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A Comprehensive Study On Handwritten Character Recognition System

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Abstract: *Nowadays handwritten character recognition is still remain an open problem because of the variability in writing style. Conversion of handwritten characters is important for making manuscripts into machine recognizable form so that it can be easily accessed and preserved. Many researchers have worked in the area of handwriting recognition and numerous techniques and models have been developed to recognize handwritten text. The study investigates that in any character recognition system there exist three major stages such as Preprocessing, Feature Extraction and Classification. This paper provides a comprehensive review of existing works in offline handwritten character recognition.*

Keywords: *Back Propagation, Chain Code, Moment invariants, Probabilistic Neural Network, SIFT, Wavelet, Zoning,*

I. Introduction

Character Recognition (CR) is one of the most successful applications in the areas of pattern recognition and artificial intelligence. It is the process of detecting and recognizing characters from input image and converts it into machine recognizable form. Handwritten Character Recognition (HCR) is useful in cheque processing in banks, almost all kind of form processing systems, handwritten postal address resolution and many more. One of the main advantages of the CR process is that it can save both time and effort when developing a digital replica of the document. CR process can be classified in to two categories namely Off-line CR and On-line CR as shown in Fig1.

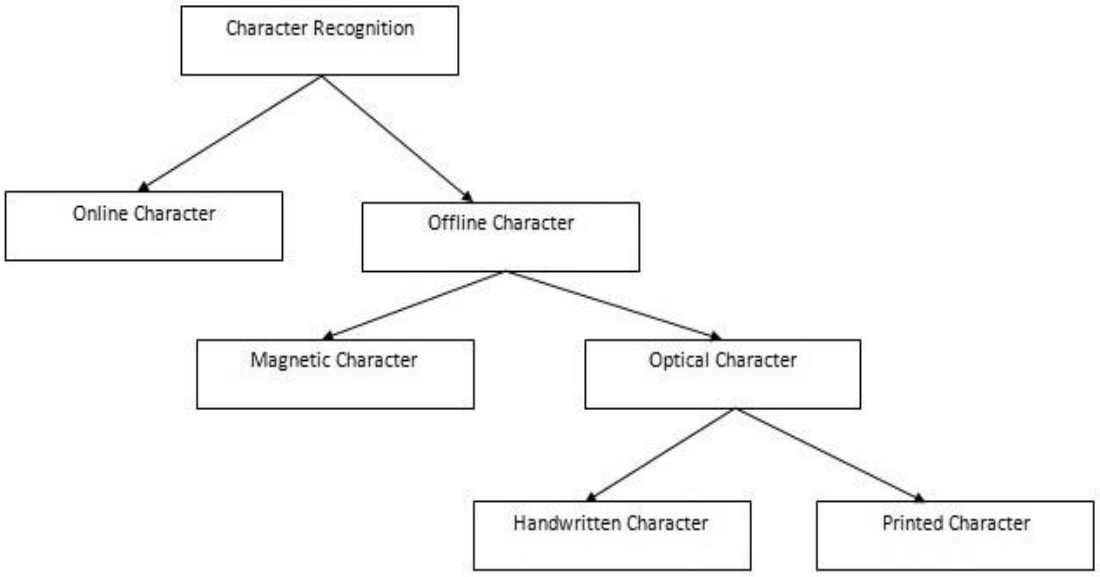

Fig 1. Character Recognition

The Off-line Handwritten Character Recognition focuses on recognizing character or words that had been recorded earlier in the form of scanned image of document. In case of On-line Handwritten Character Recognition, the process of recognition is performed at the time of writing itself through the successive points of strokes by the writers in a fraction of time. Although Off-line and on-line CR techniques have different approaches, they share a lot of common problems and solutions. Off-line CR is relatively more complex and requires more research compared to on- line CR because of variability on size and writing style of handwritten characters by different individual at different times. The character recognition system consists of three major stages as shown in Fig2:

1) Preprocessing: It improves the image data by removing unwanted noise or enhances some image features important for further processing.
2) Feature extraction: Features define the behavior of region of interest in an image. In this stage various techniques are applied to get features that will be useful in classification and recognition of character images.
3) Classification: The features extracted from the above phase are given as input to the trained classifier like Artificial Neural Network (ANN), K- Nearest Neighbor (KNN), and Support Vector Machine (SVM). Classifier compares input features with stored pattern and find out best matching class of input.

