Performance Analysis of Hybrid Feature Extraction Technique for Recognizing English Handwritten Characters

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***Abstract*—.In this paper, an off-line handwritten English character recognition system using hybrid feature extraction technique and neural network classifiers are proposed. A hybrid feature extraction method combines the diagonal and directional based features. The proposed system suitably combines the salient features of the handwritten characters to enhance the recognition accuracy. Neural Network (NN) topologies, namely, back propagation neural network and radial basis function network are built to classify the characters. The k-nearest neighbour network is also built for comparison. The Feed forward NN topology exhibits the highest recognition accuracy and is identified to be the most suitable classifier. The proposed system will aid applications for postal/parcel address recognition and conversion of any hand written document into structural text form. The performance of the recognition systems is compared extensively using test data to draw the major conclusions of this paper.**

Keywords-Handwritten Character Recognition, Image processing, Feature extraction, Feed forward propagation Neural Network, Nearest Neighbour Network, Radial Basis function Network

I. INTRODUCTION

Handwritten recognition contributes immensely to the advancement of an automation process and can improve the interface between man and machine in numerous applications. Several research works have been focusing toward evolving newer techniques and methods that would reduce the processing time while providing higher recognition accuracy [1-2]. In general, handwriting recognition is classified into two types as offline and online handwriting recognition methods.

In the offline recognition, the writing is usually captured optically by a scanner and the completed writing is available as an image. But, in the online system the two dimensional coordinates of successive points are represented as a function of time and the order of strokes made by the writer are also available. The online methods have been shown to be superior to their offline counterparts in recognizing handwritten characters due to the temporal information available with the former [3].

However, in the offline systems, the neural networks have been successfully used to yield comparably high recognition accuracy levels [4]. Several applications including mail sorting, bank processing, document reading and postal address recognition require offline handwriting recognition systems. As a result, the offline handwriting recognition continues to be an active area for research towards exploring the newer techniques that would improve recognition accuracy [5-7].

The first important step in any handwritten recognition system is pre-processing followed by segmentation and feature extraction. Pre-processing includes the steps that are required to shape the input image into a form suitable for segmentation [8]. In the segmentation, the input image is segmented into individual characters and then, each character is resized into m x n pixels towards the extracting the features.

The selection of appropriate feature extraction method is probably the single most important factor in achieving high recognition performance. Several methods of feature extraction for character recognition have been reported in the literature [9]. The widely used feature extraction methods are Template matching, Deformable templates, Unitary Image transforms, Graph description, Projection Histograms, Contour profiles, Zoning, Geometric moment invariants, Zernike Moments, Spline curve approximation, Fourier descriptors, Gradient feature and Gabor features.

An artificial neural Network as the backend is used for performing classification and recognition tasks. In the off-line recognition system, the neural networks have emerged as the fast and reliable tools for classification towards achieving high recognition accuracy [10].

In this paper, a hybrid feature extraction scheme by combining two zonal based approaches, namely, diagonal and directional is proposed. The features obtained are used to train neural network based classifiers such as feed forward network and radial basis function network. A comparison is carried out with the nearest neighbour classifier. The hybrid features are used to train to Neural Network based classifiers and the results obtained are presented. The best recognition system is identified and the experimental results are presented and discussed.

The rest of the paper is organized as follows. In section 2, handwritten recognition system is presented. In section 3, the proposed feature extraction methods are explained and Section 4 describes neural network based classifiers. Section 5 evaluates the proposed recognition system and discusses the experimental results in detail and finally, the paper is concluded in section 6.

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II. HANDWRITTEN RECOGNITION SYSTEM

In this section, the handwritten recognition system is described. A typical handwriting recognition system consists of pre-processing, segmentation, feature extraction, classification and post processing stages. The general schematic diagram of the recognition system is shown in Fig.1.

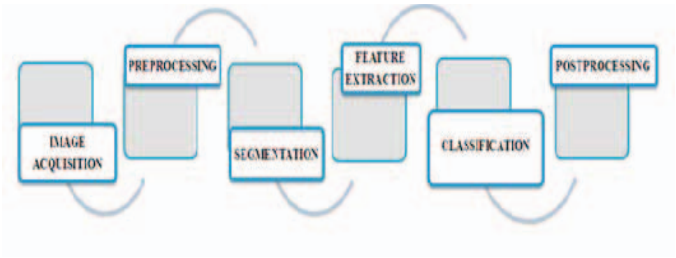

Figure 1. Schematic diagram of the proposed off-line recognition system

A. Image Acquisition

In Image acquisition, the recognition system acquires a scanned image as an input image. The image should have a specific format such as JPEG, BMP etc. This image is acquired through a scanner, digital camera or any other suitable digital input device. Data samples for the experiment have been collected from the different individuals. Samples of the collected handwritten English characters A to Z are shown in Fig.2.

