New Advancements for Off-Line Handwritten Character Recognition

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Abstract - In handwritten character recognition one of the most effective approaches for features extraction. When a zoning method is considered, the pattern image is subdivided into zones each one providing regional information related to a specific part of the pattern. Handwritten character recognition is always a frontier area of research in the field of pattern recognition and image processing and there is a large demand for Optical Character Recognition on handwritten documents. This paper provides a comprehensive review of existing works in handwritten character recognition based on soft computing technique during the past decade.

I. Introduction

It has been found that region-based feature extraction is able to absorb variability of handwritten patterns. The advancement of digital computer, machine simulation of human function has been a very challenging and fascinating research area in the field of image processing and pattern recognition [1],[2]. In this paper, all types of machine recognition of character in various application domain has been covered by character recognition (CR). The intensive research in the field of CR is not only because it helps in postal address, bank check amount reading but also because it automates processing of bulk amount of papers, transfers data into machines and web interface to paper document. CR has been classified based upon the two important aspects:

- According to the manner in which data has been acquired (On-line and Off-line).
- According to the text type (machine printed and handwritten).

This paper focuses only on the offline handwritten recognition systems developed in the past few years. Generally there are six major steps in the character recognition system which has been shown

- Data acquisition
- Pre-processing
- Segmentation
- Feature extraction
- Classification
- Post-processing

This paper is arranged as follows: In Section II, history of evolution of CR system is given, CR methodologies have been discussed in Section III, techniques used for off-line handwritten character recognition based on soft computing is given. Systems for recognizing machine printed text originated in the late 1950s and have been in widespread use on desktop computers since the early 1990s. In [3], historical review of off-line character recognition research and development is mentioned. In the early 1990s, image processing and pattern recognition are efficiently and effectively combined with artificial intelligence and statistical technique (HMM). Now a day’s Evolutionary Algorithm (EA) have been successfully applied to find the solution of numerous problems from pattern recognition domain. It uses biological evolution viz. reproduction, mutation, recombination and selection.

II. Related Work

Other global membership functions use fuzzy values that can be defined according to border-based and ranked-based criteria.
Cao et al. [29] observe that when the contour curve is close to zone borders, small variations in the contour curve can lead to large variations in the extracted features. Therefore, they try to compensate for this by using a fuzzy border. Features detected near the zone borders are given fuzzy membership values to two or four zones. Pirlo et al. use ranked-based fuzzy membership. In this case the fuzzy membership function is any weighting function defined according to the positivity, monotonicity and standard energy criteria. The selection of the best suited fuzzy membership function for a given zoning-based classification problem most certainly involves detecting optimal function weights which maximize the classification performance. For this purpose, a real-coded genetic algorithm has been proposed to find, in a single optimization procedure, the optimal fuzzy membership function together with the optimal zoning topology described by Voronoi Tessellation. Local membership functions derives from the consideration that different parts of the character can exhibit features with diverse statistical distributions. Impedovo et al. [30] present a new class of parameter-based membership functions and select the most profitable set of parameters for each zone of the zoning method. Therefore, when parameter-based membership functions are used, a set of specialized functions is considered, one for each zone of the method.

Data acquisition:
The progress in automatic character recognition systems is evolved in two categories according to the mode of data acquisition:

- **On-line** character recognition systems
- **Off-line** character recognition systems

Off-line character recognition captures the data from paper through optical scanners or cameras whereas the on-line recognition systems utilize the digitizers which directly captures writing with the order of the strokes, speed, pen-up and pen-down information.

Pre-processing:
A series of operations have to be performed during the pre-processing stages. The main objective of the pre-processing is to organise the information so that the subsequent CR task become simpler. It essentially enhances the image rendering it suitable for segmentation.

Normalisation: The main component of the pre-processing stage is normalization, which attempts to remove some of the variations in the images, which do not affect the identity of the word. Handwritten image normalization from a scanned image includes several steps, which usually begin with image cleaning, skew correction, line detection, slant and slope removal and character size normalization [8].

