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Handwritten Devanagari Numeral Recognition using Structural and Statistical Features

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Abstract: In this paper, the methodology for off-line isolated handwritten Devanagari numeral recognition is proposed. The proposed methodology is based on the structural and statistical feature extraction techniques. Numeral recognition is the important field in image processing and pattern recognition. Handwritten Numeral recognition has received extensive attention in academic and engineering fields. In this proposed method of Hindi Numeral recognition the pre-processing techniques except Binarization like thinning, slant removal are minimized. In this work structural features on the Scanned images of isolated Hindi numerals are applied like left open, Right open, above open, Vertical Crossing, horizontal crossing and so on. These features will help in primary classification of Hindi numeral set and after primary classification more features to recognize individual Hindi Numeral are applied and get the accuracy 96.80%.

Keywords: Devanagari Character Recognition, Off-line Handwriting Recognition, Segmentation, Feature Extraction, Image Classification.

I. Introduction

Recognition of handwritten Numerals has been a popular research area because of its various applications. Some of its application areas are Postal Automation, Bank cheque processing, automatic data entry, etc. Recognition of handwritten Numerals is very challenging task because every person has its own unique characteristics regarding writing of any language characters and Numerals therefore there is a large variation between the writing styles of different authors. To tackle this challenging task robust and compact feature set is being used which is a combination of structural and statistical features.

This Paper is structured as Follows: Section II describes the literature survey on various Feature Extraction techniques, Section III describes the Properties of Devanagari language, Section IV represents Database, Section V represents feature extraction and Section VI represents Feature Set.

II. Literature Survey

The work on handwritten Devanagari numeral is carried by **Hanmandlu et al[1]** and **R. Bajaj et al[2]** proposed three kinds of feature which are moment features, density features and descriptive features for classification of Devanagari Numerals and obtained 89.68% accuracy. **Heutte et al. [4]** combine different statistical and structural features for recognition of handwritten characters. They construct a 124-variable feature vector comprising following seven families of features: 1) intersection of the character with horizontal and vertical straight lines, 2) invariant moments, 3) holes and concave arcs, 4) extremas, 5) end points and junction points 6) profiles, and 7) projections. **Govindaraju et al. [5]** considered gradient features for feature selection of the characters. The gradient features computed using a Sobel operator measures the magnitude and direction of intensity changes in a small neighborhood of each pixel. A gradient map is computed by retaining those gradient magnitudes, which are above a threshold. The feature vector is constructed by concatenating the gradient vectors of the constituent blocks. **Bhattacharaya et al [6]** proposed a Multi-Layer Perceptron (MLP) neural network based classification approach for the recognition of Devnagari handwritten numerals and obtained 91.28% results. They considered a multi-resolution features based on wavelet transform in their proposed system. **N.K.Garg and Simpel Jindal, 2007 [7]** proposed a new feature set for handwritten digit recognition without bothering about improving the recognition rate, which has structural features different from the features taken by most of the researchers like number of junctions, number of loops and number of endpoints etc. The purpose of this paper is twofold. Firstly, they explained by experiments that slant invariant and size invariant features help in developing general software, which is free from some of the pre-processing steps. Secondly, they confirm that pixel counting technique is very useful for deformed images than contour following technique. SVM and Tree classifier are used for classification. Overall 90.3% handwritten digit recognition rate is achieved.

III. Properties of Devnagari Language

Devnagari is the most popular script in India and Hindi is written in Devnagari script. Hindi is very popular language in the world therefore it is an active area of research in India from last years and this work will be very important for the country to avail the automation applications in Hindi language . The alphabet of the Devnagari script consists of 14 vowels and 37 consonants. This script is written from left to right. A Devnagari text line can be partitioned into three zones. The *upper-zone* denotes the portion above the head-line, the *middle zone* covers the portion between head-line and base-line, the *lower-zone* is the portion below base-line.

In this work we are concerned with the recognition of Devnagari numerals only by using combination of structural as well as statistical feature extraction techniques. Data used in this work has been collected from different individuals. For the experiment of Devnagari Numeral recognition we collected 500 samples of Numerals (Exactly 50 samples of each Numeral). A flat bed scanner was used for digitization. Digitized images are in gray tone with 300 dpi and stored as JPG format. We have used an OTSU global binarizing algorithm to convert them to two-tone (0 and 1) images (Here '1' represents object point and '0' represents background point).

IV. Database

Database is composed by collecting a data from the authors of various professions and some part of the database is shown in figure 1a

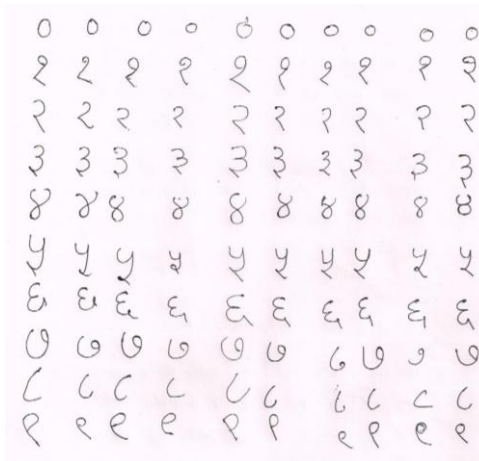


Figure 1a: Part of database

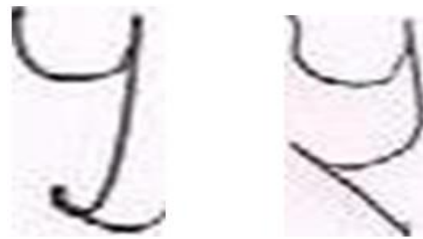


Figure 1b: variation in Hindi numeral five by different authors

V. Feature Extraction

Feature extraction may be defined as the process of finding important attributes from a large amount of data so that the problem of pattern recognition can be solved easily.