Figure 2. Samples of handwritten English characters A to Z

B. Pre-processing

The pre-processing is a series of operations performed on the scanned input image. It essentially enhances the image rendering it suitable for segmentation. Various tasks are performed on the image during the pre-processing. Binarization process converts a gray scale image into a binary image using global thresholding technique. Detection of edges in the binarized image is done using sobel technique, dilation the image and filling the holes present in it are the operations performed in the last two stages to produce the pre-processed image suitable for segmentation [11].

C. Segmentation

In the segmentation stage, an image consisting of a sequence of characters is decomposed into sub-images of individual characters [12]. In the proposed system, the segmentation of input image into isolated characters is carried out in two steps namely, line segmentation and word segmentation. In line segmentation, the pre-processed image is scanned rowwise and pixel values are summed for every scanned row in order to find the start line. If the sum is zero, the scan has to proceed to the next row. If the sum is not zero then that row is identified as the first row of the line. It is continued till again the sum is equal to zero. The row for which the sum is zero is treated as the end row of the line. This is repeated to first segregate the lines. From the lines, the characters are segregated. This is done columnwise using the similar procedure. This process is repeated for all the lines to obtain the individual characters. Finally, each individual character is uniformly resized into 40X30 pixels for classification and recognition stage.

III. PROPOSED FEATURE EXTRACTION METHODS

The most critical aspect of handwriting character recognition is the selection of important features, which should be distinct and reasonably invariant with respect to shape variations caused by various writing styles. The zonal approach is used for feature extraction. In this section, the proposed hybrid feature extraction method that combines two zonal approaches is described below.

A. Diagonal Based Feature Extraction

In this feature extraction process, each character image of size 40 x 30 pixels is divided into 48 equal zones, each of size 5x5 pixels as shown in Fig.3. The features for a zone are extracted from each pixel by moving along the diagonals. Each zone has 9 diagonal lines and the foreground pixels present along each diagonal line is summed to get a single sub-feature and thus 9 sub-features are obtained from each zone. These 9 sub-features values are averaged to obtain a single feature value for a zone. This procedure is sequentially repeated for all the zones. There could be some zones whose diagonals are empty of foreground pixels. The feature value corresponding to these zones are zero. Finally, 48 features are extracted for each character.

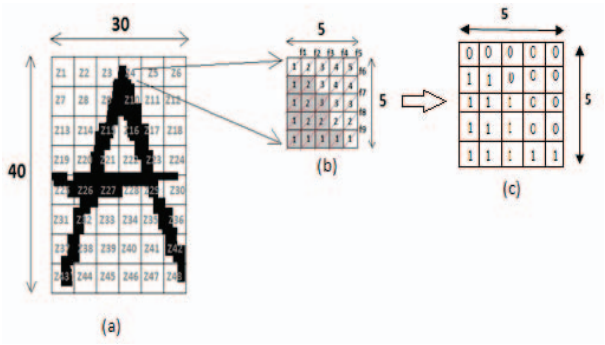

Figure 3. Diagonal based feature extraction

B. Directional Based Feature Extraction

In the directional method of feature extraction, the resized individual character of size 40x30 pixels is subjected to thinning. Thinning is the process by which the thickness of the character is reduced to obtain the skeleton of the original image. The image obtained after thinning is shown in Fig.4.

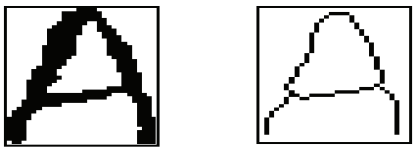

Figure 4. (a) Resized binary image (b) Thinned image

The thinned image is divided into P zones of size MxM each. A 3x3 window is moved over each zone of the thinned image to obtain the directional features. The 3x3 window is labeled from 1 through 8, where each number represents one of the eight possible directions. Fig.5 (a) shows the 3x3 window and the directions along which the features are to be secured. The window is positioned in such a way that its center is taken as reference, and the presence of pixel in each of the eight directions is checked. If the value is 1, then the count in that direction is incremented. This process is carried out along the counter-clockwise rotation. Then, the window is moved to the next pixel in the zone and the process is repeated for all the pixels in the zone.

