An Investigation on the Performance of Hybrid Features for Feed Forward Neural Network Based English Handwritten Character Recognition System

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Abstract: - Optical Characters Recognition (OCR) is one of the active subjects of research in the field of pattern recognition. The two main stages in the OCR system are feature extraction and classification. In this paper, a new hybrid feature extraction technique and a neural network classifier are proposed for off-line handwritten English character recognition system. The hybrid features are obtained by combining the features extracted using diagonal, directional, Principal Component Analysis (PCA) techniques along with statistical and geometry feature extraction technique. The hybrid features are used to train a feed forward back propagation neural network employed for performing classification tasks. The hybrid features derived from two hundred character sets of lowercase English alphabets (a to z) were used for training the network. The overall recognition system has been tested extensively and shown to perform better than individual feature extraction techniques. The hybrid technique suitably combines the salient features of the handwritten characters to enhance the recognition accuracy.

Key-Words: - Handwritten English character recognition, image processing, hybrid feature extraction, neural network classifier

1 Introduction

Handwritten Character Recognition (HCR) has been quite a fascinating and challenging research area in field of image processing and pattern recognition. It contributes significantly to the advancement of automation process and improving the interface between man and machine in numerous applications. Several research works have reported different methodologies to achieve the reduction in processing time, while simultaneously improving the recognition accuracy [1][2].

In general, handwriting recognition is classified into two major categories, namely online and offline handwriting recognition methods. In the online recognition, the writing is usually captured optically using a scanner and the completed writing is available as an image. 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].

Offline handwriting recognition is comparatively a difficult task, as different people exhibit different handwriting styles. Currently, the offline character recognition systems are primarily developed for recognizing machine printed and Handwritten texts. Handwritten documents entail special consideration as it involves recognizing the character written with varying styles.

The steps in any handwritten recognition system are pre-processing followed by segmentation, feature extraction and classification. Pre-processing shapes the input image into a form suitable for segmentation [4]. This includes filtering, morphological operations, noise modelling and normalization. In the segmentation, the input image is segmented into individual characters and then, each character is resized into m x n pixels. Segmentation includes external and internal segmentation. External segmentation decomposes page layout into logical units, while internal segmentation decomposes words into characters.

Feature extraction methods are classified based on three types of features, namely, statistical features, structural features and transformation-based features. Several feature extraction techniques for

character recognition have been reported in the literature [5]. The widely used 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.

The artificial neural networks have been shown to be effective in performing classification and recognition tasks using features obtained from extraction techniques. The architecture of the neural network, to a large extent, determines the capability for classification. XinWanga [6] proposed handwritten character recognition system based back propagation algorithm in visual studio2005 platform. In this system, the binary image is used as the input for the training network and the maximum recognition accuracy obtained is 95%. Blumenstein et al investigated direction feature extraction and modified directional feature extraction technique with neural classifiers. The Directional Distance Distribution (DDD) is adopted as feature extraction technique and the recognition rates are compared between the modular and non-modular networks [7]. Manju Rani et al introduced a new cross corner feature extraction technique for handwritten English capital characters using back propagation neural Network [8]. Dayashankar Singh [9] et al introduced a handwritten recognition system based on twelve direction feature extraction using back propagation classifier**.** It provides high accuracy with less training time for handwritten character recognition system. B.V.Dhandra [10] et al presented a handwritten Kannada and English Character recognition system based on directional spatial features using KNN classifier. The average distance from zone centroid is computed in [11] and the average distance from the character centroid to each pixel present in the zone is computed in [12]. In [13] a zonal based method divides a character into 24 zones and normalized distance measure is used for Hindi characters.

Hirabara *et al* presented a two level based character recognition method using dynamic zoning selection scheme for feature extraction technique [14]. Desai proposed recognition system for Gujarat handwritten numerals using four different profiles namely; vertical, horizontal and two diagonal profiles feature extraction techniques with multi-layer feed forward neural network [15].

The reported works motivated the authors to propose a new zonal technique called diagonal based feature extraction and compare the same with conventional vertical and horizontal methods. It has been found that diagonal approach outperforms the conventional horizontal and vertical approaches [16].

