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Segmentation and Recognition of Unconstrained Bangla Handwritten Numeral

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Abstract: This study deals with the segmentation and recognition of unconstrained off-line Bangla handwritten numerals. The projection profile-based heuristic technique is used to segment handwritten numerals. The results, based on this approach are quite satisfactory for the next classifier stage. Following the segmentation, character matrices from each numeral are extracted, normalized and then passed through an Artificial Neural Network (ANN) classifier for classification. The proposed scheme is tested on data collected from different individuals of various background and foreground colors.

Key words: Bangla numeral segmentation, numeral recognition, projection profile-based technique, artificial neural network, connected numerals

INTRODUCTION

Segmentation and recognition of handwritten numerals has been a popular research area for many years because of its various application potentials[1,2]. Some of its application areas are automatic postal sorting, automatic bank cheque processing, share certificate sorting, recognition of various other special forms etc. Although research on segmentation and recognition of unconstrained handwritten numerals has been made impressive progress in Roman, Chinese and Arabic script[3,4], segmentation and recognition of handwritten Bangla numeral is largely neglected. Only a few research papers have been published on Bangla handwritten numeral recognition[5,6,7].

Segmentation of connected numerals is the main bottleneck in the handwritten and printed numeral recognition system. In general, there are two types of segmentation schemes: recognition-free-segmentation and recognition-based-segmentation[8]. In recognition-free-segmentation, a numeral string can be divided into segment by rules without recognition. On the other hand, in recognition-based-segmentation, the candidate segmentation points are verified with recognizer. In this paper, a recognition-based segmentation scheme for automatic classification and segmentation of unconstrained handwritten connected numerals is proposed.

Various approaches have been proposed by the researchers for numeral recognition[9] most of them are used for non-Bangla numeral recognition. One of the most widely used approaches is based on neural network. Some researchers used structural approach, where each pattern class is defined by structural description and the recognition is performed according to structural similarities[10]. Statistical approach is also applied to numeral recognition. It is relatively insensitive to pattern noise and distortion, however modeling of statistical information is a tedious task[9]. Among others, Hidden Markov Models, Fourier and Wavelet Descriptors, Fuzzy rules[11], Tolerant rough set[12] are reported in the literature. In this paper, a neural network based scheme is used for the recognition of the segmented numerals.

Bangla is the fifth-most popular language in the world. About 200 million peoples in the South Asia use Bangla as their language[5]. However, a very few research has been done on connected Bangla handwritten character or digit segmentation system. Although some research[5,6,7] has been done on printed Bangla digit recognition, however research on connected Bangla digit segmentation is very small. The printed digits have a significant shape. On the other hand, handwritten Bangla digits vary from person to person, on emotion, on pen pressure upon paper, on different situations, the smoothness of pen c olor and the other factors. To get an idea of Bangla numerals and their variability, one set of printed and five sets of handwritten numerals have been shown in Fig. 1.

Our proposed scheme has two parts: (a) Segmentation and (b) Recognition. The segmentation part of the scheme first detect whether a component of numeral(s) is isolated or connected. If it is connected, the touching numeral segmentation scheme is applied on it to get individual numerals. The touching numeral segmentation scheme detects the touching position

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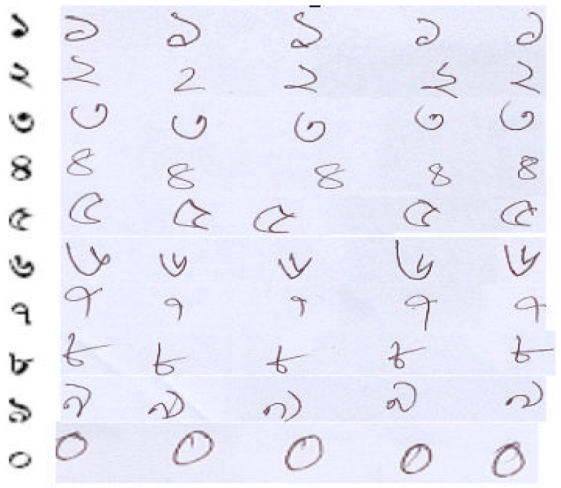