Compression: Space domain techniques are required for compression. Two important techniques are thresholding and thinning [9, 10]. Thresholding reduces the storage requirements and increases the speed of processing by converting the gray-scale or colour images to binary image by taking a threshold value. Thinning extracts the shape information of the characters.

Segmentation:
Segmentation is an important stage in CR system because it affects the rate of recognition. Segmentation can be external and internal. External segmentation is the isolation of various writing units, such as paragraphs, sentences or words. In internal segmentation an image of sequence of characters is decomposed into sub-images of individual character [11], [12].

Representation or Feature extraction:
The feature extraction step selects and prepares data which is used by a classifier to achieve the recognition task. Feature extraction involves representing a handwriting text by a set of discriminative features. The feature representation is based on extraction of certain types of information from the image. A survey on feature extraction methods can be found in [13, 14].

Classification:
The classification stage is the decision making part of the recognition system. The performance of a classifier relies on the
quality of the features. There are many existing Classical [15] and soft computing techniques for handwriting identification.

III. CLASSIFICATION TECHNIQUES
In this section the handwritten character recognition based on soft computing approach is presented. The discussion is based on the research methodology used during the last decade.

Technique based on Neural Network and Fuzzy Logic
A neural-network-based user adaptive handwriting recognition system has been proposed by Hsin-Chia Fu at al. [17]. This recognition system performs pre-classification, character recognition, and personal adaptation. The self-growing probabilistic decision based neural networks (SPDNNs) has been applied to implement the major recognition modules of this system. This modular neural network deploys one subnet for one object (character); therefore, it is able to approximate the decision region of each class locally and precisely. This locality property is attractive, especially for personal handwriting recognition or signature identification. Moreover, because its discrimination function obeys a probability constraint, SPDNNs has some properties, such as low false acceptance/false rejection rates. An incremental EM algorithm-based adaptation module has been proposed and implemented to further improve the recognition performance for personal handwriting. The recognition accuracy was reported 90.2% in ten adaptive cycles. A novel application of multidimensional Clifford analysis has been proposed in [18]. It has been demonstrated that employment of neural networks capable of processing Clifford numbers is very useful in modelling written characters and can help build a successful OCR system, especially in the context of a multiple expert decision combination framework. The proposed multiple expert framework incorporating multiple Clifford networks has demonstrated real potential for future applications. Nafiz Arica at al. [19] proposed a method which avoids most of the pre-processing operations, which causes loss of important information. One of the major contributions of the method is to development of a powerful segmentation algorithm. Utilization of the character boundaries, local maxima and minima, slant angle, upper and lower baselines, stroke height and width, and ascenders and descenders improve the search algorithm of the optimal segmentation path, applied on a gray-scale image. This approach decreases the over-segmentation. Another contribution is the use of Hidden Markov Models(HMM) training, not only for the estimation of model parameters, but also for the estimation of some global and feature space parameters. Also, HMM probabilities are used to measure the shape information and rank the candidate character. One-dimensional representation of a two-dimensional character image increases the power of the HMM shape recognizer. M. Hanmandlu at al. [20] presented an innovative approach called box method for feature extraction for the recognition of handwritten characters. In this method, the binary image of the character is partitioned into a fixed number of sub images, called boxes. The features consist of vector distance (ή) from each box to a fixed point. To find (ή) the vector distances of all the pixels, lying in a particular box, from the fixed point are calculated and added up and normalized by the number of pixels within that box. Artificial neural networks and fuzzy logic techniques are used for recognition and recognition rates are found to be around 97 per cent using neural networks and 98 per cent using fuzzy logic. The methods are independent of font, size and with minor changes in pre-processing; it can be adopted for any language. M. Hanmandlu, O.V. Ramana Murthy[21] have presented in their study the recognition of handwritten Hindi and English numerals by representing them in the form of exponential membership functions which serve as a fuzzy model. The recognition is carried out by modifying the exponential membership functions fitted to the fuzzy sets. These fuzzy sets are derived from features consisting of normalized distances obtained using the Box approach. The