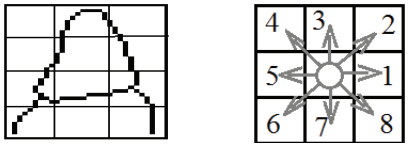

Figure 5. (a) 3x3 windows used to extract features (b) 12 zones of size 10X10

The window is moved rowwise. In this paper, the image is divided into 12 zones (P=12), each of size 10x10(M=10) as shown in Fig.5(b) Eight features are obtained from each zone corresponding to eight directions. Each feature indicates the number of pixels connected in that particular direction. Thus a total number of 96 features are obtained.

C. Hybrid Feature Extraction

The integration of features from the two techniques is called as a hybrid Feature extraction approach. This approach combines the features obtained from diagonal extraction and directional extraction. As a result, 144 features are obtained, that is, 48 diagonal features plus 96 directional features. The features obtained are given as input to a classifier. Different Neural Based Classifiers are investigated in the next section.

IV. Neural Network Based Classifers

Neural Network techniques offer a promising solution as classifiers in the handwritten character recognition system. The extracted hybrid features is taken as an input. The classification capability of the network depends on the architecture and learning rule [13]. The architectures considered in this paper are feed forward architecture, radial basis function architecture. The k-nearest neighbour algorithm is used for comparison. To evaluate the performance of the proposed method the handwritten uppercase English alphabets were collected from different individual writers. Of the 7800 samples collected, 5200 samples were used for training purpose and remaining 2600 samples were used for testing. The proposed recognition system has been implemented using Matlab7.1. The recognition systems were designed using different methods as listed below.

A. Feed Forward Back Propagation Neural Network Classifier

Feed forward architecture is used for classifying the characters. The inputs to the network are 144 features obtained from the hybrid feature extraction techniques described in the previous section. The number of outputs is 26 as there are 26 English alphabets. All the neurons use log-sigmoid transfer functions. The back propagation algorithm with momentum and variable learning rate is used to obtain the parameters of the network. Two hundred different handwritten data sets were used for training the neural network. The number of hidden layers and the number of neurons in each layer are determined through trial and error. Through numerous simulations, the 144-100-100-26 architecture was found to be compact and yielded the best results for character recognition. This feed forward neural network architecture was trained for the target MSE of 10e-6. After the network is adequately trained, the parameters of the trained network are fixed to enable testing. The architecture of the two layer neural network for the handwritten recognition system is shown in Fig.6.

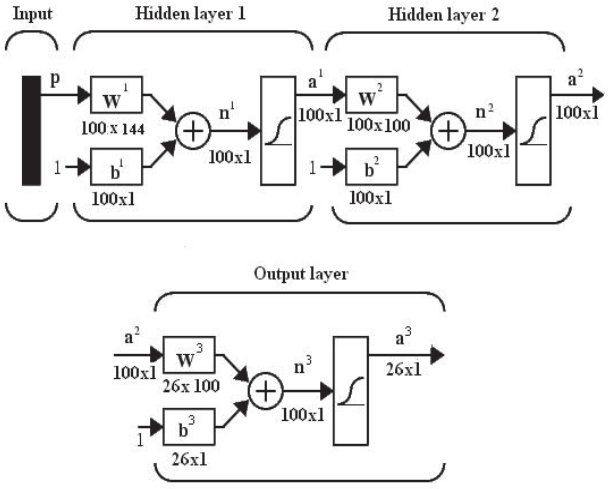

Figure 6. Two hidden layer neural network for character recognition

The output of layer is defined by

$$a^i = \log sig\,(w^i a^{i-1} + b^i) \quad (1)$$

where, $a^0 = P$, $i = [1,2,3]$, w^i = Weight vector of i^{th} layer

a^i = Output of i^{th} layer, b^i = Bias vector for i^{th} layer

P = Input vector for the network

B. Radial Basis Classifier

Radial basis function (RBF) network is a good classifier and used for a wide range of applications. It is a linear

combination of radial basis functions. The RBF architecture used for character recognition and the total number of radial basis function neurons is 100. The output layer has 26 neurons corresponding to 26 English alphabets [14]. The output of i^{th} layer is given by

$$a_i^l = radbas(\|IW_{i,j} - p_i\|b_i^1) \quad (2)$$

$$a^2 = purelin(LW_{2,1}a^1 + b^2) \quad (3)$$

where, $a_i^1 = i^{th}$ element of a^1 $_iIW_{1,1}$ is a vector made of the i^{th} row of i^{th} $IW_{1,1}$ .The results obtained are summarized in Table.2

