# A Fast Recognition Scheme for Off-line Bangla Numerals

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***Abstract*—The requirement of Bangla character recognition has become one of the prime attentions among the current researchers due to the increase of automated systems and usage of hand held devices. This paper presents a novel approach to recognize handwritten bangla numerals and addresses a robust feature extraction scheme that spawns 23- dimensional features based on the numeral's structure and topology. The recognition scheme is organized with a proposed decision tree that has been justified using entropy calculation. Considering inconsistency in individuals' writing style and the presence of significant curves and loops, the proposed feature extraction method restricts to less dimensional features of each numeral from 14600 data samples. The recognition time of this scheme is much lower than the existing procedures, since the preprocessing tasks have been performed during down sampling operation. The quick response time 13.04 ms and the higher accuracy (96.82%) explore a new era for the proposed scheme of being implemented in Bangla numeral LeadPad toys.**

***Keywords — Character Recognition, Bangla Numeral, Down Sampling, Entropy, Feature Extraction***

## I. INTRODUCTION

Hand writing is one of the most effective ways of communication for general people. Though its popularity has reduced a little bit in this automatic Internet era, the efficient recognition scheme of handwritten scripts is desirable in every aspect of automated system. Bangla is the fifth-most popular language in the world. One set of bangle numerals from seven different handwritings are shown in Fig. 1. Automatic postal sorting, automatic bank cheque processing, children learning toys are some of the well known application areas for the hand written Bangla character recognition.

The history of character recognition is very rich and started around the mid twentieth century [1-2]. For the case of unconstrained handwritten numerals research has made impressive progress in Roman, Chinese and Arabic script in the recent time [3]. Bangla character recognition has also its well known literature for the last twenty years [4-6]. Pal and Chaudhuri worked with the recognition of unconstrained offline Bangla characters [7]. Islam et al. proposed grid method for recognizing On-line Bangla numerals by extracting different features which has an overall recognition rate of 96% [8]. Pal et al. used a novel scheme for Bangla handwritten numeral recognition which is mainly based on new features obtained from the concept of water overflow from the reservoir as well as topological and structural features of the numerals and it has overall accuracy of 92.8% from 12000 data [9]. Later on, highly efficient Bangla character recognition systems are proposed by artificial neural networks in [10-11] but they are computationally expensive. Y.Wen has presented a recognition system based on support vector machine, Kirsch mask and principal component analysis putting emphasis on response time [12]. They have extracted 1280-dimensional features from the input and then reduced to an unspecified number using principal component analysis (PCA).

This research takes into account on less computation in the preprocessing step employing a down sampling strategy and quick response time of recognition along with high accuracy. Though down sampling reduces the information, the off-line characteristics of the input numeral remain unchanged (as shown in fig. 2(a)).This research presents a novel decision tree for the fast recognition of the hand written Bangla numerals, considering the scope of implementing in interactive hand held devices. Since recognition scheme mostly depends on the feature extraction, all possible aspect of structural and topological characteristics of numerals have been considered and have found some unique features.

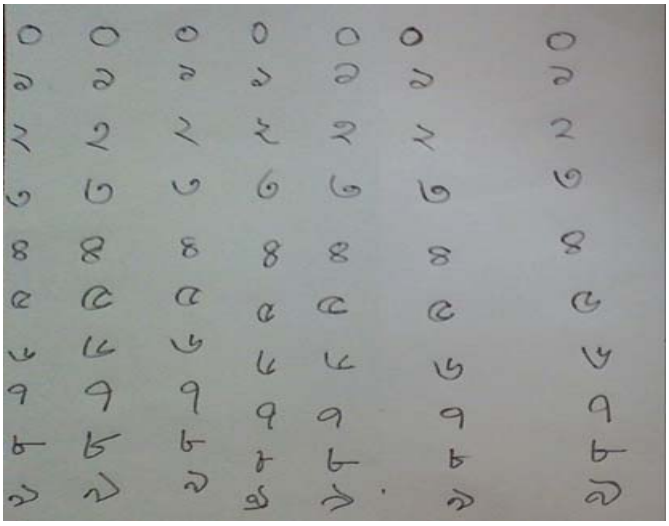

Fig. 1 Example of Bangla Numerals from 0 to 9 written by 7 different individuals.