A hybrid technique using structural and statistical features for English handwritten characters, digits and graphemes is proposed in [17]. A Multi-stream approach for off-line handwritten word recognition is reported in [18]. This approach combines feature streams namely, density based features extracted from two different sliding windows with different widths and contour based features extracted from upper, and lower contours. The experiments have been carried out on two IFN/ENIT benchmark database.In [19], Aradhya *et al* proposed a multilingual character recognition system by combining the PCA method and Fourier transform and which is compared with conventional PCA method. Haradhan *et al* conducted an experiment for handwritten text recognition based on the transition feature, sliding window amplitude feature and contour features using scaled conjugate gradient algorithm for neural network [20].

This paper proposes a hybrid feature extraction technique and investigates its performance in recognizing offline handwritten English handwritten characters. This approach combines four different techniques, namely, diagonal, directional, PCA techniques along with statistical and geometry technique in order to produce the best possible hybrid feature set. The hybrid features are used to train the neural network classifiers. The best hybrid feature combination for recognizing offline handwritten English handwritten characters is identified and the results obtained are presented and discussed.

The rest of the paper is organized as follows. In section 2, handwritten recognition system is described. Section 3 presents hybrid feature identification for neural network based recognition. Section 4 evaluates the performance of proposed hybrid feature set for neural network based recognition and discusses the results in detail. The paper is concluded in section 5.

2 Handwritten Recognition System

In this section, the proposed handwritten recognition sys-tem 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.

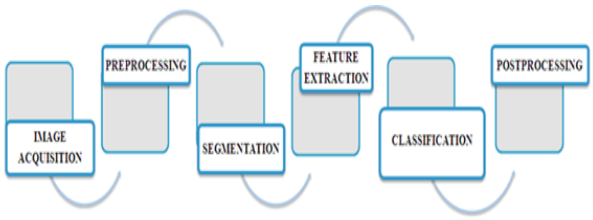


Fig.1 General Offline character recognition system

2.1 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 300 different individuals. Totally, 7800 samples were collected out of which 5200 samples were used for training and remaining 2600 samples for testing. Samples of the collected handwritten English characters a to z are shown in Fig.2.

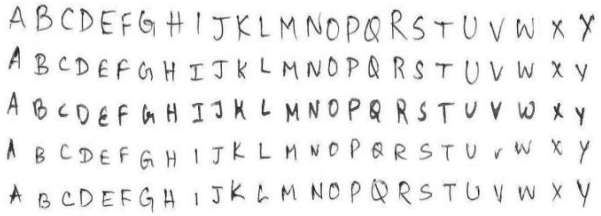


Fig.2 Samples of handwritten English characters A to Z

2.2 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. A series of tasks are performed on the image during the pre-processing. Binarization process converts a gray scale image into a binary image using global thresholding. The edges in the binarized image are detected using sobel technique. Dilation of 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 [21].

2.3 Segmentation

In the segmentation stage, an image consisting of a sequence of characters is decomposed into sub-images of individual characters [22]. 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 by preserve the image aspect ratio to extract the features.

2.4 Feature Extraction

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 [5]. In this paper, each character is resized into 40x30 pixels and features are extracted from each of the resized characters. There are different feature extractions techniques namely: diagonal feature, directional feature, PCA and statistical and geometry feature to extract the features and each feature extraction technique is explained in the section 3. The hybrid feature set is a combination of the features obtained from different feature extraction techniques. The hybrid feature sets are the input to the neural classifiers.

2.5 Classification

The classification stage is the decision making part of the recognition system. The classification capability of the network depends on the architecture and learning rule. Neural network techniques offer a promising solution as classifiers in the handwritten character recognition system. In [23], the authors have investigated different neural architectures and concluded that the feed forward architecture is suitable for recognizing handwritten English alphabets with good accuracy. In this paper, the feed forward architecture is used for classification. The inputs to the network are different combinations of hybrid features obtained from various techniques. The number of input nodes depends on the number of hybrid features. The

number of outputs is 26 as there are 26 English alphabets. The back propagation algorithm with momentum and variable learning rate is used to obtain the parameters of the network.

3 Hybrid Feature Identification for Neural Network based Recognition

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 four different feature extraction approaches used are described in this section.

3.1 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.

