5th International Conference on Electrical and Computer Engineering
ICECE 2008, 20-22 December 2008, Dhaka, Bangladesh

Bangla Numeral Recognition Engine (BNRE)

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Abstract: Numeral recognition is the process to classify the given character according to the predefined character class. This paper proposed a methodology for recognizing Bangla handwritten numerals which are based on fuzzy logic theory due to its low computational requirement. Every numeral is segmented and several features are extracted for each segment. In this paper, we use unique fuzzy rule base for each numeral. We have tested our engine for Bangla numerals considering various writing style and got more than 80% recognition accuracy.

I. Introduction

On-line numeral recognition involves the real time recognition of numeral as the writes them. Process of numeral recognition takes place within very short period of time. In fuzzy logic approaches, some global and local or geometric features are used. There are a lot of works on Bangla handwritten numeral recognition techniques in the world at present. One of these works has been presented in [1] where online Bangla numeric characters are recognized by automatically fuzzy linguistic rules. Bangla letters are recognized by self organizing mapping method has been presented in [2], other technique has been presented in [3] where online Bangla alphabetic characters are recognized by extraction of meaningful fuzzy rules. Automatic generation of fuzzy rule base for online handwriting recognition process has been presented in [4]. Handwriting recognition is a challenge with On-line character recognition is the development of a system that can recognize these characters in real-time. So for humans the possibility to communicate with the computer via handwriting is a tremendous enhancement of the man-machine interface. With the increasing the interest of computer applications, modern society needs the handwritten text into computable readable form. Therefore, handwriting recognition is a very interesting input method. The main objective of this paper is to recognize the Bengali numeral using fuzzy logic considering various writing styles of different users. For recognition, we have to use fuzzy rule-base for each character and extract features. The main advantages of fuzzy logic approaches are that it requires small amount of memory space and accuracy is very high.

II. Bangla Numeral Recognition Engine (BNRE)

The core of the recognition engine is the knowledgebase that is in the form of fuzzy rules. The outline of the BNRE can be depicted as Fig. 1. The input of a new numeral has to pass following processing steps: segmentation, fuzzy features extraction, learning, and recognition. Input data is segmented according to angle difference. The numbers of features can be categorized into global, geometric and position features in the fuzzy features extraction step. Fuzzy features are distorted into database and stored into rule base in the next steps.

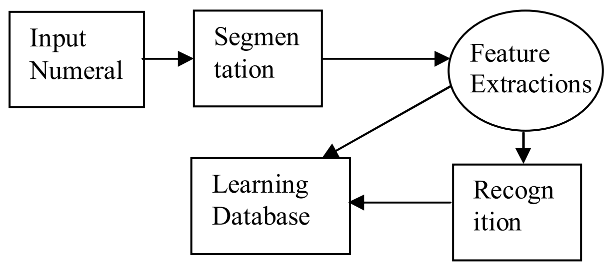


Fig. 1 Architecture of the BNRE

III. Segmentation

Each numeral divided into a several segments. The segmentation is based on the movement and angle differences between first four point connected line and consecutive second four point connected line. A segmented Bangla numeral seven is depicted in Fig. 2.

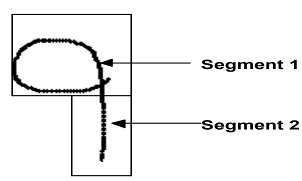


Fig. 2: Segmented Bangla numeral seven.

If the angle difference is more that 90^0 then recognized a new segment. When electronic pen or mouse is up recognized also a new segment. Segmentation steps are described in the following:

Step 1: Initialize a new segment when pen down occur. Set coordinate = current coordinate;
Step 2: Store Coordinate and increase no_of_point;
Step 3: Set Coordinate = next coordinate and go to step 2 until pen up or abrupt change in direction with no_of_point >4;
Step 4: If pen up store coordinate and set coordinate to 0;
Step 5: Go to step 1;
Step 6: If abrupt change in direction with no_of_point>4 set no_of_point to 0;
Step 7: Initialize new segment;

Step 8: Go to step 2.

IV. Features Extraction

Fuzzy features play an important role in the character recognition. Features are divided into three categories: global features, positional features and geometric features.