The rest of this paper is organized as follows: Section 2 describes the steps of prepossessing technique needed for

recognition. Section 3 deals with detailed procedure of feature extraction. Section 4 comprises of proposed recognition scheme. Experimental results, achieved by the proposed method are shown in Section 5. Finally overall conclusion is drawn in section 6.

## II. PREPROSSESSING

### A. Data Acquisition

Acquisition of Bangla numerals are performed in two different ways: (i) with the help of mouse by direct drawing on the panel, and (ii) loading the image of the handwritten numeral. In order to get the numeral to be recognized, the user is given an interface (as shown in fig. 2). They can either draw the numeral in the white area of the writing panel or load an image of the numeral.

### B. Warping the numeral with rectangle

Only single numeral input has been considered, hence segmentation of numeral has not been focused. An efficient segmentation technique has been mentioned through the concept of water reservoir [9]. From the input numeral four corner points are extracted, and rectangle is drawn from these four points (as shown in fig. 3 (a)).

### C. Preparing the input image for feature extraction

In order to reduce the computational cost the wrapped input image is down sampled into 11x11 grids and features in different regions of interest are extracted(as shown in fig. 2).

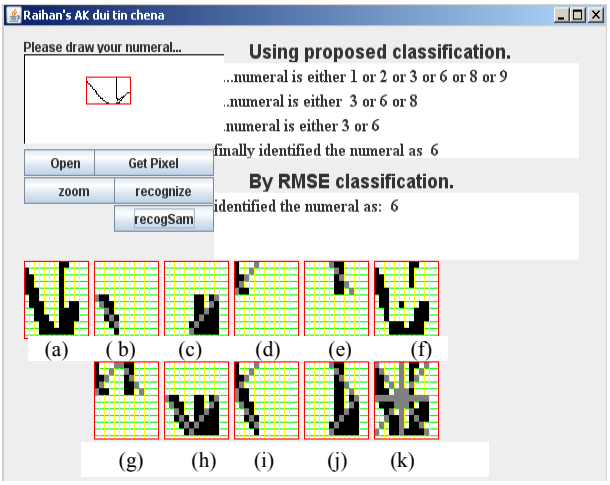


Fig. 2 User interface of the numeral recognition system

### D. Pre-processing Computation

The pre-processing operation is performed as follows:

a. Compute the centre of gravity (later denoting as cg) of the positions of pixels in the bounded region considering the left- down point of the numeral as origin (as shown in fig. 3(b)).

b. Find number of pixels around the cg of one unit distance i.e. eight neighbours.

c. Find the occurrences of pixels of each section of the 8-half quadrant which is considered as the 8-symmetric segments of a circle (as shown in fig. 3(c)) and compute the sum-product of the occurrence of pixels in each row and column and their respective weight, $EHQ_i$ is given by the expression:

$$EHQ_i = \sum_{i=0,j=0}^{i=3,j=3-i} n_{ij}.\ W_i \qquad (1)$$

where $n_{ij}$ is represented as the occurrences of pixels in the jagged array (as shown in fig. 4(a) which is the 0th segment of the fig. 3(c)) and $W_i$ is the weight matrix. The values of $n_{ij}$ and the components of W are as follows

$$W = [15\ 4\ 1\ 1\ ],\quad n_{ij} = \begin{cases} 1, \text{ if pixel exists} \\ 0, \text{ otherwise} \end{cases}$$

The components of W have been chosen in such a way to give emphasis on the weight of the pixels near the circumference. The justification of the chosen value of W is existence of one pixel in the 2nd row produce larger value (EHQ= $n_{1,j}$ W=1×4=4) than all the three pixels in the 3rd and 4th row (EHQ= 1×1+1×1+1×1=3), again the existence of one pixel in the 1st row (EHQ= $n_{0,j}$ W=1×15=15) will produce the same as produced by the six pixels in the 2nd, 3rd and 4th row (EHQ=1×4+1×4+1×4+1×1+1×1+1×1=15) (fig. 3(c) and fig.4(a)).

d. Compute the number of pixels inside and outside the diagonal of the four quadrants (as shown in fig. 5(a)).