Fig. 1: Example of bangla numerals

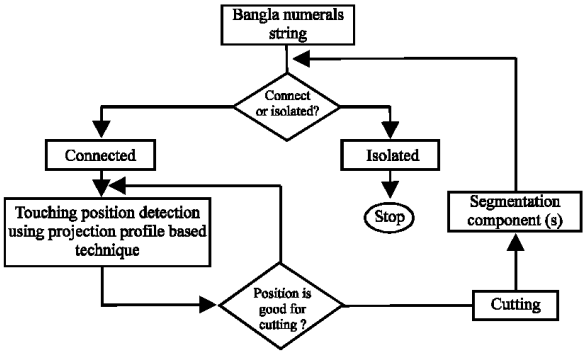

Fig. 2: Segmentation scheme

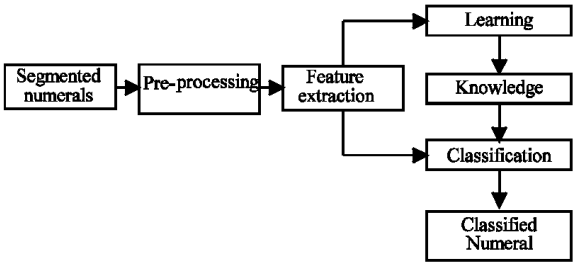

Fig. 3: Numeral recognition

using the projection profile based technique. The touching position is tested whether it is appropriate for cutting. If the position is appropriate for cutting then the character is segmented. Otherwise, we precede backward or forward direction to detect the best touching position. Our proposed scheme is shown in Fig. 2.

The recognition technique is then applied on the segmented numerals. The proposed recognition scheme is shown in Fig. 3.

NUMERAL SEGMENTATION

The numeral segmentation method is based on the use of projection profile histograms, has been investigated and proposed. Projection profile is a data structure used to store the number of non-background pixel when the image is projected over the normal X-Y axes, given by the equation:

$$X, Y \rightarrow M(x,y) \tag{1}$$

Each of the projection vectors is associated with the number of pixels above a predefined threshold (Eq. 2 and 3). The threshold value is set as the background pixel intensity.

$$X_n = \sum_{i=0}^{h} Y_i \ , \qquad n \in [0,v] \tag{2}$$

$$Y_n = \sum_{i=0}^{v} X_i \ , \qquad n \in [0,h] \tag{3}$$

where X and Y represent the horizontal and vertical axes, h represent the height of the image (vertical size of the digit) for X axis and v represent the width of the image for Y axis.

The proposed image segmentation process includes three steps: (i) Image Compensation (ii) Numeral Separation and (iii) Segmentation of touching numerals.

Image compensation: This step is used in the trial to compensate the quality of the original image, enhancing certain details of the image and removing unwanted noise. A low resolution scanned image, not clean original image or colored envelope, certainly produces a poor result. For this type of image, a threshold factor has been set to remove the background color by filtering. Figure-4 shows the background noise removed from a white studyscanned image with the resolution of 300 dpi.

(a) Original image **(b) Filtered image**

Fig. 4: Background noise removal

(A) Original image (B) Enhanced image

Fig. 5: Contrast Enhancement

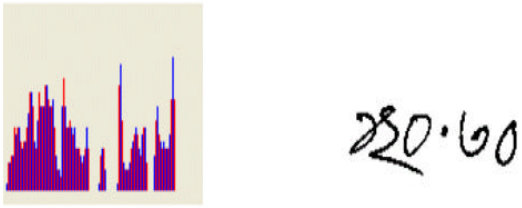

Fig. 6: Projection histogram of handwritten string 120.30

Contrast enhancement technique is used to enhance the brightness of the image (Fig. 5).

Image separation: This stage of the scheme classifies an input numeral into isolated and connected digit groups. The aspect ratio (height width ratio) of the component is used for the separation. If two or more numerals connected, then the width of the connected components should be larger than its height. In principle, when two numerals get connected, one of the following happens in most cases: (i) Two numerals create a larger width as shown in Fig. 6 and (ii) The projection histogram at the connected points is almost equal in height.

Based on the projection histogram and aspect ratio of numeral isolated and connected numerals are identified as follows:

Let for a string of numerals N:

N_{CP} = Column pointer of the string
N_{IW} = Width of the string
N_{MH} = Maximum height of numeral in the string
N_{MW} = Minimum width of the numeral in the string
P_{BC} = Black pixel counter

Also let C be a component of the string to be separated. Based on the above values the separation algorithm is as follows:

Step-1: Set ColumnCounter to Zero
Step-2: Repeat while $N_{CP} \leq N_{IW}$
- Increment ColumnCounter and Set P_{BC} to Zero
- Repeat while $i < N_{MH}$

(a) If any Black pixel found in the *i-th* column then increment P_{BC}

[End of step (ii) loop]
(iii) If (($P_{BC} = 0$) and (ColumnCounter < $2*N_{MW}$))
Then C is isolated
Otherwise C is connected
[End of step-2 loop]
Step-3: End.

The above separation method is independent of the size of the numeral and there is no need of any normalization of the component.

