State of The Art in Handwritten Digit Recognition
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Abstract: In this paper, we present an overview of existing handwritten character recognition techniques, specially handwritten digit recognition. All these algorithms are described more or less on their own. Handwritten character recognition is a very popular and computationally expensive task. We also explain the fundamentals of handwritten character recognition. We describe modern and popular approaches for handwritten character recognition. Their strengths and weaknesses are also analyzed. We have concluded with the common problems existing in these methods.

I. Introduction

Character recognition is an art of detecting and identifying characters from image. More precisely Character recognition is process of detecting and recognizing characters from input image and converts it into ASCII or other equivalent machine editable form [1,2,3]. HDR has major contribution to the advancement of automation process and improving the interface between man and machine in many applications [4]. Character recognition is one of the most interesting and fascinating areas of pattern recognition and artificial intelligence [5], [6]. Character recognition is getting more and more attention since last decade due to its wide range of application. Recognition of handwritten characters is important for making several important documents related to our history. It will help in recognition of historical documents such as manuscripts into machine editable form so that it can be easily accessed and pres independent work is going on in Optical Character Recognition that is processing of printed/computer generated document and handwritten and manually created document processing i.e. handwritten character recognition, which includes handwritten digit recognition. In offline character recognition system, the handwritten document is first generated, digitalized, and stored in computer and then it is processed. While in case of online character recognition system the character is processed while it was under creation. Image processing and pattern recognition also plays significant role in handwritten character recognition.

II. Literature Survey

In [10], Rajbala et al have discussed various types of classification of feature extraction methods like statistical feature based methods and structural feature based methods etc. All the statistical methods are based on planning of how data are selected. They use the information of statistical distribution of pixels in image. It can be mainly classified in three categories namely: Partitioning in regions, Profile generation and projections. Distances and crossing. Structural features are extracted from structure and geometry of character like number of horizontal and vertical lines, number of cross points, aspect ratio, number of branch points, number of loops, number of curves, number of strokes, etc. Global transformation features are calculated by converting image in frequency domain like Discrete Fourier Transformation (DFT), Discrete Cosine Transformation (DCT), Discrete Wavelet Transformation (DWT), Gabor filtering, Walsh-Hadamard transformation etc.

Feature extracted can be either low level or high level. Low level features include width, aspect ratio, height, curliness, etc. These features alone are not sufficient to distinguish one character from another in the character set of the language [11]. So there are a number of other high level features which include number and position of loops, curves, lines, headlines etc.

Tirthraj Dash et al have discussed HCR using associative memory net (AMN) in their paper [12]. They have directly worked at pixel level, in which the dataset was designed in MS Paint 6.1 with normal Arial font of size 28. The characters are extracted first and then their binary pixel values are directly used to train AMN.

I.K. Pathan et al have proposed offline approach for handwritten isolated Urdu characters in their work mentioned in [13]. Urdu character may contain any number of segments. In which one segment is known as primary and rest of all are known as secondary components. Authors have used moment invariants (MI) feature to recognize the characters. MI features are well known to be invariant under rotation, reflection, scaling & translation. These features are measure of the pixel distribution around the center of gravity of character and it captures the global character shape information. If character image is single component than it is normalized in 60 X 60 pixels and horizontally divided in equal 3 parts. 7 MI are extracted from each zone and 7 MI are calculated from overall
image, so total of twenty eight features are used to train SVM. And if image is having multi component than 28 MI are extracted from primary component (60 X 60) and 21 MI are extracted from secondary component (22 X 22). Separate SVM are trained for both and decision is taken based on rules satisfying some criteria. In [4], Pradeep et al have proposed neural network based classification of handwritten character recognition system. Every character is resized to 30 X 20 pixels for processing. Proposed method is using binary features to train neural network. Although such features are not robust. In post processing stage, recognized characters are converted to ASCII format. In this method, the input layer has 600 neurons equal to number of pixels. Output layer has 26 neurons as English has 26 alphabets. It also uses back propagation algorithm with momentum and adaptive learning rate.

