Projection-Based Features: A Superior Domain for Handwritten Bangla Basic Characters Recognition

Kazi Lutful Kabir[1], Md. Kishwar Shafin[2], Tasmiah Tamzid Anannya[3], Deepon Debnath[4], Md. Rayhan Kabir[5], Md. Aminul Islam[6], Hasan Sarwar[7]
Department of Computer Science and Engineering
[123456]Military Institute of Science and Technology
[7]United International University
Dhaka, Bangladesh
mlutful.02526@gmail.com[1], kishwar.shafin@gmail.com[2], anannya.tasmi@gmail.com[3], deepon.mist@gmail.com[4], rayhancse29@gmail.com[5], sumon2907@yahoo.com[6], mdhasan70@gmail.com[7]

***Abstract*— In spite of wide use of projection-based features in handwritten character recognition of several languages, its implementation was somewhat scanty in Bangla handwritten character recognition. This paper introduces the usage of projection profile features in recognizing handwritten Bangla basic characters. Alongside it also demonstrates a qualitative and quantitative analysis to visualize the effect of using projection based features on accuracy of recognition of Bangla handwritten characters through a number of approaches. In fact, this particular effort comprises of five different approaches where first one used longest-run, quad-tree and octant centroid features, second one adopted additional shadow features in association with the features of first approach, third one used longest run, quad-tree, shadow and chain code histogram features, next approach used longest-run, quadratic center of mass, shadow and left projection profile features and finally fifth approach with additional right projection profile features along with other features involved in the fourth approach. Throughout this analysis, neural network (trained via back-propagation algorithm) acted as classifier to observe the change in accuracy of recognition. It is seen that, with the increase in number of projection-based features, percentage of accuracy enhances at a greater rate than in case of inclusion of other features. This effective analysis can certainly assist a researcher to choose the optimal feature vector (consisting of several feature sets) for handwritten Bangla basic characters recognition.**

***Index Terms*—Accuracy, artificial neural network, back-propagation algorithm, handwritten character recognition, projection-based features.**

I. INTRODUCTION

Due to its natural complexity, recognition of handwritten characters is one of the most promising and challenging zones of research in the sector of image processing. Extraction of features being the most important step of character recognition has significant impact on the rate of recognition. Feature generation algorithms take care of individual characteristics common for a particular alphabet set. As there always remains the chance that inaccurate features may cause inefficient recognition, special attention should be given to identify the set of optimal features for a character set in order to achieve expected accuracy. Adequate studies have been performed on handwritten scripts of foreign languages such as English, Japanese, Chinese and Arabic. Mentionable amount of works have been traced on recognition of handwritten Indian scripts like Sanskrit (Devnagari), Malayalam, Tamil, Kannada and some other major Dravidian languages. Actually, Bangla is the second most popular Indian script (next to Devnagari) and fifth among the most widely spoken languages (over 200 million people use Bangla as their medium of communication) of the world. Along with the diversity in the handwriting styles of individuals, Bangla handwritten character recognition always poses some potential threats for researchers due to its wide variety of character classes and to be particular Bangla alphabet possesses 50 basic character classes, about 160 compound character classes plus some vowel and consonant modifiers. In fact, significant research on Bangla character recognition was started in early 1990s and is still ongoing. Even though, not much research work towards recognition of handwritten Bangla characters have been traced in comparison. Technology of Bangla printed OCR can't even be extended to that of handwritten due to drastic diversity in people's handwriting styles. Several potential features have been defined, derived and already adopted. However, no research work has been done yet to emphasize the implementation of projection-based features for recognizing handwritten Bangla characters.

The **objective** of this attempt is to analyze the idea that involvement of projection-based features always has a greater positive impact on recognition rate than that of inclusion of other features. And in this paper, a combination of qualitative and quantitative explanation has been presented to support that fact. The remaining of the paper has been arranged in the sequence: Related research works in Section II, Section III deals with the architecture of the recognition system, Results and Discussion are in Section IV followed by Section V with conclusion.