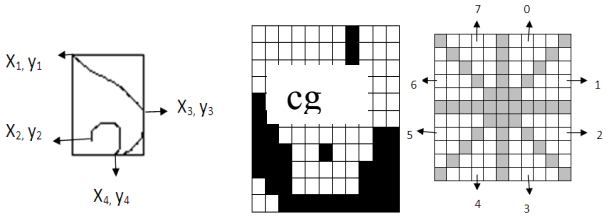


Fig. 3 (a) Rectangle boundaries around the numerals (b) Showing the cg of numeral 6 (c) Eight region of interest for EHQ

e. Find the discontinuity or cavity (i.e. absence of pixel in between pixels in the same row or column).

| | | | |
|---|---|---|---|
| $W_0$ = 15 | $W_0$ = 15 | $W_0$= 15 | $W_0$ = 15 |
| $W_1$ = 4 | $W_1$ = 4 | $W_1$ = 4 | |
| $W_2$ = 1 | $W_2$= 1 | | |
| $W_3$ = 1 | | | |

$EHQ_0$ = 0×15 + 1×15 + 1×15 + 0×15 + 0×4 + 1×4 + 0×4 + 0×1 + 1×1 + 0×1 = 35, using(1).

Fig. 4 (a) Jagged array showing the different values of W (enlarged picture the 0th portion of Fig.3(c)) (b) Sample EHQ calculation (The encircled portion of of Fig. 5(c))

## III. FEATURE EXTRACTION

The features of each numerals have been extracted depending on its evidence by 14600(=146x10x10) data samples. In this proposed scheme eight major areas have been taken into consideration for effective feature extraction. After testing the data samples the average values of $EHQ_{i=0...7}$ for all numerals have been taken (as shown in fig.6). From the average values of $EHQ_i$, distinctive classes of numeral have been formed such as the $EHQ_7$ of numeral 3 and 6 are significantly low from the other numerals. For mathematical interpretation of the term 'low' has been used as a threshold value $T_1 <= 15$, which is the largest value of W in (1).

Along with some fixed topological and structural property viz. numeral 5 always has concave property in the right-half portion, some other crucial features have been extracted. The computation described in section IIDe has revealed the discontinuity feature that numeral 1 does not have discontinuity in either region 1 or region 2 (fig. 5(b) and 6(c)) whereas numeral 9 always has (fig. 6(a) and 6(b). This discontinuity feature can easily separate the closely related numeral pair such as numeral 1 and numeral 9. The convex property in eight different regions (fig. 2(b, c, d, e, g, h, i, j)) and the discontinuity in another six areas of interest (fig. 5(b)) have also taken into account for effective recognition. Therefore, along with EHQ in eight different region and cg, twenty three dimensional features of each numeral have been extracted.

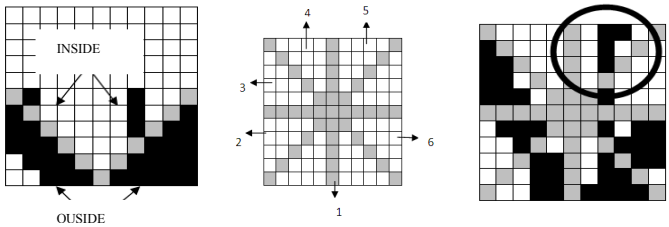


Fig. 5 (a) Showing lower half inside concavity of numeral 6 (b) Six area of interest to find discontinuity (c) Numeral 6 for EHQ calculation