membership function is modified by two structural parameters that are estimated by optimizing the entropy subject to the attainment of membership function to unity. The overall recognition rate is found to be 95% for Hindi numerals and 98.4% for English numerals. Velappa Ganapathy, and Kok Leong Liew [22], they proposed a method in which first multi-scale neural training with modifications in the input training vectors is adopted to acquire its advantage in training higher resolution character images and then selective thresholding using minimum distance technique is proposed to increase the level of accuracy of character recognition. A simulator program (a GUI) is designed in such a way that the characters can be located on any spot on the blank paper in which the characters are written. The results show that such methods with moderate level of training epochs can produce accuracies of at least 85% and more for handwritten upper case English characters and numerals. Chichang Jou and Hung-Chang Lee[23] have designed and implemented a tree-like classifier for handwritten numeral recognition based on simplified structural classification and fuzzy membership. They integrated a smoothing algorithm and a thinning algorithm to obtain a skeleton for each image. Hu and Yan’s algorithm (1996) was then simplified, through ignoring the bending points, to catch feature points of each skeleton and to decompose it into several paths. Simplified Nishida and Mori’s right-hand rule (1992), through ignoring the differentiation of the convex of the curve, is then applied to merge these paths. They classified the resulting paths into a set of five fundamental primitive types. The number of feature primitives is the smallest up to now. A fuzzy S-function was then applied to these primitives to estimate the likelihood of a point or primitive being close to the top of the image. Finally, a tree-like classifier is utilized to classify these numerals based on the feature points, primitives, and memberships. Mathias M.Adankon, Mohamed Cheriet [24], The LS-SVM classifier, like other kernel machines, gives a poor generalization when the hyper parameters are not tuned efficiently. The authors proposed a model selection strategy for the LS-SVM which is a variant of the popular SVM classifier. They formed model selection using the empirical error criterion through the LOO procedure. They applied an algorithm on a handwriting recognition problem, which gave promising results. Compared with the SVM, the sparse LS-SVM classifier, empowered by model selection based on the empirical error criterion and the LOO procedure, achieved higher performance. They conclude from this that the sparse LS-SVM with model selection would be an interesting alternative classifier for the SVM in pattern recognition systems. Alex Graves at al. [25] proposed an alternative approach based on a novel type of recurrent neural network, specifically designed for sequence labelling tasks where the data is hard to segment and contains long-range bidirectional interdependencies. This approach achieves word recognition accuracies of 79.7 per cent on online data and 74.1 per cent on offline data, significantly outperforming a state-of-the-art HMM-based system. In addition, the work demonstrates the network’s robustness to lexicon size, measure the individual influence of its hidden layers, and analyse its use of context. The paper provides an in-depth discussion of the differences between the network and HMMs, suggesting reasons for the network’s superior performance. Ujjwal Bhattacharya and B.B. Chaudhuri [26], have presented a pioneering effort for the development of handwritten numeral database of Indian scripts. A multistage method for high accuracy recognition of these handwritten numerals has been described. The proposed method has been implemented for recognition of handwritten numerals in mixed script situations. In the proposed scheme, a numeral is subjected to three MLP classifiers corresponding to three coarse-to-fine resolution levels in a cascaded manner. If rejection occurs even at the highest resolution, another MLP is used as the final attempt to recognize the input numeral by combining the outputs of three classifiers of the previous stages. This scheme has been extended to the situation when the script of a document is not known a priori or the numerals written on a document belong to different scripts. Handwritten numerals in mixed scripts are
frequently found in Indian postal mail and tabular form documents. Salvador Espan˜a-Boquera at al. [27] used hybridization of Hidden Markov Model (HMM) and Artificial Neural Network (ANN) models for recognizing unconstrained offline handwritten texts. The structural part of the optical models has been modelled with Markov chains, and a Multilayer Perceptron is used to estimate the emission probabilities. This paper also presents new techniques to remove slope and slant from handwritten text and to normalize the size of text images with supervised learning methods. Slope correction and size normalization are achieved by classifying local extrema of text contours with Multilayer Perceptrons. Slant is also removed in a nonuniform way by using Artificial Neural Networks. The recognition is based on hybrid optical HMM/ANN models, where a multi-layer perceptron is used to estimate the emission probabilities.