II. RELATED RESEARCH

Among Indian scripts, first research work on handwritten Devnagari characters was reported [1] in 1977. Replacement of the recognized characters with standard fonts through back-propagation algorithm- this technique was adopted for feature extraction by Rajput and Mishra [2] for recognition of Devnagari handwriting. Shadow features and chain code histogram features were used by Arora and Bhattacharjee [3] for recognition of handwritten non-compound Devnagari characters and later on a two stage classification approach was reported by them [4]. Profile features were used by Sigappi, Palanivel and Ramalingam [5] for retrieval of handwritten Tamil documents. A collection of structural features were taken into task by Kumar and Ravichandran [6] for recognition of handwritten Tamil characters. Variation of zonal pixel densities was considered for feature extraction by Shanthi and Duraishwamy [7] to recognize handwritten Tamil characters. Attempt of Suresh and Arumugam [8] to recognize handwritten Tamil characters was based on fuzzy approach. Technique used by Sureshkumar and Ravichandran [9] for both recognition and conversion of handwritten Tamil characters was based on spatial space detection. Bhattacharya, Ghosh and Parui [10] used K-means clustering in a two stage recognition approach for handwritten Tamil characters. Lajish [11] considered normalized vector distance features basing on fuzzy approach in recognition of handwritten Malayalam characters and state space point distribution parameters were utilized by him afterward. Implementation of Daubechie wavelet coefficients in handwritten Malayalam character recognition was reported by Raju [12]. Intensity patterns of Malayalam characters were taken into task for recognition by Rahiman [13]. A technique using chain code and image centroid for feature extraction was reported by John, Pramod and Kannan [14]. Extraction of invariant moments feature from zoned image for recognition of handwritten Kannada vowels was proposed by Sangame, Ramteke and Benne [15]. A feature extraction technique basing on zone and distance metric for the recognition of Telugu and Kannada numerals was reported by Rajashekararadhya [16]. Moments features were extracted from Gabor wavelets by Ragha and Sasikumar [17] for Kannada handwritten character recognition.

On the other hand, mentionable research works on Bangla handwritten character recognition was begun in early 1990s. A recognition scheme was proposed by Chaudhuri, Majumder and Parui [18] for Bangla handwritten numerals based on matching of character skeleton. Bhattacharya and Nigam [19] reported an analytical scheme involving stroke features, center of gravity and histogram features. Dutta and Chaudhuri [20] used curvature features for recognition of Bangla alphabets and numerals. Rahman and Fairhurst [21] proposed a multistage approach involving some major structural features for handwritten Bangla character recognition. Bhoumick, Bhattacharya and Parui [22] used stroke features to recognize handwritten Bangla characters via an MLP based scheme. Basu and Das [23] considered a feature set comprising of 76 elements (16 centroid features, 36 longest-run features and 24 shadow features) along with MLP classifier for recognition purpose. Pal, Roy and Kimura [24] used directional chain code histogram features of contour points in association with water reservoir principle to derive a lexicon driven method for recognition of unconstrained Bangla handwritten words. Bhattacharya and Gupta [25] used direction code based features for recognition. Biswas and Bhattacharya [26] adopted bilinear interpolation technique in a HMM based approach using Dirichlet distributions. Bhattacharya, Shridhar, Parui, Sen and Chaudhuri [27] contributed by reporting the generation of a database of handwritten basic characters of Bangla language and also by developing a suitable handwritten character recognition scheme for Bangla alphabets and numerals using a two stage classifier basing on rectangular grid technique.