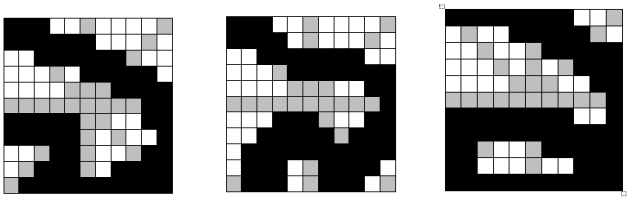

Fig. 6 (a) Numeral 9 having discontinuity in region 2 (Fig. 5(b)) (c) Numeral 9 having discontinuity in region 1 (Fig. 5(b)) (c) Numeral 1 has no discontinuity in either region 1 or 2 (Fig. 5(b))

| | EHQ0 | EHQ1 | EHQ2 | EHQ3 | EHQ4 | EHQ5 | EHQ6 | EHQ7 | cg |
|---|---|---|---|---|---|---|---|---|---|
| ১ | 38 | 48 | 66 | 66 | 51 | 27 | 6 | 61 | 2 |
| ২ | 25 | 21 | 12 | 55 | 29 | 31 | 9 | 55 | 2 |
| ৩ | 34 | 56 | 64 | 64 | 31 | 23 | 63 | 8 | 3 |
| ৪ | 54 | 43 | 57 | 59 | 55 | 34 | 57 | 69 | 6 |
| ৫ | 48 | 24 | 45 | 66 | 52 | 53 | 63 | 58 | 2 |
| ৬ | 30 | 19 | 62 | 64 | 33 | 24 | 57 | 8 | 3 |
| ৭ | 52 | 52 | 54 | 18 | 2 | 7 | 67 | 65 | 3 |
| ৮ | 5 | 29 | 12 | 26 | 62 | 63 | 64 | 29 | 4 |
| ৯ | 31 | 44 | 64 | 52 | 26 | 28 | 14 | 53 | 4 |
| ০ | 60 | 59 | 61 | 57 | 58 | 62 | 59 | 56 | 1 |

Fig. 6 the values of EHQ and cg of 10 numerals from 14600 data

## IV. NUMERAL RECOGNITION

Two major aspects, accuracy and response time must be considered in recognition process. Considering this fact the proposed scheme uses two types of recognition processes using the extracted features.

a. Root Mean Square Error (RMSE): This classifier first find the root mean squared error by the following equation:

$$e_i = \sqrt{\frac{1}{n}\sum_{j=0}^{n}(S_{ij} - T_j)^2} \quad (2)$$

Where, $S_{i=0...9,\ j\ =\ 0....23}$ represents the features of printed 10 numerals and $T_{j=0...23}$ is the features of the test numeral. Then the classifier computes the minimum of $e_i$ and decides that the tested numeral belongs to $i^{th}$ class.

b. A Decision Tree: This is the proposed classifier for numeral recognition based on a decision tree (as shown in fig.7). The decision tree has also been justified using entropy calculation using the following equation:

$$\text{Entropy} = \sum p_i \log_2 p_i \quad (3)$$

where i=1, 2, 3,……,n and p is the probability of chance.

For constructing the decision tree some notations are discussed as follows:

- $EHQ_{i=0\ to\ 7}$, $T_1$ and cg have already been defined.
- $IsCont_{i=0\ to\ 5}$, presents a boolean function. It returns true if continuity exists in any of six region of interest (as shown in fig. 5(b)) else returns false.
- $T_2$, represents a boolean value. It returns true if the number of pixels present in the eight neighbouring position of centre of gravity is more than or equal to 4 else return false.