Rajib et al have proposed Hidden Markov Model based system for English HCR in their literature [8]. They have employed global as well as local feature extraction methods. Global feature involves four gradient features, six projection features and four curvature features. And to extract local features, image is divided in to nine equal blocks and 4 gradient features are calculated from each block, so total of 36 features are extracted. So overall feature vector contains 50 features per character. O = [G(4) P(6) C(4) L(36)], where G, P, C and L represents global gradient, projection, curvature and local gradient features respectively. Number in parenthesis represents number of respective features. HMM is trained using these feature and experiment is carried out. Post processing is also applied after recognition phase of HMM to highly confused group of characters like N and M, O and Q, C and O etc. For each group new feature is calculated to discriminate characters within the group.

Gradient features based method is discussed in [14] by Ashutosh et al. Experiment is carried out on Hindi, third most popular language in the world. The first research work on handwritten Devnagari characters was published in 1977. 300 Million People use the Devnagari script for documentation in central and north region of India [8]. In proposed method, Gradient Vector is calculated at each pixel and image is divided in 9 X 9 blocks. Then strength of gradient is accumulated in eight standard directions in each sub block. 9 X 9 blocks is further down sampled to 5 X 5 block using Guassian filter. Preprocessing steps for proposed methods are as follows: Intensity values of image are adjusted and then images were converted to binary with threshold value 0.8. Connected component with pixel density less than 30 were removed from further processing. Median filter was applied to remove pepper and salt noise present in binary images. And finally, individual characters were extracted by row and column histogram processing and normalized to 90 X 90 pixel block. Gradient feature were extracted using sobel operator.

Velappa et al have proposed multiscale neural network based approach in [15]. Neural networks like Feed forward back propagation neural network requires long training time to memorize and generalize all input feature vectors [10]. And still there are good chances of misclassification. Generalization problem can be overcome by using multi scale neural network [11].Proposed system first convert camera captured RGB image to binary image. Width to Height Ratio (WH), Relative Height (RH) ratio, Relative Width ratio (RW) is calculated to remove unnecessary connected components from image. For multi scale neural network, detected character is resized to 20 X 28 pixels, 10 X 14 pixels and 5 X 7 pixels. Binary features of these different resolution images are given to three layer feed forward back propagation algorithm.

In literature [16], T.Som et al have discussed fuzzy membership function based approach for HCR. Character images are normalized to 20 X 20 pixels. Average image (fused image) is formed from 10 images of each character. Bonding box around character is determined by using vertical and horizontal projection of character. After cropping image to bounding box, it is resized to 10 X 10 pixels size. After that, thing is performed and thinned image is placed in one by one row of 100 X 100 canvas. Similarity score of test image is matched with fusion image and characters are classified.

In literature [17], Rakesh Kumar et al has proposed single layer neural network based approach for HCR to reduce training time. Characters are written on A4 size paper in uniform box. Segmented characters are scaled to 80 X 80 pixels. Each 0 is replaced by -1 for better training. Diagonal based feature extraction work is mentioned in [19], which is improved by Sharma et al, discussed in [20]. They have proposed zone based hybrid feature extraction method. Euler number concept is used to improve speed and accuracy. Thresholding, filtering and thinning operations are performed as a part of preprocessing. Segmentation can be classified into three broad categories: Top down, Bottom up and Hybrid techniques. In proposed method segmented character is resized to 90 X 60. After calculating Euler number from this image, character is divided in to 10 X 10 pixel 54 zones. Each zone value is replaced by average intensity value and is used as feature value. 9 and 6 features are extracted by averaging values row wise and column wise, so it forms total 69 features. A FFBPNN with configuration 69-100-100-26 is used for classification.

### III Conclusion

In this paper, we elaborated the basic concept of handwritten digit recognition. We analyzed some popular and modern methods for handwritten character recognition. Accuracy of HCR is still limited to 90 percent due to presence of large variation in shape, scale, style, orientation etc. Lots of work has been done on handwritten digit recognition. But still it is a heart favourite research topic. Because the accuracy is needed to be improved.
IV References


