep M. Patil and T. R. Sontakke, "Rotation, Scale and Translation Invariant Handwritten Devanagari Numeral Character Recognition Using General Fuzzy Neural Network", *Pattern Recognition*, Vol. 40, No. 7, pp. 2110-2117, 2007.

[20] U. Bhattacharya, S. K. Ghosh and S. K. Parui, "A Two Stage Recognition Scheme for Handwritten Tamil Characters", *Ninth International Conference on Document Analysis and Recognition*, Vol. 1, pp. 511-515, 2007.

[21] J. Sutha and N. Ramaraj, "Neural network based offline Tamil handwritten character recognition System", *International Conference on Conference on Computational Intelligence and Multimedia* , Vol. 2, pp. 446 – 450, 2007.

[22] R. Indra Gandhi and K. Iyakutti, "An Attempt to Recognize Handwritten Tamil Character Using Kohonen SOM", *International Journal of Advance d Networking and Applications*, Vol. 1, No. 3, pp. 188-192, 2009.

[23] C. Sureshkumar, T. Ravichandran, "Recognition and Conversion of Handwritten Tamil Characters", *International Journal of Research and Reviews in Computer Science*, Vol. 1, No. 4, 2010.

[24] Selvakumar Raja and Mala John, "A Novel Tamil Character Recognition Using Decision Tree Classifier", *IETE Journal of Research*, Vol. 59, No. 5, pp. 569-575, 2013.

[25] Øivind Due Trier, Anil K. Jain and Torfinn Taxt, "Feature Extraction Methods for Character Recognition - A survey", *Pattern Recognition*, Vol. 29, No. 4, pp 641–662, 1996.

[26] Sherif Abdleazeem and Eezzat EI-Sherif, "Arabic handwritten digit recognition", *International Journal of Document Analysis and Recognition*, Vol. 11, No. 3, pp.127-141, 2008.

[27] Sumana Barman, Amit Kumar Samanta, Tai-hoon Kim and Debnath Bhattacharyya, "Design of a view based approach for Bengali Character recognition", *International Journal of Advanced Science and Technology*, Vol. 15, pp. 49-62, 2010.

[28] Khalid Saeed and Marek Tabedzki, "A New Hybrid System for Recognition of Handwritten-Script", *International Scientific Journal of Computing*, Vol. 3, No. 1, pp. 50-57, 2004.

[29] K. P. Soman, R. Loganathan and V. Ajay, "*Machine Learning in SVM and Other Kernel Methods*", PHI Learning Private Limited, 2009.

[30] Binu P. Chacko, "Intelligent character recognition: A study and analysis of Extreme Learning Machine and Support Vector Machine using Division Point and Wavelet Features", Ph.D Thesis, Department of Information Technology, Kannur University, 2011.

[31] S. Sobhana Mari, G. Raju, "Zero crossing method for Tamil Handwritten Character Recognition Using MLP classifier," *Proceedings of National Conference on Language Computing*, 2011.

[32] G. Raju and K. Revathy, "Wavepackets in the Recognition of Isolated Handwritten Characters", *Proceeding of the World Congress on Engineering*, Vo1. 1, 2007.

[33] V. Lajish, "Adaptive Neuro-fuzzy Inference based Pattern Recognition Studies on Handwritten Character Images, Ph.D Thesis, Department of Computer Science, Calicut University, 2014.

[34] Rafeal C Gonzalez and Richard E.Woods, "*Digital Image Processing*", Second Edition, Prentice-Hall, 2002.

[35] A. Kawamura, K. Yura, T. Hayama, Y. Hidai, T. Minamikawa, A. Tanaka, and S. Masuda, "On-Line Recognition of Freely Handwritten Japanese Characters Using Directional Feature Densities," *Proceedings of 11th International Conference B: Pattern Recognition Methodology and Systems*, Vol. 2, pp. 183-186, 1992.

[36] S. Sobhana Mari and G. Raju, "Handwritten Tamil Character Recognition using chain code method", *Proceedings of International Conference on Mathematics and Computer Science*, pp. 138-142, 2011.