III. RECOGNITION SYSTEM ARCHITECTURE

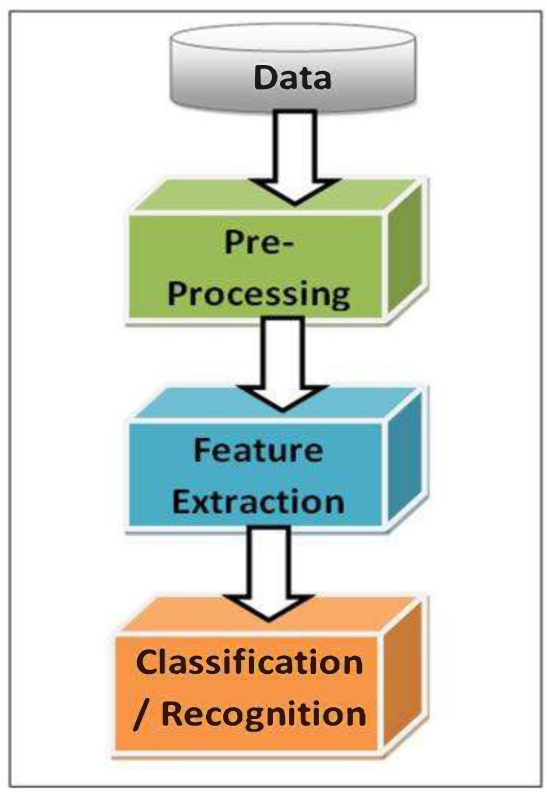

Fig. 1. Block diagram of Recognition system

The major steps involved in handwritten character recognition include pre-processing (binarization, segmentation, thinning, etc.), feature extraction and classification- each of which is a field onto itself. The schematic block diagram of Fig. 1 provides a bird's eye view of the major steps involved in the approaches that have been considered here for analysis.

Bangla basic characters from ISI handwritten character database [28] have been used after a little modification. Here, modification represents addition of samples of handwritten character images to integrate the analytical job done. About 7250 sample characters (where exactly 7200 were taken from ISI handwritten Bangla basic character database and 50 samples were added from other sources) were taken into task for training and another 2300 sample characters (taken from ISI handwritten Bangla basic character database) for testing respectively.

Fig. 2. A Small Portion of the Character Database

A. Pre-processing

In this particular step, some standard measures have been undertaken. At first, each character image is scaled to 32x32 pixels size gray scale image using bi-cubic interpolation technique. Afterward, binarization is done by applying Bernsen algorithm [29]. There are several sliding-window thresholding methods available for binarization. Bernsen's approach is applied due to its efficiency and effectiveness in cases of unequal brightness, non-uniformity of thickness, shadow conditions that actually suits the case.

B. Feature Extraction

Feature extraction is the most essential step of character recognition. Accurate and distinguishable feature plays a significant role to leverage the performance of a classifier. The complexity level of feature identification algorithm differs for alphabet sets of different languages. To recognize handwritten Bangla characters, a number of features have been considered here for analysis with projection profile features at the spotlight.

1) Left Projection Profile: Left projection profile denotes the projection from left side of the character. It is measured by counting the total number of non-black pixels until reaching the starting left side portion of the character for all rows [30].

2) Right Projection Profile: Right projection profile denotes the projection from right side of the character. It is measured by counting the total number of non-black pixels until reaching the starting right side portion of the character for all rows [30].

