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Review paper

Bengali Handwritten character recognition modeling: A comprehensive survey

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Abstract

Handwritten character recognition from a document image is no-doubt a challenging task and active research filed of interest because of its several application domain. It becomes more challenging in pattern recognition domain because of variability of human writing style, skew and orientation. Noises, smears and faded ink makes it more complicated. Digitization of Bengali scripts, handwritten official documents and forms demands a Bengali Optical Character Recognition (OCR) system. OCR research success has limited to very few scripts like Roman, English and Chinese. Among Indian script, In general existing Bengali handwritten character recognition system accuracy is around 90%. Bengali Handwritten Script identification is still an open and active research area. In this paper basic steps and popular approaches are discussed to indentify the handwritten Bengali character recognition process and it finds the research gap in existing systems. It also points out major issues to be considered while designing a framework for Bengali handwritten character recognition system.

Keywords: Handwritten Character, Bengali Font, Features Extraction, Classification.

Introduction

Handwritten character recognition is required to covert historical documents, letters, diaries and many others manuscript in digital form. Any character recognition process involves in extracting classification features and application of a classifier. Proper selection of features and classifiers are also important task for recognition process. Some of the research works have demanded developing Bengali optical character recognition system with very good success rate. Here some of these approaches are listed and tried to find out the problems associated with developing OCR system mainly for handwritten Bengali fonts. This paper is organized as follows: Section II gives brief description and application of Bengali Script. Section III covers various existing approaches towards HWR process. Section IV shows existing work and section V points out research gaps of the approaches discussed in section IV followed by the conclusion of this survey.

Overview of Bengali Script

Bengali script is derived from ancient Brahmin script which consists of 11 vowels and 39 consonant. 10 Vowels when attached with consonant sometime get special shape called modifiers and more than one consonant combined together makes compound characters. There are more than 250 compound characters[1]. It is normally written from left to write mostly following a header line called matra which is normal used to for segmentation of words. There are various application domains where handwritten character recognition has major role. Some of these areas are postal address interpretation to identification of city, pin code and other information from postal address, Bank cheque processing, signature authentication, author identification; identify authors from the handwritten manuscript and medical transcription[2].

Character Recognition Approach

Character recognition process was started in early 1900 but real progress stated around 1990 because of availability of powerful computers[1]. Handwritten character recognition from document image follows basic steps like image preprocessing which removes noise, correct skew etc, image segmentation that extracts lines, words and individual characters, feature extraction and classification. Feature extraction and classification is the main important parts of any character recognition system. Extracted features from font character are processed by classifier for identification of the font class. Various character recognition approaches were made. Some of them are discussed here.

Template Matching: In this approach, some group of pixels set in the form of curve, line is matched to identify a single character. To find similarity between two curves of set of points, Euclidian, Yule similarity measures are considered to classify by decision tree, k-nearest neighbor or template matching classifiers[3]. Correlation coefficient value in template matching will be 1 for perfect match[4]. One sample is shown in Figure-1.

Figure-1: Character representation using curvature distance function.

Syntactic Approach: Here structure of the character is analyzed and general rules are formed to identify individual character. Based on their syntactic structure, characters are grouped into various classes. Syntactical features can be represented by chain code or grammatical rules[5,6]. Given Figure-2 shows a simple example of grouping of characters based on horizontal line, a simple pattern primitives, present on the right most side of a character.

অ আ ঋ এ খ গ ঘ ণ থ ধ ন
প ব ম য র ল শ ষ স য় ৰ ৱ

Figure-2: Bengali characters group having horizontal line at right side.

Hidden Markov Model Approach: After getting successfully result in speech recognition system, it is now used in character recognition also. It may be for one HMM per word or for complete language domain. It uses HOG features, statistical features, local gradient features, GABOR feature[7,9]. The main advantage is that the model can be applied for many scripts. Figure-3 shows how an image converted into frames for HMM input[9].

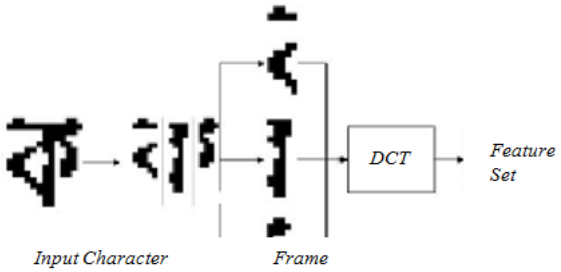

Figure-3: Feature extraction for HMM Approach.