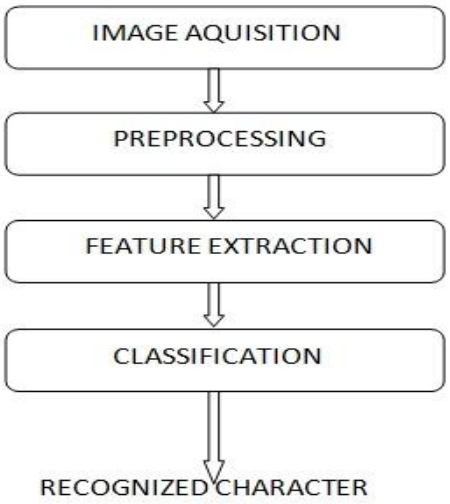

Fig 2. Block Diagram of Character Recognition

This paper is arranged to focus on Off-line CR methodologies with respect to these three stages of CR systems.

II. Literature Review

A number of researches have been proposed over the years for character recognition. This section highlights the methods under each of the three phases of character recognition and thus provides an overview of various literatures based on character recognition. Before moving on to the first stage of character recognition system, character image can be acquired by online or offline mode. In offline mode handwritten character are acquired by scanning the documents or capturing photographs of documents.

A. Preprocessing

The process of extracting text from the document is called preprocessing. The accuracy of text recognized by means of OCR depends on the factors such as scanner quality, scan resolution, paper quality, fonts used, linguistic complexities and so on. The problems that may occur due to these factors can be solved by using preprocessing techniques. It enhances character image preparing it for later stages and its objectives are noise reduction, data normalization and compression of information to be retained. An OCR system can be made more robust by applying some of the effective preprocessing techniques such as image enhancement techniques, binarization, noise reduction techniques, skew detection and correction, character segmentation, image normalization and morphological processing.

B.V. Dhandra et al. [1] have performed series of operations like binarization, filtering and morphological operations as part of preprocessing for recognizing Kannada handwritten vowels. Here gray scale image is binarised using Otsu's global thresholding and median filter is applied for removing noise due to erratic hand movements and digitization inaccuracies. After this, morphological operations are performed for removing isolated locations and spikes around the end of the vowels. Even if median filter overcomes the limitations of the linear filters it may cause removal of corners and threads, blurring of texts in the documents. In order to overcome these limitations Kanika Bansal et al. [2] proposed an algorithm named K-algorithm, which is the combination of filtering and binarization. For reducing within- class variation of shape of unconstrained handwritten numerals, Suzete E. N. Correia et al.[3] have used slant and size normalization as preprocessing methods. Ntogas Nikolaos et al.[4] proposed four Binarization methods such as Otsu's, Niblack, Sauvola's and Bernsen's for discriminating degraded and very poor quality gray scale Byzantine manuscript from the background based on pure thresholding and filtering. As per his work Otsu's provide better result as

compared to other three methods. In [5] Xiang Zhao et.al used morphological operations (thinning, skeletonization etc.) for recognizing characters from map.

B. Feature Extraction

In this phase, features of individual character are extracted. The performance of any character recognition system depends on the features that are extracted. The extracted features of input character should allow its classification in a unique way. Feature Extraction serves two purposes, one is to extract properties that can identify a character uniquely. Second is to extract properties that can differentiate between similar characters. This phase of character recognition system is very problem dependent. Good features are those whose values are similar for objects belonging to the same category and distinct for objects in different categories. Selection of an appropriate feature extraction method is the most important factor in achieving high recognition performance. In feature extraction stage each character is represented as a feature vector, which becomes its identity. The major goal of feature extraction is to extract a set of features which maximizes the recognition rate with the least amount of elements. Therefore, better features that are able to recognize characters distinctively must be extracted. Different feature extraction methods are Global Transformation and Series Expansion, Statistical Representation, Geometrical and Topological Representation.

i) Global Transformation and Series Expansion

The linear combination of a sequence of simpler functions provides a compact representation of continuous signal known as transformation and series expansion. Global transformation features are calculated by converting image in frequency domain like Discrete Fourier Transformation (DFT), Discrete Cosine Transformation (DCT), Discrete Wavelet Transformation (DWT), Walsh- Hadamard Transformation etc. Some related methods used in CR field are Fourier transform, Wavelets, Moments and Gabor transform.