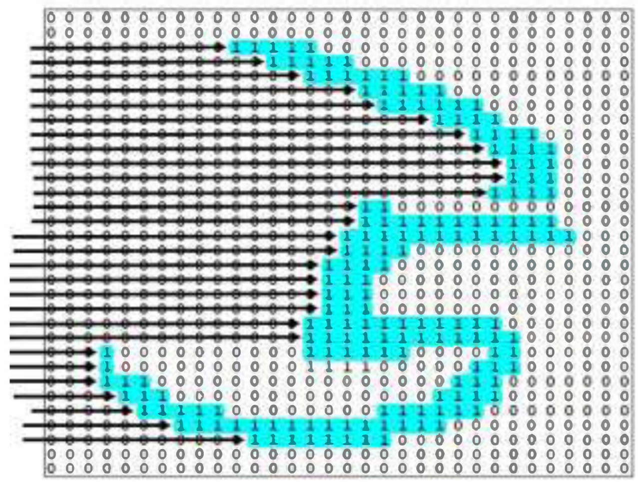

Fig. 3. An Illustration of Left Projection Profile Feature

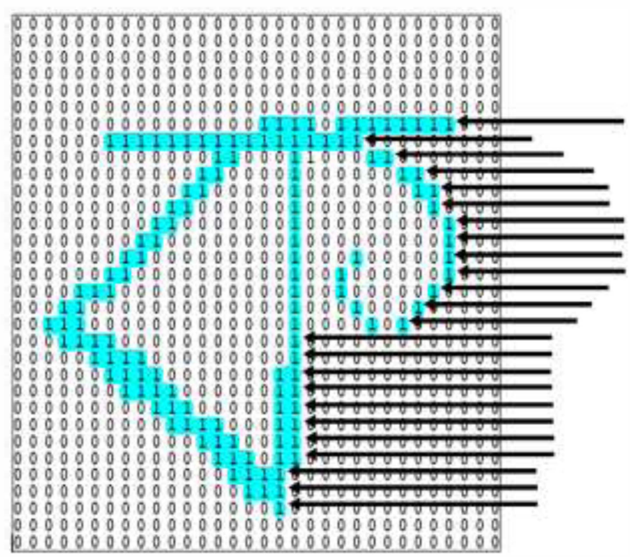

Fig. 4. An Illustration of Right Projection Profile Feature

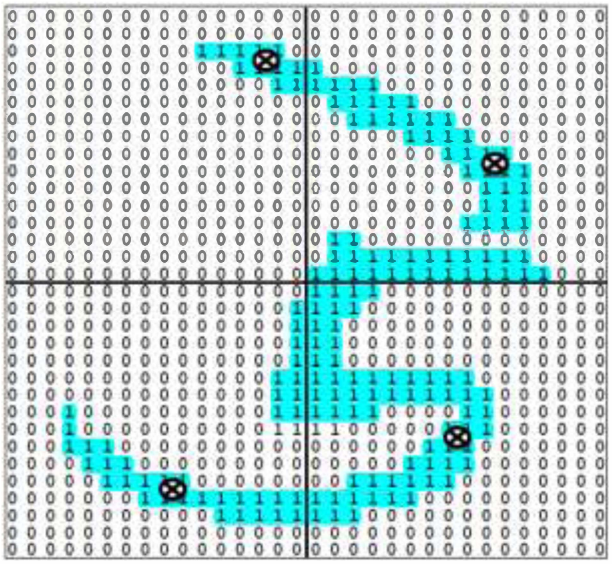

Fig. 5. An Illustration of Quadratic Center of Mass Feature

3) Quadratic Center of Mass: Center of mass for the whole character is determined and each character is divided into four equal parts to find out the center of mass for each part [30]. For any image frame, if (Mx ,My) be the coordinates of the center of mass, then

$$M_x = \frac{1}{mn}\sum x.p(x,y) \text{ and } M_y = \frac{1}{mn}\sum y.p(x,y)$$

where, p(x,y)= 1 (for black pixels) and 0 (for white pixels).

However, shadow features [31], longest-run features [31], chain code features [32] and octant centroid features [33] have also been taken under consideration to ease the analytical task. And it is to be noted that, projection profile features and quadratic center of mass features have not yet been implemented before for recognition of handwritten Bangla characters.

C. Classifier

Classifier has been designed in the spirit of back-propagation algorithm utilizing artificial neural network. Classifier justified the working principle of the back-propagation algorithm and its generalizing capability using a simple procedure [34] after accommodation of appropriate modification. Image which is to be tested is specified right at the end. Feature sets that are formed due to feature extraction are used as inputs to separate classifier tools each of which is an artificial neural network itself. Each network operates based on maximum matching approach particularly, cross-correlation between testing and training pattern. At the penultimate stage, a customized method named decider gathers and compiles the decisions obtained from all the networks to complete the recognition task by providing the final decision basing on majority.