A. Global Features

Global features are common to all types' features. Global features belong to whole character. Some global features are given in Equations (1)-(4).

$$\min X^{seg(n)} = Min(x_i) \quad (1)$$

$$\max X^{seg(n)} = Max(x_i) \quad (2)$$

$$\min Y^{seg(n)} = Min(y_i) \quad (3)$$

$$\max Y^{seg(n)} = Max(y_i) \quad (4)$$

The coordinate of the center points of each segments are calculated by the Equations (5)-(6).

$$centreX^{seg(n)} = (\min X^{seg(n)} + \max X^{seg(n)})/2 \quad (5)$$

$$centreY^{seg(n)} = (\min Y^{seg(n)} + \max Y^{seg(n)})/2 \quad (6)$$

These global features are necessary for calculating the both positional features and geometric features.

B. Positional Features

The positional feature determines the relative position of identified segment with respect to universe of discourse. If the individual segments have been identified, the next step is the determination of the center of the identified segment. The universe of discourse is divided into two linguistic variables which are *Vertical position (VP)* and *Horizontal Position (HP)*. The *Vertical Position* is divided into eight linguistic terms: {Nearly Top (NT), Top Centre (TC), Top (T), Middle (M), Bottom Centre (BC), Bottom (B), Nearly Bottom (NB), Centre (C)} and the *Horizontal position* is divided into seven linguistic terms: {Left (L), left corner (LC), nearly left (NL), Center (C), Right (R), Nearly Right (NR), Right Centre (RC)}. Then the relative position of the identified segment is expressed by the Equations (7)-(8).

$$\mu_{HP} = \frac{\left(centreX^{seg(n)} - \min X^{seg(n)}\right)}{\left(\max Xseg(n) - \min X^{seg(n)}\right)} \quad (7)$$

$$\mu_{VP} = \frac{\left(centreY^{seg(n)} - \min Y^{seg(n)}\right)}{\left(\max Y^{seg(n)} - \min Y^{seg(n)}\right)} \quad (8)$$

Then this membership value is compared with predefined linguistic terms for horizontal and vertical position.

C. Geometric Features

Geometric features are extracted per segment and divided into two main categories which are straight line and arc. The fuzzy values involved these features are *arcness* and *straightness* [4].

C.1. Straightness Determination

The straightness ($\mu_{Straightness}$) of a given segment is calculated by fitting a straight line with minimum least squares error. The membership function for straightness of the every segment are calculated by the Equation (9).

$$\mu_{Straightness} = \frac{\left[D_{P(0)P(N)}\right]}{\sum_{K=1}^{N} D_{P(K)P(K+1)}} \quad (9)$$

Where $D_{P(K)P(K+1)}$, is the straight-line distance between point K and point $(K+1)$ on the n[th] segment. The number of element in the segment is depicted by N. If ($\mu_{Straightness}$) is greater than 0.6 then the segment is straight line and otherwise it is an arc.

C.2. Arcness Determination

The ratio of the distance between end-points and total arc length determined the arcness ($\mu_{Arcness}$) of a particular segment. The membership function for arcness is given according to Equation (10).

$$\mu_{Arcness} = 1 - \mu_{Straightness} \quad (10)$$

If given segment is determined to be an arc then categorized the arc into one of the five types such as: A-shape (A), U-shape (U), C-shape (C), D-shape (D) and O-shape (O). These categories are distinguish by using the angle of rotation, angle of slope joining end points, the measure of arcness, relative length and area covered by the segment [5]. Different types of arc can be defined according to the Equations (11)-(15).

The equation of the A-like curve is

$\mu_A = \min(1, \sum I_y / n)$, where $I_y = 1$ if $y > (y_s + y_e)/2$; Otherwise 0 (11)

The equation of the U-like curve is

$\mu_U = \min(1, \sum I_y / n)$, where $I_y = 1$ if $y < (y_s + y_e)/2$; Otherwise 0 (12)

The equation of the C-like curve is

$\mu_C = \min(1, \sum I_x / n)$, where $I_x = 1$ if $x < (x_s + x_e)/2$; Otherwise 0 (13)

The equation of the D-like curve is

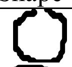
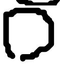
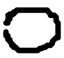
$\mu_D = \min(1, \sum I_x / n)$, where $I_x = 1$ if $x > (x_s + x_e)/2$; Otherwise 0 (14)

The equation of the O-like curve is

$$\mu_O = \left(\sum_{K=1}^{N} D_{P(K)P(K+1)}\right)/(2 * 3.1416 * r) \quad (15)$$

Where r is the radius of the curve, x_s, x_e is the start point and end point of segment respectively in the X-axis and y_s, y_e is the start point and end point of segment respectively in the Y-axis. The other types of O-shape arc and corresponding equation and picture are given in Table 1.