Neural Network Based Approach: Artificial Neural network or Multi Layer Perceptron based neural network, back propagation neural network, convolution neural network are the common classifier using this approach[10-13]. Mostly used classification features are Fractural based features, topological features, water reservoir concept based features, busy – zone based features, shadow features, longest run features. The performance of this approach mainly depends on number of hidden layers, epochs and image sampling size. Now-a-days, advanced in deep learning gives more accuracy in recognition process[14]. Basic block diagram of neural network is shown in Figure-4.

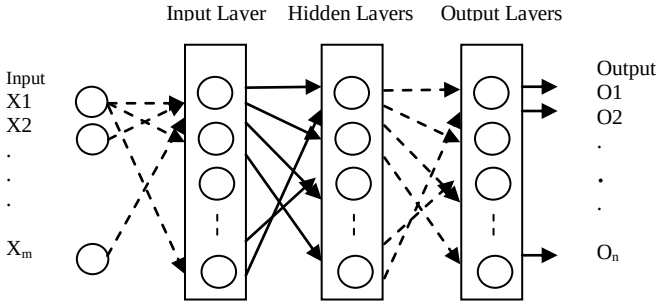

Figure-4: Block diagram of MLP Based neural network.

SVM Based Approach: In support vector machine based approach, a feature vector is prepared and then it is applied to SVM for classification. Chaudhuri and Maunder proposed a new scheme for recognition by combining 5 different SVM outputs using curvlet transform based features. In compare with MLP, Bhowmik et al. shows that SVM outperforms for handwritten character recognition[15-16].

Existing work in Bengali Handwritten Character recognition

The in-depth survey of the relevant literature on the mentioned theme has mainly focused on recognizing basic characters (namely, 11 vowels and 39 consonants) with very few attempts was made upon recognizing compound characters (like ক্ষ). Most of the character recognition models exploited the segmentation mechanism of font shapes; some tagged them as region (also called as view-based or zone-based) models while others tagged them as contour based models.

Irrespective of varied segmentation styles used to extract structural components of Bengali characters, the closely relevant literary works can be broadly categorized to have used non-deep learning (NDL) and deep learning (DL) approaches of feature extraction step. In deep learning approach, training data set directly feeded into CNN or DCNN model and the model itself extracts features and train the network. On the other hand features set are extracted from the individual images and then these features are trained for classification purpose. Some of these approaches are discussed here.

Basu et al. used non-deep learning octant concept of segmenting Bengali font shapes by extracting three sets of 24 shadow features, 16 centroid features and 36 longest run features using concept of centroid coordinate for font-segmentation. MLP based classifier is used in recognition process[17].

Barman et al. designed a non-deep learning view-based model considering top and bottom views that finds characteristic points by dividing each single character vertically into number of segments. It calculates aspect ratio of each segment by these characteristic points. Instead of using whole image only few characteristic points are considered and no need of thinning process[18].

Pal et al. implemented water reservoir techniques to identify touching components for Bengali character recognition. In this approach, seven circular rings and convex hull rings are used to divide individual character into smaller zones and finds for zone-wise local feature to improve recognition rate. The angles of pixels inside ring are grouped into 8 bins. As these features are based on angular information of the contour pixel sequence, they are rotational invariant. Finally, 8 features from each convex hull ring and circular ring and another 64 features from angular information based upon centre of minimum enclosing circle makes a total of 176 feature vector set for classification. SVM classifier is chosen as it gives better performance using this type of features[19]. Bag and Harit proposed a shape-based graph representation for character set. Features set are closed region, stroke convexity from four viewing direction and straight line strokes. Individual character image is skeletonised. Convex shape is detected from north .south, east west direction and shape based graph is formed for each convex shape. Position of the convex shape in the graph depends upon the centroid of that topographic component. Closed region and straight line are detected by 8-connected neighbor pixel relationship. This method discriminates similar type of characters efficiently[20].

Das et al defines primitive set of stroke patterns to identify constant characters in Bengali script and tries to identify their existence by defining a mathematical morphology. Patterns are represented by chain code. In this method, instead of training, multiple iterations involved, resulting faster recognition[21-22].

Singh et al divides an input image of 64×64 pixels into 16 sub images of 16x16 pixels by moving 32×32 overlapping window. From these 16 sub-images local features are extracted by non-deep learning approach and introduced quadrangular transition count that form a feature vector of 144 elements[23].