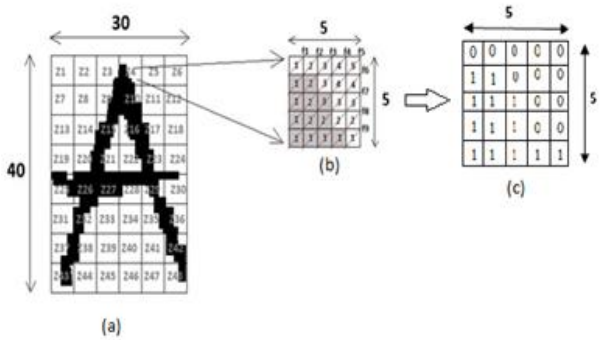
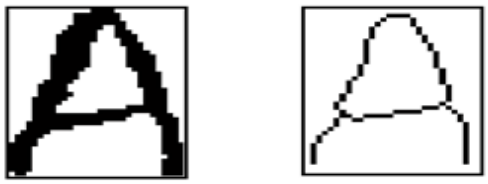


Fig.3 Diagonal based feature extraction

3.2 Directional based Feature Extraction

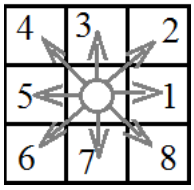
In the directional method of feature extraction, the resized individual character of 40X30 size pixels is subjected to thinning. Thinning is the process by which the thickness of the character is reduced to obtain the skeleton of the original image. The image obtained after thinning is shown in Fig.4.



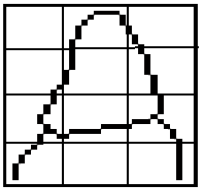
(a) (b)

Fig.4 Resizing and Thinning (a) Resized image (b) Thinned image

The thinned image is divided into P zones of size M x M each. A 3x3 window is moved over each zone of the thinned image to obtain the directional features. The 3x3 window is labelled 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 centre 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. The window is moved rowwise. In this paper, the image is divided into 12 zones, each of size 10x10 as shown in Fig.5 (b) eight features are obtained from each zone corresponding to eight directions. Each feature indicates the number of pixels present in that particular direction. Thus, a total number of 96 features are obtained.



(a)



(b)

Fig.5 Directional Features (a) 3x3 windows used to extract features (b) 12 zones each of size 10x10

3.3 Principal component analysis

Principal component analysis (PCA) is one of the statistical feature extraction approaches for machine

learning. This approach is mainly used for extracting statistical features by reducing the dimensionality of the data. Features are extracted in the form of Eigen vectors. Each eigenvector represents a principle component and Eigen values are the weights associated with these Eigen vectors.
In this feature extraction process, each character image of size 40x30 pixels is resized into 20X20 pixels. The resized image converted into a column vector is used to perform the principal components analysis. Using the column vector the mean and covariance are calculated for each image. From the covariance matrix, the Eigen values are determined and arranged in an ascending order. The principal component values corresponding to the Eigen values are computed. By removing the five least significant principal components, the dimensionality of the feature vector is reduced. Finally, 300 features are extracted for each character. These feature vectors are used for training the neural network.

3.4 Geometrical and Statistical based Feature Extraction

In this feature extraction process, the features are geometrical features based on the shape and dimensions of a character's image. The various shape based features used are Eccentricity, Kurtosis, Skewness, Standard deviation, variance, mean and covariance. These features are obtained for each character image.

3.4.1 Eccentricity

It is defined as the ratio of the distance between the foci of the ellipse and its major axis length.

3.4.2 Kurtosis

It is a measure of flatness of distribution. It gives an idea of whether the data are peaked or flat relative to a normal distribution.

$$Y = \frac{\sum (X-\mu)^4}{\sigma^4} \quad (1)$$

where, μ is the mean of x, σ is the standard deviation of x.

3.4.3 Skewness

It is a measure of the asymmetry of the data around the sample mean. The skewness of the normal distribution is zero.

$$Y = \frac{\sum (X-\mu)^3}{\sigma^3} \quad (2)$$

where, μ is the mean of x, σ is the standard deviation of x.

3.4.4 Mean

It is Average or mean value of array. It returns the mean values of the elements along different dimensions of an array.