Table 1: Different types of O-Like curve

Shape	Name	Function
	O-shape Top	$\mu_{OT} = \min(\mu_O, \mu_U)$
	O-shape Bottom	$\mu_{OB} = \min(\mu_O, \mu_A)$
	O-shape Left	$\mu_{OL} = \min(\mu_O, \mu_D)$
	O-shape Right	$\mu_{OR} = \min(\mu_O, \mu_C)$

After calculating all fuzzy features, the next step is to mapping these values to linguistic term according to predefined range of Table 2.

Table 2: Linguistic terms and corresponding range

Linguistic terms	Meaning	Range
Z	Zero	≤ 0
VVL	Very Very Low	$> 0 \sim\leq 0.12$
VL	Very Low	$> 0.12 \sim\leq 0.24$
L	Low	$> 0.24 \sim\leq 0.36$
M	Medium	$> 0.36 \sim\leq 0.48$
H	High	$> 0.48 \sim\leq 0.60$
VH	Very High	$> 0.60 \sim\leq 0.72$
VVH	Very Very High	$> 0.72 \sim\leq 0.84$
E	Excellent	> 0.84

V. Fuzzy Rule-Base Generation

The rule base is depends on the number of segment contained in the given numeral. If the numeral contains n segments then the number of rule base are n!.

A. Algorithm for Rule Generation

For each segment different variation is collected for the character. Variation of a segment means which has the same segment serial but different position in the universe of discourse. For each variation mean the important geometric feature are calculated using important features analysis. For finding the important global feature same segment number is used as the criteria. The details of rule generation algorithm have been described in [1]. Fuzzy rule is unique for every character. The fuzzy rule is built up according to important features and a small fragment of fuzzy rules for Bengali numerals 0, 1 and 5 are presented in Table 3.

Table 3: Fuzzy Rules for numerals ০ , ১ and ৫ .

Numerals	Segment No.	Fuzzy Rules
০	1	If ((seg.(1).μ_{ARC} =VVH) OR ((seg.(1).μ_{ARC} =E)) AND ((seg.(1).μ_{STR} =VVL) OR (seg.(1).μ_{STR} =Z)) THEN Output=20;
১	2	If (seg.(1).μ_{ARC} =M) AND (seg.(1).μ_{VP} =BC) AND (seg.(1).μ_{DL} =VH) AND (seg.(1).μ_{CL} =VL) AND (seg.(2).μ_{ARC} =VH) AND ((seg.(2).μ_{OL} =E) OR(seg.(2). μ_{OL} =VVH)) THEN Output=21;
৫	5	If (seg.(1).μ_{STR} =VVH) AND (seg.(1).μ_{HP} =L) AND (seg.(1).μ_{HL} =VVH) ((seg.(2).μ_{STR} =H) OR (seg.(2).μ_{STR} =VH)) AND (seg.(2).μ_{VP} =LC) AND (seg.(2).μ_{PS} =M) AND(seg.(2).μ_{SLEN} =VH) AND ((seg.(3).μ_{ARC} =M) OR (seg.(3).μ_{DL} =Z)) AND (seg.(3).μ_{CL} =VVH) AND (seg.(3).μ_{HP} =NB) AND (seg.(4).μ_{ARC} =VH) AND (seg.(4).μ_{CL} =M) AND (seg.(4).μ_{DL} =VL) AND (seg.(5).μ_{ARC} =H) AND (seg.(6).μ_{UL} =VVH) AND ((seg.(5).μ_{AL} =VVL) OR (seg.(5).μ_{AL} =Z)) THEN Output=25;

VI. Learning Mode

In learning mode, user draws the numeral in the drawing pad. The overall learning process describes in the following:

Step 1: Numeral segmentation.

Step 2: Feature extraction. The important features extraction is described by the tabular form in the following.

Step 3: Data store. Features stored mechanism into databases in the following manner.

```
Set rs = New ADOBD. Recordset
If segmentno = 1 Then
Rs.Open "INSERT INTO seg1table
ElseIf segmentno = 2 Then
Rs. Open "INSERT INTO seg2table
ElseIF segmentno = 3 Then
Rs. Open "INSERT INTO seg3table
Else
Rs.Open "INSERT INTO others
```

VII. Recognition Mode

The overall recognition process can be described in the following way:

Step 1: Recognition mode segmentation is same as the learning mode segmentation.