Wavelet transformation is a mathematical technique that decomposes the signal into series of small basis function called wavelets. It allows the multiresolution analysis of image and is well localized in both time and frequency domain. As a result of wavelet transformation the image is decomposed into low frequency and high frequency components. The information content of these sub images that corresponds to Horizontal, Vertical and Diagonal directions implies unique feature of an image. Moreover it is efficient than Fourier transform which faces the resolution problem and localized in frequency domain only.

B. V. Dhandra et al [1] developed an algorithm for extracting features from Kannada characters. In this algorithm, two level forward wavelet packet transform is applied to the character image using db4 filter. Then count the number of zero crossings, the position of sharp variation points in an image, out of the resulting sub bands and this number is taken as a feature vector. By using this concept of zero crossings of discrete dyadic wavelet transform, Xian Zhao et al [5] have recognized character in scanning map and it is considered as the primary investigation in this field. Diego Romero et al [6] applied different continuous wavelet transforms to handwritten numerals to extract multiscale features such as orientation, gradient and curvature. George S Kapogiannopoulous et al [7] applied biorthogonal discrete wavelet transform to decompose the curvature function which characterizes the contour of the handwritten character image. Wavelet representation of curvature function has the advantages that variations in the shape of the curve will cause only minor changes in the wavelet representation.

In [8] Joohun Lim et al. have presented a comparative analysis of scale invariant feature extraction using different wavelet bases. This paper shows that Gabor wavelet basis function extracts image features more efficiently than Haar, Daubechies basis function in wavelet bases. Gabor wavelet means Gaussian enveloped orthogonal basis function and it uses five different scales and eight orientations. In [9] Lee et al. have extracted features using Haar orthogonal wavelet at one resolution level. When Suzete E. N. Correia et al [3] used Cohen-Daubechies- Feauveau (CDF) family of bi- orthogonal spline wavelets as feature extractor he finds that the recognition rate obtained with CDF 3/7 is superior to that of Haar wavelet. The Cohen- Daubechies- Feauveau (CDF) family of bi- orthogonal spline wavelets has special properties such as short support and regularity which is useful for off-line recognition of unconstrained handwritten numerals.

Wavelet based approaches are becoming increasingly popular in pattern recognition and have recently been applied to character recognition. In wavelet theory, there is a large variety of wavelet bases to choose from. Obviously, the choice of the best wavelet is dependent on the application. Recently, some papers have been published using wavelet transform as a feature extractor for handwritten character recognition because of its multiresolutional analysis property.

I K Pathan et al. have proposed an off-line approach for handwritten isolated Urdu characters in their work mentioned in [10]. Authors have used moment invariants (MI) feature to recognize the characters. MI features are well known to be invariant under rotation, translation, scaling and reflection. These features are measure of the pixel distribution around the center of gravity of character and it captures the global character shape information. V Karthikeyan [11] proposed a system for recognizing Tamil characters. In his paper, the

character image skeletonised using Hilditch's algorithm and features are extracted based on the concept of image moment which is the weighted average of entire pixel intensities. Here four features are extracted from each of the character, the equation of which is derived from Hu's moment invariants [12].

ii) Statistical Representation

Statistical methods are based on the probability theory and hypothesis. Statistical distribution of pixels of an image takes care of variations in writing styles. In this approach, a character image is represented using a set of n features which can be considered as a point in n-dimensional feature space. The main goal of feature selection is to construct linear or non-linear decision boundaries in feature space that correctly separate the character images of different classes. The major statistical features used for character representation are zoning, projection profiles and Crossings and distances.