3.4.5. Variance

The variance (σ^2) is a statistical measure that measures data variation from the average value of the set of data. In other words, it is defined as the sum of the squared distances of each term in the distribution from the mean (μ), divided by the number of terms in the distribution (N).

$$\sigma^2 = \frac{\sum (X-\mu)^2}{N} \quad (3)$$

3.4.6 Standard Deviation (σ)

It is the square root of the variance.

3.4.7 Covariance

It is a vector of variances for each data column, which represent a measure of the spread or dispersion of data in the corresponding column.

$$\mathrm{cov}(X,Y) = \frac{\sum (X_i - X)(Y_i - Y)}{N} \quad (4)$$

where X and Y are matrices with the same number of elements
The features corresponding to each parameter are extracted and thus 7 robust features are obtained for each character.

3.5 Hybrid Feature Extraction

The integration of features from the four feature extraction techniques is called as hybrid feature extraction approach. This approach combines the features obtained from diagonal, directional, PCA and Geometry extractions. As a result, totally 451 features are obtained including 48 diagonal features, 96 directional features, 300 PCA features and 7 geometry features. The schematic of this approach is depicted in Fig.6 and the results are tabulated in Table.2.

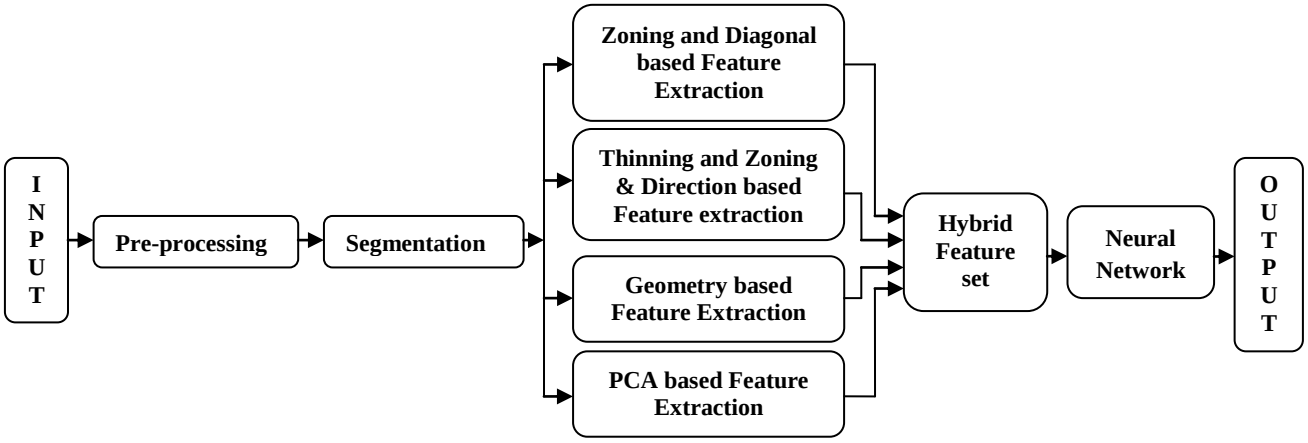


Fig.6 Proposed Hybrid feature extraction approach

4 Performance of Proposed Hybrid Feature Set for Neural Network Based Recognition

The features are combined in three different ways and used for training the network. Using three different features set, three different neural networks were built. All the three networks were trained using 200 datasets (5200 samples). All the three networks are tested using 100 datasets (2600 samples). The target MSE is 10e-8.The recognition system has been implemented using Matlab7.1.All the three networks are similar, in architecture except for the number of inputs. Then the networks are adequately trained and the parameters of each network are fixed to enable testing. The results obtained are shown in Table.1.The recognition rates obtained for all the three networks are shown in Table.2. It is observed that network 3 has the highest recognition accuracy. Further investigations are carried out for network 3. To determine the recognition accuracy for each alphabet, the confusion matrix was computed. This was done to investigate the worst case recognition accuracy, which indicates the minimum accuracy for any data stream. The average and worst case recognition rates obtained for network 3 are shown Table.1.