Segmentation of connected numerals: For the segmentation of connected numerals, at first the connected numerals are separated from the isolated numerals. The connected numeral segmentation algorithm extracts the feature points from touching numerals. The structural features of the numerals are used to detect the appropriate touching position of the connected numerals. Each connected numerals are inspected in an attempt to locate the characteristics representatives of segmentation points. Six major steps are executed to perform segmentation of touching numerals:

Step-1: Average character width of the numerals is estimated.
Step-2: Upper and lower word contours are examined to enable the location of possible ligatures.
Step-3: Histogram of the vertical pixel density is calculated. Minima in the histograms are used to further confirm the location of possible segmentation points in each connected numerals.
Step-4: Connected numerals are also scanned from left to right and the segmented portion is compared with a predefined structure to find an appropriate cutting position.
Step-5: During the scanning process the backtracking may be required for proper segmentation position.
Step-6: Segmentation of the numerals using the best cut point.

Figure 7 shows the examples of some best cut points.

NUMERAL RECOGNITION

The numeral recognition technique in this system is divided into two phases: Training phase and Recognition phase. In the training phase, the handwritten numerals representing the matrices of pixels are extracted and

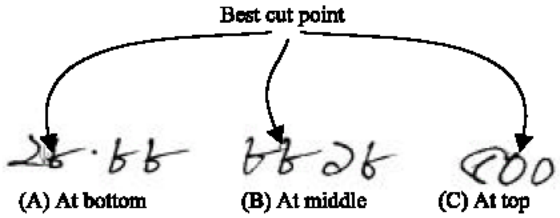

Fig. 7: Best cut points

stored in an ANN training file to train the network. Each matrix is first normalized and then significantly reduced in size by a simple feature extractor. The feature extractor breaks the normalized matrix down into small windows of equal size and analyses the density of black and white pixels. Therefore instead of presenting the raw pixel values of the handwritten numerals to the ANN, only the densities of each window are presented. Accompanying each matrix the desired output is also presented to the ANN for training purpose. After the training session, the knowledge of the network is stored in a file for next testing stage.

Following the training phase, the handwritten numerals which have been segmented using our segmentation scheme are used for testing the recognition accuracy. This time the segmented handwritten numerals are extracted, normalized and reduced in size and then fed into the trained ANN. The ANN then verifies which numeral fall into which classes.

RESULTS AND DISCUSSION

We experiment our scheme on 500 numerals obtained from different individuals of different professions like university students and teachers, bank and post office employees. We noted that data sets contain varieties of writing styles. The numeral sets were collected on a plain study (different colored) on different foreground colors (different inks). Initially, the collected numerals had been acquired from flatbed scanner at 300 dpi. The color depth for the experiments in this research are defined in standard RGB with 24-bit per pixel in gray level.

The proposed numeral separation algorithm is applied on the collected data set to separate the isolated and touching numerals. It is observed that the separation method had 98.99% accuracy. The rejection rate of the system is very small. During the numerals separation method we was obtained the isolated numerals from touching numerals. The connected numerals separation algorithm was applied on the same data set to separate the touching numerals. The segmentation results obtained by

Table 1: Different Types of Touching Components and Their Segmentation Results

Original Numeral String				
Segmented Results				

Table 2: Overall Recognition Rate

Bangla Digits	Recognition Accuracy %	Unrecognized Digits %	False Recognition %
0	50	30	20
1	75	25	0
2	70	25	5
3	50	40	10
4	62	30	8
5	60	40	0
6	60	25	15
7	87	13	0
8	65	30	5
9	70	30	0

this method was verified manually and observed that 89.7% of the touching numerals were segmented correctly. The rejection ratio of our segmentation scheme is 10%. The principle features for rejection were:

- The width of one of the segmented part is very small compare to the average width of a digit.
- The segmented part is very dissimilar of the original numerals.

Table 1 shows some numeral strings and their segmentation results obtained by the proposed approach.

In the recognition stage, all segmented numerals are used to classify them. The detail of the ANN for training and recognition was specified by representing the input in the form of matrix. The average root-mean-square error goal was less than 0.01 for this network. The number of iterations in which the network reached the specified error goal is equal to 75000 for all numerals. The learning rate of the network was set to 0.5 (i.e., $\eta_1=\eta_2=0.9$) and the spread factors is 0.25 (i.e., $k_1=k_2=0.25$. The error tolerance level for recognition purpose was fixed at 0.05 or 5%. In this research, the recognition accuracy has been measured for individual numerals. The overall recognition rate for our sample numerals is shown in Table-2. It has been shown that, the recognition rate reduce due to some extra blank pixels which have been connected to the segmented parts of the numerals during segmentation.

CONCLUSIONS

Intelligent segmentation and recognition schemes for connected Bangla digits are proposed here. Although the proposed methods are developed for touching handwritten Bangla numeral segmentation and recognition, the developed methods are tested on printed

Bangla digits segmentation and recognition. It is observed that the accuracy rate on printed numerals is 100%. Therefore, the proposed method can be used to segment both handwritten and printed Bangla numerals string segmentation and recognition. Eliminating the extra blank pixels from the segmented part, the recognition accuracy rate can be improved. In the next studies we plan to develop more improved intelligent approaches to increase the segmentation and recognition accuracy results.

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