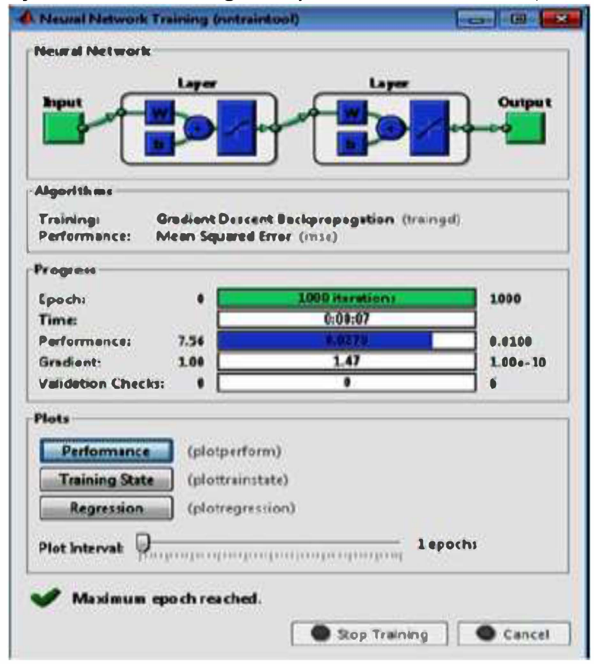

Fig. 6. Sample Neural Network Tool as Classifier Constituent

IV. RESULTS AND DISCUSSION

The entire work has been carried out in MATLAB R2008a. However, reported accuracy for the strategy proposed by N. Das, B. Das, R. Sarkar, S. Basu, M. Kundu and M. Nasipuri [31] with MLP classifier was 79.25% whereas with SVM classifier was 80.51%. This acute change in recognition rate was entirely for the type of classifier used. In fact, five approaches have been considered involving different combinations of features to observe the change in accuracy rate. The strategy put forward by first approach involving longest-run, quad-tree based and octant centroid features yielded an accuracy rate of only 76.75%. Second approach used shadow features in addition to all the features of first approach to push the recognition rate to 80.25%. Third approach adopted chain code histogram features instead of octant centroid features to enhance the performance up to 81.55%. Fourth and fifth approach accommodated two and three projection-based features respectively to attain recognition rates of 82.52% and 84.15%. Compared to first approach, second approach yielded an increase of 3.5% in recognition rate for inclusion of a projection-based feature type namely shadow features. Fourth approach adopted two types of projection-based features (shadow feature and left projection profile feature) to attain an enhancement of 2.27% in comparison to third approach. Fifth approach accommodated three types of projection-based features (shadow feature, left projection profile feature and right projection profile feature) to provide an increase of 1.63% in accuracy rate with respect to fourth approach.

Table I and Table II denote that, accuracy rate shifts sharply for inclusion of feature sets other than projection-based features. On the other hand, better increment rates of recognition have been traced for involvement of projection-based features irrespective of the classifier used. The reason behind it is that projection-based features analyze characters more thoroughly to extract identical properties of each character which leads to better recognition rate. In fact, the same classifier pattern and identical pre-processing steps have been followed for all of the five proposed approaches with only change in quality and quantity of feature sets. And it is experimentally found that, for Bangla handwritten character recognition projection-based features play a vital role to optimize feature extraction.

V. CONCLUSION

Character recognition and classification is highly dependent on feature extraction step and obviously Bangla handwriting recognition is not an exception to this. Actually, an injudiciously chosen set of features will yield futile recognition rates by any classifier. On the other hand, this particular effort has already justified that projection-based features are suitable to act as main ingredients to constitute optimal feature sets for recognition of Bangla handwritten characters. That is, inclusion of projection-based features is needed to uplift the performance in terms of accuracy. And we are looking forward to justify the same for Bangla compound characters and numerals. In addition to this, an attempt to ameliorate the accuracy of recognition by modifying the projection profile features is already underway.

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TABLE I. PERFORMANCE ANALYSIS (FOCUSING ON NUMBER AND TYPES OF FEATURES)

Approach	Number of Features	Classifier	Accuracy
First Approach	• Longest-run feature • Quad tree-based feature • Octant centroid feature	ANN (trained via back-propagation algorithm)	76.75%
Second Approach	• Longest-run feature • Quad tree-based feature • Shadow features • Octant centroid features	ANN (trained via back- propagation algorithm)	80.25%
Third Approach	• Longest-run feature • Quad tree-based feature • Shadow feature • Chain code(8-connected) histogram feature	ANN (trained via back-propagation algorithm)	81.55%
Fourth Approach	• Longest-run feature • Quadratic center of mass feature • Shadow feature • Left projection profile feature	ANN (trained via back-propagation algorithm)	82.52%
Fifth Approach	• Longest-run feature • Quadratic center of mass feature • Shadow feature • Left projection profile feature • Right projection profile feature	ANN (trained via back-propagation algorithm)	84.15%

TABLE II. PERFORMANCE ANALYSIS (FOCUSING ON INVOLVEMENT OF PROJECTION-BASED FEATURES)

Approach	Projection-based Feature Sets	Classifier	Accuracy
First Approach	None	ANN (trained via back-propagation algorithm)	76.75%
Second Approach	One	ANN (trained via back- propagation algorithm)	80.25%
Third Approach	One	ANN (trained via back-propagation algorithm)	81.55%
Fourth Approach	Two	ANN (trained via	82.52%

		back-propagation algorithm)	
Fifth Approach	Three	ANN (trained via back-propagation algorithm)	84.15%

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