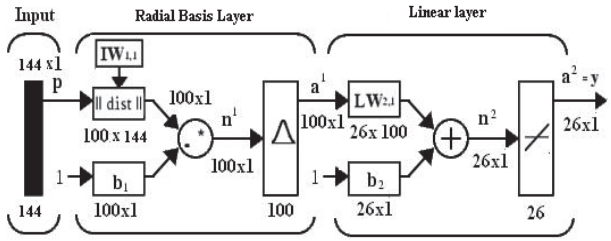

Figure 7. Radial basis function architecture for character recognition

C. *Nearest neighbour classifier*

In pattern recognition, the k-nearest neighbour algorithm is a method used for classifying the characters based on neighbourhood in the feature space. The training phase of the algorithm consists only of storing the feature vectors and class labels of the training samples. In the classification phase, the same features are computed from the test samples. The Euclidean distance between the test samples vectors and all the stored vectors are computed in order to find nearest neighbours and then obtained distances are ranked in ascending order the smallest distance is taken. Different types of nearest neighbour techniques have been reported in the literature [15-17]. The k-nearest neighbour technique is used in this paper. In this classifier, the classification and recognition are performed on the basis of similarity measurement. The Euclidean distances are computed for the different k-nearest neighbours between the testing vectors to all the stored vectors. The computed distances are ranked in ascending order, from which the smallest distance is taken. Simulation results show that the 3th nearest neighbours yield good accuracy while recognizing the handwritten English alphabets. The results obtained using this 3th nearest neighbours for recognizing the handwritten English alphabets are summarized in Table.1 .

V. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental results obtained using hybrid features for the three different classifiers are presented. The results obtained are summarized in Table.1.From the Table.1 it is observed that the feed forward network exhibits the highest average recognition accuracy. Also the worst case accuracy is high indicating superior performance for any combination of alphabets.

TABLE 1
PERFORMANCE COMPARISON OF DIFFERENT CLASSIFIERS

Classifier	Number of correctly recognized alphabets	Average recognition Accuracy in %	Worst case recognition Accuracy in %
Feed Forward NN	2494	95.96	88
Radial basis function NN	2439	93.82	87
Nearest neighbour NN	2389	91.88	76

Table.2 details the number of alphabets having recognition rate greater than 95%. It is seen from Table.2 that among the classifiers, the Feed forward neural network recognizes 17 alphabets with more than 95% accuracy. The maximum number of misclassification occurs for the character I and it has been misclassified 12 times for every 100 presentations (88% recognition). All other alphabets have higher recognition accuracy. From Table.2, it can be observed that Feedforward NN classifier is distinctly superior compared to other networks. The investigations of this work show that the Feedforward NN recognition system is best suited as a classifier for handwritten English characters.

TABLE 2
SUMMARY OF THE RESULTS ACHIEVED BY THE PROPOSED HYBRID APPROACH

Classifier	No of alphabets with a recognition rate greater than 95%	Alphabets with recognition rate greater than 95%
Feed Forward NN	17	A,B,C,D,E,G,H,L,N,O, P,S,T,U,V,W,Y
Radial basis function NN	14	C,D,E,F,G,H,L,N,O,P,S ,T,U,V
Nearest neighbour NN	10	C,G,H,L,N,O,P,S,T,U

VI. CONCLUSION

A Hybrid feature extraction based off-line handwritten character recognition system with different classifiers namely, Feed forward NN, radial basis function NN and nearest neighbour network for recognizing handwritten English alphabets is proposed. A hybrid feature extraction technique, combining two different approaches namely, diagonal based feature extraction and directional based feature extraction is used. The different classifiers have been trained with 200 sets of 26 alphabets and tested extensively. Experimental results show that the feed forward neural network is distinctly superior to the other classifiers in recognizing the handwritten English alphabets.

The Feed forward classifier is found to exhibit an average recognition accuracy of 95.96% and a worst case accuracy of

88%. The proposed system will find useful applications in recognizing the handwritten characters. Further improvements are possible with increased features and more complex Feed forward NN architectures, but this in turn would increase the computational overhead of the system. Therefore, it is concluded that the proposed hybrid feature extraction technique with Feed forward NN is a less complex and more accurate recognition system that provides a promising alternative to other methods for English handwritten characters.

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