TABLE.1 Details of the feed forward neural network classifier

Input nodes	451
Hidden layers	2
Hidden layers nodes	100
Output nodes	26(alphabets)
Training epochs	50000
Training algorithm	Gradient descent with momentum training and adaptive learning
Performance function	Mean Square Error (MSE)
Training goal	10e-8

TABLE.2 Performance Comparison of Different Combination of Features

Sl. No.	Networks	Type of feature extraction	No of features	Maximum recognition rate in %
1	Network 1 (144-100-100-26)	Combination of directional and diagonal feature extraction	144	96.30
2	Network 2 (444-100-100-26)	Combination of directional, diagonal and PCA feature extraction	444	96.46
3	Network 3 (451-100-100-26)	Combination of directional, diagonal, PCA, statistical and geometric feature extraction	451	97.03

TABLE.3 Summary of the results achieved by the proposed network 3

English handwritten characters	Number of correctly recognized alphabets	Average recognition accuracy in %	No of Alphabets with a recognition greater than 95%	Worst case recognition accuracy in %	Alphabets with a recognition rate less than 95%
Lowercase letters	2522	97.03%	18	89%	f, g, j, k ,l, r, s, y

It is observed from Table.3 that the English handwritten character recognition system recognizes 18 alphabets with more than 95% accuracy. The classification accuracy for each alphabet is shown for each in Fig.7.
The maximum number of misclassification occurs for the letter 'f' which is misclassified 11 times for every 100 presentations (89% recognition). All other alphabets have better recognition accuracy. The investigations and studies conducted in this research work show that the 451 hybrid features yield superior performance for handwritten English characters.

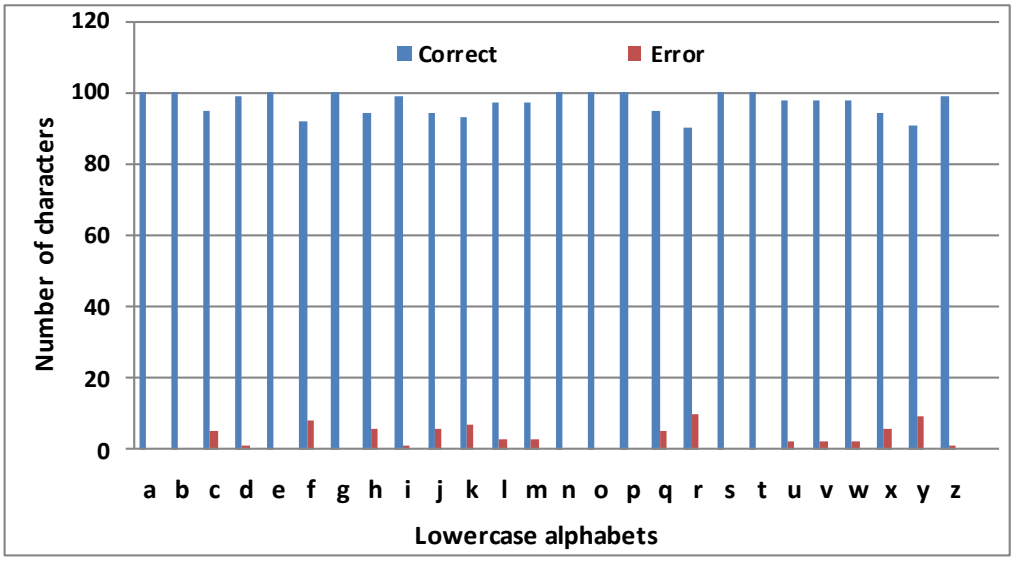


Fig.7 Performance illustration of proposed feature extraction technique in terms of recognition rate

5 Conclusion

An offline handwritten character recognition system based on Hybrid features has been proposed in this paper. The hybrid feature set is obtained by combining diagonal, directional, Principal Component Analysis (PCA), statistical and geometrical feature extraction techniques. The feed forward back propagation neural classifier is trained with 200 sets of 26 alphabets and extensively tested. The investigation is carried out for the different combination of features and the experimental result shows that the 451 feature combination approach yields good recognition accuracy of 97.03%.Further improvements are possible by increasing the number of features and using a more complex Feed forward NN architecture, but this in turn would increase the computational complexity of the system. Therefore, it is concluded that the proposed feature set offers an accurate and less complex solution using Feed forward NN for English handwritten characters. The proposed offline hand written character recognition system with better recognition accuracy will be eminently suitable for many applications including postal/parcel address recognition, bank processing, document reading and conversion of any handwritten document into structural text form. Further improvements are currently under investigation.

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