In zoning, the character is divided into several overlapping or non overlapping zones of predefined sizes. Then features such as average pixel density, histogram and sum squared distance are extracted from each of the zones based on the percentage of black pixels present. Gradient features based method is discussed in [13] by Ashutosh et al. where gradient vector is calculated at each pixel by means of sobel operator and then image is divided into different zones. Then strength of gradient is accumulated in eight standard directions in each zone.

iii) Geometrical and Topological Representation

Characters can be represented by structural features with high tolerance to distortions and style variations. Structural features are based on topological and geometrical properties of the character such as chain code, aspect ratio, cross points, loops, branch points, strokes and their directions, inflection between two points, horizontal curves at top or bottom, etc.

Scale Invariant Feature Transform (SIFT) is a structural descriptor which considers the local features of an image. The speciality of the features derived as a result of implementing this algorithm is that they are invariant to image translation, scaling and rotation. SIFT consists of four steps namely Scale space extrema detection, Key point localization, Orientation assignment and Key point descriptor. The output of the fourth step will be highly distinctive that are suitable for the recognition purpose.

Zahedia et al used SIFT algorithm in his paper [14] for recognizing the Arabic characters. Here the preprocessed image is passed through SIFT algorithm in order to extract the features. As the first step of this algorithm, the candidate key points are find out. In the next step, the key points that have low contrast and having poor edge localization are eliminated. Then orientation is assigned to each of the localized key points for achieving rotation invariance. In the final step, key point descriptor is created using a set of 16 histograms, aligned in 4x4 grids, each with 8 orientation bins. As a result 128 element feature vector is obtained.

Sreeraj M et al [15] presented an approach for on-line grantha character recognition. Here features such as time domain, writing direction and curvature are extracted. In [1] B V Dhandra used the concept of chain code for handwritten Kannada vowel recognition. Chain codes are used to represent the boundary based on 4-connectivity or 8-connectivity of its segments. Then the direction of each segment is coded using a numbering scheme.

C. Classification

Classification is the process of assigning the data to their corresponding class with respect to similar groups with the aim of discriminating multiple objects from each other within the image. Its goal is to predict the categories of input image using its features. It is carried out on the basis of stored features in the feature space such as structural features, global features etc. Some classification techniques used in character recognition systems are Template Matching, Statistical Techniques, Structural Techniques, Neural Network, and Support Vector Machine.

i) Template Matching

It is a method for finding areas of an image that match to a template image, the image patch to be compared with the input image. According to Oivind Due Trier et al [16], this method is not well suited for character skeleton because of the lesser chances of input image pixels to coincide with pixels of template skeleton.

ii) Neural Network (NN)

Neural network develop its information categorization capabilities through learning process from examples known as training samples. After getting feature space from the binary character image, an efficient classifier is used to classify the class of a character. It is one of the commonly used classifier in handwritten character recognition system because of their humanoid qualities such as adapting the changes and learning

from prior experience. Handwritten character recognition can be implemented by using a back propagation neural network that has been trained according to train dataset. That is, neural network recognizers learn from an initial image training set. The trained network then makes the character identifications. One of the most common learning methods used in this training process is called back-propagation (BP). When network is presented with a set of training data the BP algorithm compute the difference between the actual output and desired output and feeding back the error exist in the output and correct the weights and biases that are responsible for the error.

Jasbir Singh et al. [17] have used Artificial Neural Network as classifier in his work for Devanagari character recognition. ANN consist of number of processing units called neurons distributed in three layers namely input, hidden and output that communicate with one another over a large number of weighted connections. Such a network can be trained using sample training data and then the trained network is used to predict the class of unknown test sample. Each output layer neurons corresponds to each class.

Seong- Whan Lee et al [9] have used Multilayer cluster neural network (MCNN) as classifier for recognizing handwritten numerals. In MCNN the units in each layer are clustered and each cluster is fully connected to a corresponding cluster in following layer independently. The advantage of MCNN is that it converges in fewer iteration as compared to fully connected multilayer neural network because each sub network of MCNN start from different initial state and learn with different multiresolution feature. Based on the concept of MCNN, Suzete E. N. Correia et al. [3] used three layer cluster neural network for training and classification.

In [18] D K Patel used Euclidean Distance Metric in combination with artificial neural network for classification. For each unknown input pattern vector, distances to the mean vectors which characterize each pattern class are computed by EDM. Minimum distance determines the class membership of input pattern vector. In case of misclassification, the learning rule through ANN improves the recognition accuracy. G Raju et al, used feed forward neural network for classification in his work mentioned in [19]. Based on the survey conducted by Oivind Due Trier et al [16] Multilayer feed forward neural network have been used extensively in optical character recognition.