IV. Evolutionary computing techniques

Bio-inspired evolutionary algorithms are probabilistic search methods that simulate the natural biological evolution or the behaviour of biological entities. All Evolutionary computing techniques can be implemented independently or hybridization of these techniques is also possible [20, 27,39]. C. De Stefano, A. Della Cioppa and A. Marcelli [28] presented a learning system that uses genetic programming as a tool for automatically inferring the set of classification rules to be used during a pre-classification stage by a hierarchical handwritten character recognition system. Starting from a structural description of the character shape, the aim of the learning system is that of producing a set of classification rules able to capture the similarities among those shapes, independently of whether they represent characters belonging to the same class or to different ones. In particular, the paper illustrates the structure of the classification rules, the grammar used to generate them and the genetic operators devised to manipulate the set of rules, as well as the fitness function used to drive the inference process.

Handwritten English character recognition strategy using artificial immune system and wavelet packet transform was proposed by Yu Yang [38]. The preliminary experiment has been done on the consonant character using artificial immune system. With 116 feature coefficients extracted from 32*32 Nepali character images as its feature vector, which 84 were from wavelet packet transform and 32 achieved by horizontal and vertical histogram, consonant antibody libraries for its character categories were trained and built to recognize handwritten Nepali consonant characters with artificial immune algorithm. The contrast experiment was done using three-tiered feed-forward, back-propagation neural network model with 116 feature coefficients as input, 36 hidden nodes and 31 output nodes for consonant category, sigmoid transfer function. The experimental results indicated that the artificial immune system model has more advantages than Back Propogation neural network in character recognition. Saurabh Shrivastava and Manu Pratap Singh [39] describe the performance evaluation for the feed forward neural network with three different soft computing techniques to recognition of hand written English alphabets. Evolutionary algorithms for the hybrid neural network are showing the numerous potential in the field of pattern recognition. The authors have taken five trials and two networks of each of the algorithm: back propagation, Evolutionary algorithm, and Hybrid Evolutionary algorithm respectively. They analysed that the feed forward neural network by two Evolutionary algorithms makes better generalization accuracy in character recognition problems. The problem of not convergence the weight in conventional back propagation has also eliminated by using the soft computing techniques. It has been observed that, there are more than one converge weight matrix in character recognition for every training set. The results of the experiments show that the hybrid evolutionary algorithm can solve challenging problem most reliably and efficiently.

G. Pirlo and D. Impedovo [40] presented a new class of membership functions, which are called Fuzzy-membership functions (FMFs), for zoning-based classification.
These FMFs can be easily adapted to the specific characteristics of a classification problem in order to maximize classification performance.

V. Conclusion

In this paper, the main approaches used in the field of handwritten character recognition during the last decade have been surveyed. Different preprocessing, segmentation techniques and various classifiers with different features are also discussed. We described many methods, some of which are somewhat related to each other and some of which are more or less independent. The important point is that we should make these methods more precise in the sense of an exact science, not a mere accumulation of empirical knowledge. Neural Network and Fuzzy Logic methods of optimization are not robust to the dynamic changes in the problem of the environment and often require a complete restart in order to provide a solution (e.g., dynamic programming). To overcome these problems, researchers have proposed evolutionary computation for searching near optimum solutions to problems. We are intending to develop new techniques with the help of literature review. We believe that our survey will be helpful to the researcher in this field.

References

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