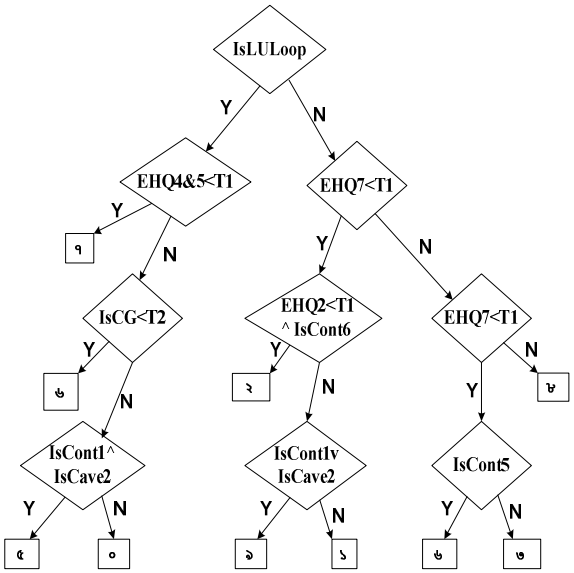


Fig. 7 Decision tree for the recognition process of bangle numerals.

- $IsCave_{i=0\ to\ 3}$(0-left, 1-top, 2-right and 3-bottom), presents a boolean function. It returns true if number of pixel inside is less than the number of pixel outside (as shown in Fig. 5(a)) else returns false.

- IsLULoop presents another boolean function that returns true if both $IsCave_0$ and $IsCont_3$ are both true else returns false.

## V. Result and Discussion

The proposed scheme has been tested on 14600 numerals from 146 different individuals. Each individual has tried 10 different writing styles for each numeral. They used mouse to draw numeral through the interface (as shown in fig. 2). It is noted that the overall accuracy of the recognition scheme is 96.82% (as shown in table I).

TABEL I

| Numeral | No. of sample data | Average response time(ms) | Accuracy |
|---|---|---|---|
| 0 | 1460 | 11.4 | 98.50% |
| 1 | 1460 | 14.3 | 97.71% |
| 2 | 1460 | 13.6 | 98.50% |
| 3 | 1460 | 15.3 | 94.20% |
| 4 | 1460 | 15.3 | 93.70% |
| 5 | 1460 | 12.7 | 98.50% |
| 6 | 1460 | 11.8 | 95.70% |
| 7 | 1460 | 12.2 | 99.20% |
| 8 | 1460 | 12.6 | 95.80% |
| 9 | 1460 | 11.2 | 96.40% |
| | Overall | 13.04 | 96.82% |

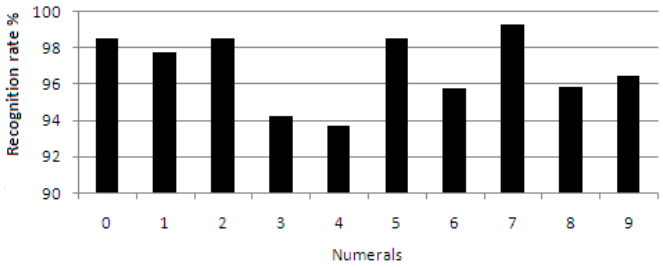


Fig. 8 Chart of success rate of recognition of bangla numerals.

The experiment shows that the highest accuracy achieved for numeral 7(as shown in table I). It is because its unique lower half features. The failed rate of 0.8% happened owing to the vulnerability of the proposed scheme to unnecessary segments (as shown in fig. 9(a)). It can be solved using pruning technique.

Low rate of accuracy of numeral 4 has occurred because it's large deviation of orientation and large discontinuity in the upper loop (as shown in fig. 9(c)).

The proposed scheme has achieved high accuracy for the most confusing pairs (numeral 1 and 2, numeral 1 and 9) [5] [1] by introducing the discontinuity features (section IIDe). This feature is also responsible for the high accuracy of numeral 2, since extra looping (as shown in fig. 9(b)) has been taken care of by this feature.