Rahman et al. proposed line base feature set and applied SVM and ANN based classifier for Bengali character recognition that achieves 84.56% and 75.6% respectively. Skeletal image is divided into zones. It uses 9 features set (vertical, diagonal horizontal lines, their normalized length and area of skeleton) for each zone segment that creates 9xN feature set feature set vector for N number of zones. Regional features like Euler number and eccentricity are regional area are also extracted for defining final feature set[24].

Rizvi et al. applied support vector machine and convolutional neural network of 18 layers for classification on hybrid feature set that achieves recognition accuracy of 87% and 98.04% respectively[25].

Chatterjee et al. applied deep learning based transfer learning to improve number of iteration required for training purpose in deep learning. It uses Resnet 50 on Bangla-Lekha isolated data set and achieved around 98.95% accuracy on 50 basic character set[26].

Roy, Akash proposed a CNN based model named AKHCRNet to recognize Bengali digits and characters and achieved 96.80%. Input images are gray scaled and resized to 32x32[14].

Das et al. has also worked on Bengali Handwritten character and designed CNN model which shows around 99.5 accuracy in numeral data whereas it achieves little bit less accuracy in vowel (93.18%) and consonant (90%) in combined around 91.59% accuracy on basic font characters set[27].

Khandokar et al. developed CNN using MATLAB and applied NIST dataset. Training dataset gradually increased to 1000 images and achieves 92.91% test accuracy[28].

Table-1: Results of existing methods of Bengali Handwritten character recognition.

References	Features and Classifiers	Results
29	View based and layer based 80 features, k-Nearest Neighbour	76.8%
21 –22	30 Pattern Primitives Stroke Features, Chain Code Classifier	Consonant – 80% Vowel-94.54% Average-87.27%
30	CNN, 20000 Dataset	85.36%
31	CNN, 166105 Dataset	89.93%
32	CNN, CMATERDb Dataset	95.01%
33	CNN, CMATERDb Dataset	95.71%
24	CNN , 20000 Dataset	85.36%
25	Zone based 26 features, SVM and ANN	87% and 98.04%
26	DCNN, Banglalekha Isolated	96.12%
14	Resnet 50, Bangla Lekha Isolated	96.80%
27	CNN, BanglaLekha	91.59%
28	CNN, NIST Dataset	92.91%

Literature reviews on Bengali handwritten character recognition is summarized in Table-1. It can be inferred from the above surveyed literature that feature extraction method itself is a complicated task and an efficient font recognition task largely depends upon the accuracy of feature set extracted before these manuscript fonts are fed to classification step. In summary, the feature set for recognizing any hand written manuscript font must be precisely minimal taking up optimal feature extraction times. It must have high tolerance to noise and varied scripting styles of similar fonts so that the recognition models become invariant to several writing distortions for a specified font.

Research Gap: The main challenging task in handwritten character recognition is to indentify proper feature set and classifiers. Some features as well as classifiers are suitable for one dataset but may have poor result in other handwritten character recognition or some other different dataset. Feature extraction methods becomes more difficult because of the quality of the document image, writing style, and stroke and broken or overlapping of characters. Image segmentation has massive impact on recognition process. Major problems that are found in Bengali handwritten character recognition is that in conventional approach, feature extraction methods are very complicated. Feature extraction needs more computation and pre-processing stage plays very important role in this context. Extracted features are then used by SVM, ANN, HMM or MLP based classifiers for font classification. In supervised approach, it requires huge data set. The supervised approach also requires more number of parameters and it takes huge time to train the network. Supervised approach using convolution neural network suffers from over fitting and under fitting problems. Under fitting problem occurs when validation accuracy is higher than training data set accuracy. Over fitting problems occurs when designed model fits too well for training dataset then it causes problems in new dataset on test data set. It results training accuracy much higher than validation or test accuracy. Dropout and polling layers have more impact on the performance of convolutional neural network based model. Adding more sample data can reduce it. It also needs an architecture that fits for general pattern.

Conclusion

Though many works have been done, everyone has taken their own dataset for testing purpose. So it is required to test these algorithms on a benchmark standard dataset to get really meaningful and acceptable results to compare their performance. New features can be explored in this domain to get more accurate result. Performance can be improved by multi level classification methods. Finer rule based classification or can be implemented in this syntactic approach domain by including position feature. Average Bengali handwritten character recognition accuracy is around 90%. So improvement is required in this domain. This will help for developing a perfect OCR system for Bengali script font. Thus we need a simplified method of feature extraction and classification process or need a supervised model that can improve recognition accuracy or optimize required time and parameters.

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