Step 2: Recognition mode feature extraction is same as the learning mode extraction.

Step 3: Store mechanism of data into array are described according to following the code.

```
Dim SL AS INTEGER
SL = 1
If MVL<= 0 Then
    Ch1 (SL, 5) = "Z"
    ElseIf MVL > 0 and MVL <=0.125 Then
    Ch1 (Sl, 5) = "VVL"
    ElseIf MVL > 0.125 and MVL <=0.25 Then
    Ch1 (SL, 5) = "VL"
```

Step 4: In comparison stage, array data are compared with the Rule base data.

Step 5: Highest value is calculated from step 4 as percentage.

Step 6: Recognized the numeral.

VIII. Experimental Results

In experimentation, we have 10 Bangla numerals (zero to nine) each consisting of five different samples of each numeral and collected from hundreds different users. We have tested our engine for total of five thousands different sample numerals for Bangla numeral segmentation and to evaluate the different types of features that are necessary for recognizing the numerals.

A. Segmentation Results

The segmentation result of Bangla numeral 1 and 5 are presented in Table 4.

Table 4: Segmentation results for numeric ১ and ৫ .

Numerals	Segment Number					
	1	2	3	4	5	6
১	N	N	Y	Y	N	N
৫	N	N	Y	Y	Y	N

In Table 4, Y means ‘yes’ and N means ‘no’. Every numeral can have many segments and it depends on writing style of different users.

B. Feature Extraction Results

Several features are extracted for each character according to segmentation basis. Number of Segment and features can be varied with numeral writing styles. Table (5)-(7) represents the positional features (HP: horizontal and VP: vertical), straightness features (ST: straightness, VL: vertical line, HL: horizontal line, PS: positive slanted, NS: negative slanted, HLEN: horizontal length, VLEN: vertical length, and SLEN: slanted length) and arcness features (ARC: arcness, CL: C-like, DL: D-like, AL: A-like, UL: U-like, OL: O-like, OLL: O-like left, OLR: O-like right, OLB: O-like bottom and OLT: O-like top.) for numeral one (১) respectively. Table 8 shows the recognition percentages for Bangla numeral ৫ (five) with two different writing styles and Table 9 portrays the overall recognition accuracy for ten Bangla numerals each consisting of five different samples which are collected from different users.

Table 5: Positional feature for numeral ১ (one).

Numeral	Segment serial	μ_{HP}	μ_{VP}
১	1	L	BC
১	2	LC	C

Table 6: Straightness feature for numeral ১ (one).

Segment	μ_{ST}	μ_{VL}	μ_{HL}	μ_{PS}	μ_{NS}	μ_{HLEN}	μ_{VLEN}	μ_{SLEN}
1	Z	-	-	-	-	-	-	-
2	VL	-	-	-	-	-	-	-

Table 7: Arcness feature for numeral ১ (one).

Segment	μ_{ARC}	μ_{CL}	μ_{DL}	μ_{AL}	μ_{UL}	μ_{OL}	μ_{OLL}	μ_{OLR}	μ_{OLB}	μ_{OLT}
1	M	VL	VH	L	VL	VH	H	VL	Z	M
2	VH	L	Z	VH	H	E	M	M	L	L

Table 8: Recognition result for numeral ৫ (five)

Numeral	No. of segment	First recognized		Second recognized		Original
	3	5	74.11%	6	13.89%	5
	4	5	61.78%	0	39.5%	5

Table 9: Performance evaluation

Number of numeral	Number of Samples/numeral	Total number of numerals	Recognition accuracy
10	500	5000	82.099%

IX. Conclusion

Handwritten numeral analysis involves the computational identification of numerals and other written in handwritten script. The goal of this work is to develop an idea and to make module to recognized online handwritten Bangla numerals regardless of various writing style using fuzzy logic because of low computational requirements and ease of implementation. We have used fuzzy logic for features extraction. Fuzzy features are mapped into some predefined linguistic variables. All the features value is stored into temporary database, then central database. For recognizing a numeral, fuzzy rule are calculated, this fuzzy rule is compared with rule base and the character that contains highest percentage value is recognized character. The recognition rate of the proposed system is about more that 80% and speed are very well. The accuracy of the proposed system depends on the writing styles. A comprehensive approach of neural network and fuzzy logic may help to achieve the higher accuracy. This work may be accomplished in computer vision research for example, tracking the vehicle in a road by recognizing its number plate in its back side or font side. This will be helpful for road traffic management, to count number of particular vehicle and their types.

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