Probabilistic Neural Network (PNN) is a form of radial basis function network that can be used as a solution of pattern classification problem. To prepare a PNN classifier for pattern classification, some training is required for the estimation of probability density function associated with classes. For PNN, training process is faster than other neural network model such as back propagation and it is also guaranteed to converge to an optimal direction as the size of the representative training set increases. In [1] B V Dhandra et al. have adopted PNN as a classifier in his work for recognizing Kannada, Telugu, and Devanagari numerals.

ii) K- Nearest Neighbor Classifier (KNN)

KNN is an instance based classification algorithm where the objects are classified on the basis of closest training examples in the feature space. Here, a test sample is assigned a same class label as that of the majority of its K- nearest neighbors. The performance of KNN classifier depends on the proper choice of K and the distance metric used to measure the neighbors distances.

For Kannada character recognition B V Dhandra et al[1] have used KNN as classifier. In [15] Sreeraj M et al. have used KNN classifier where DTW (Dynamic Time Warping) is used as a distance metric in order to enhance recognition rate. As per Jasbir Singh et al [17] KNN is simplest of all classifier for predicting the class of the test sample.

iii) Support Vector Machine (SVM)

SVMs are a group of supervised learning methods, the goal of which is to produce a model that predicts the target value of the test data given only the test data attributes. The standard SVM classifier takes the set of input data and predicts to classify them in one of the only two distinct classes. SVM classifier is trained by a given set of training data and a model is prepared to classify test data based on the trained data. In SVM, training and classification are performed using kernel function. An SVM is a binary classifier with discriminant function being the weighted combination of kernel functions over all training samples. The samples of non-zero weights after learning are called support vectors which are stored and used in classification.

For recognizing Devanagari characters Rajneesh Rani et al [13] have used SVM classifier by taking gradient based feature as its input. In [10] I K Pathan have also used SVM for training purpose based on moment invariant features of Urdu characters. As per the comparative analysis by Jasbir Singh et al [17] on Devanagari characters, SVM is a very useful technique for data classification as compared to ANN and KNN.

Comparison between the various literatures that is mentioned in this section is summarized in the following table1.

Table 1: Comparison of Various Techniques in HCR

Paper	*Character Image*	*Phases Of Character Recognition*			*Accuracy Claimed*
		Pre-processing	*Feature Extraction*	*Classification*	
[1]	Kannada Vowels	Otsu's thresholding, Median Filter, Morphological operation	Normalized Chain code, Zero Crossing of wavelet	KNN	95.07
[3]	Handwritten Numerals		Biorthogonal Spline wavelet	Multilayer Cluster Neural Network	94.70
[5]	Characters in map	Median Filter, Binarization	Zero Crossing of Wavelet	DTW	
[6]	Handwritten Numerals		Wavelet Transform	NN	98.22
[7]	Optical Character		Biorthogonal Discrete Wavelet transform	Learning Vector Quantization (LVQ)	93.56
[9]	Handwritten Numerals		Wavelet Transform	Multilayer Cluster Neural Network	99.17
[10]	Urdu character		Moment Invariant Feature	SVM	93.59
[11]	Tamil Character	Binarization, Normalization, skeletonization	Image moment	SVM	
[13]	Devanagari Character	Median Filter, Binarization	Gradient	SVM	
[14]	Arabic	Noise Removal	SIFT		88
[15]	Grantha		Time domain feature	DTW	92.11
[18]	Handwritten Character	Binarization, Thinning	Wavelet	NN with Euclidean distance metric	98.46
[19]	Handwritten Character	Thinning, binarization, Normalization	Zero Crossing of Wavelet	NN	95

III. Conclusion

In this paper comparative study of various phases in character recognition has been carried out. From this literature review, Wavelet transform based features provides maximum classification accuracy compared to other methods. It can be concluded that selection of relevant feature extraction and classification techniques plays an important role in performance of CR system. The accurate recognition directly depends on the nature of the material to be read and its quality. A lot can be improved in each of the phases of character recognition system because each step contributes directly to accuracy of system.

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