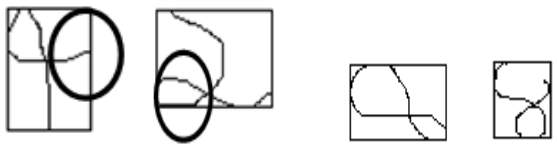

Fig. 9 (a) Numeral 7 with large unwanted segment (b) Numeral 2 with extra loop like numeral 1 (c) Numeral 4 with flatted orientation and large discontinuity in the top region

Though different researchers use different data sets from their respective space and time, main objective is to achieve the high accuracy of recognition numerals. Comparison among some methods of recognition of Bangla numerals is shown in fig. 10.

The response time includes down sampling the numeral image, feature extraction and the recognition phase. Since the proposed method mainly focuses on a novel Bangla numeral recognition approach, it only deals with a single numeral. Image segmentation of over lapping or touched numerals is not done in this experiment as it is considered in [9][14]. Moreover, after feature extraction all the decision making process towards the numeral recognition is done in unit time, hence a quick response time is achieved. Though the base-line of the comparison is not same, in terms of response time of Bangla numeral recognition a comparison is exposed in fig. 11.

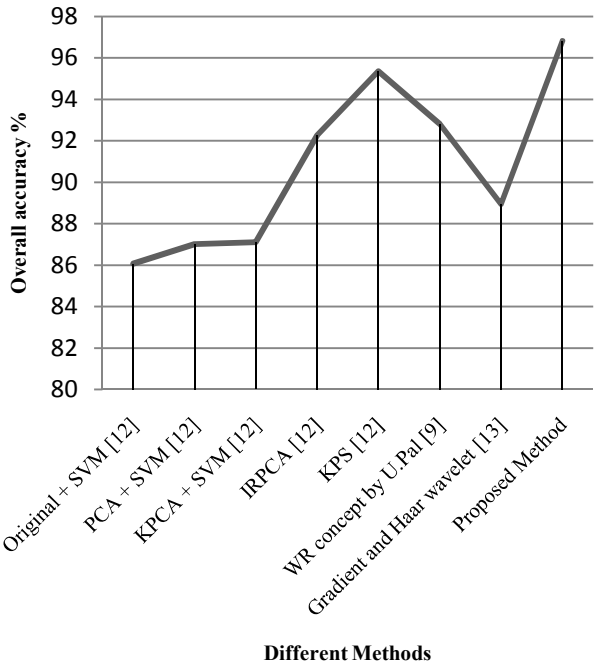


Fig. 10 Numeral recognition accuracy of different methods

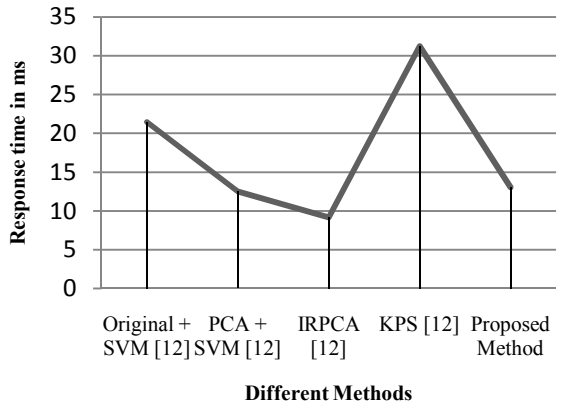


Fig. 11 Recognition response time of different methods in ms.

The experiment is done on the system with Pentium dual core processor of 1.8 GHz and 1GB ram and the implementation is done using JDK 1.6.

## VI. CONCLUSIONS

This paper presents a novel approach for feature extraction of off-line Bangla numerals. The feature is extracted on the basis of pixels distribution in the eight equivalent segments of the rectangle wrapped around the test numerals. Considering the discontinuity and the curvature properties of the numerals, the variation in orientation of the handwritten numerals has been taken care of. Based on the features, the proposed scheme uses two classifiers for recognition process: (i) Root Mean Square Error and (ii) A decision tree. Sufficient test samples reveal the accuracy of this new approach. At present this scheme only deals with faster recognition. It will continue its journey by proposing a new recognition scheme of on-line bangla numeral as well as bangla character with more accuracy.

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