A. Statistical & Structural Features

In this category, zoning, moments, *n*-tuples, crossing, lines, curves, spines, extreme points, maxima and minima, cups above and below a threshold, openings to the right, left, up and down [11], cross (X) points, branch (T) points, line ends (J), loops (O), direction of a stroke from a special point, inflection between two points, isolated dots, a bend between two points, horizontal curves at top or bottom, straight strokes between two points, ascending, descending and middle strokes and relations among the stroke that make up a character are considered as features.

Structural features are extracted from each image. The digits are divided into 5 classes depending upon the similarity in features:

Class 1: It includes only digit 0.

Class 2: It includes digits 1 and 9.

Class 3: It includes digits 2 and 3.

Class 4: It includes digits 4, 5 and 7

Class 5: It includes digits 6 and 8.

The size of a single digit has been taken of size varying from 16 * 16 to 300*400 pixels. The pixels of the digit images are stored in two dimensional arrays. Then all features are extracted by manipulation on this two-dimensional array. The percentage of the parts for different features is taken after analyzing data of 500 samples. The following features are extracted from the digits:

(1) **Open from left side of image (F1):** If 80% part of the image has open mouth from left side & has depth near about 73% then it is taken as 1 otherwise 0. **It distinguishes class 3 from other classes.** This feature F1 is used in the recognition of Hindi Numerals two and three. This is represented by taking the example of Hindi numeral three in figure 2.

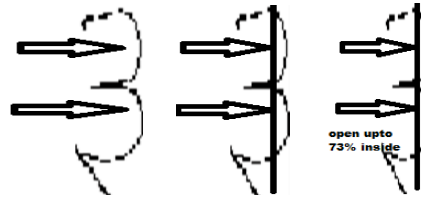


Figure 2: Hindi numeral two with F1=1

(2) **Open from Right side of image (F2):** If 80% part of the image has open mouth from right side & has depth near about 73% then it is taken as 1 otherwise 0. **It distinguishes class 5 from other classes.** This feature F2 is used in the recognition of Hindi Numerals six and eight. This is represented by taking the example of Hindi numeral six in figure 3.

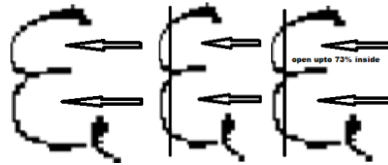


Figure 3: Hindi numeral six with F2=1

(3) **Open from above side of image (F3):** If 80% part of the image has open mouth from above side & has depth near about 43% then it is taken as 1 otherwise 0. **It distinguishes class 4 from other classes.** This feature F3 is used in the recognition of Hindi Numerals four, five and seven. This is represented by taking the example of Hindi numeral five in figure 4.



Figure 4: Hindi numeral five with F3=1

(4) **Open from Below side of image (F4):** If 80% part of the image has open mouth from below side & has depth near about 43% then it is taken as 1 otherwise 0. **It distinguishes class 1 from other classes.** This feature F4 is used in the recognition of Hindi Numeral zero. This is represented by taking the example of Hindi numeral zero in figure 5.



Figure 5: Hindi numeral zero with F4=0

(5) **Vertical crossing of image 76 (F5):** It checks vertical crossing of two consecutive columns of 2-D array of image after 76% portion of image from left side of image. If vertical crossing is greater than six then it is taken as 1 otherwise 0. **It distinguishes class 1 from other classes.** This feature is used in the recognition of Hindi numerals two and three. This is represented by taking the example of Hindi numeral two in figure 6.



Figure 6: Hindi numeral two with F5=1

(6) **Vertical crossing of image 33 (F6):** It checks vertical crossing of two consecutive columns of 2-D array of image after 33% portion of image from left side of image. If vertical crossing is greater than four then it

is taken as 1 otherwise 0. This feature is used in the recognition of Hindi numerals six and eight. This is represented by taking the example of Hindi numeral six in figure 6.

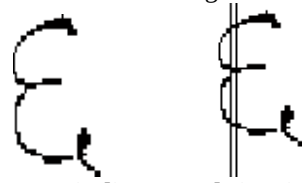


Figure 6: Hindi numeral six with F6=1

(7) **Horizontal crossing below of image (F7):** It checks Horizontal crossing of the below half portion of the 2-D array of image after complete scanning if the two horizontal crossing is greater than six times for the half lower portion then it is taken as 1 otherwise 0. This feature is used in the recognition of Hindi numerals four and five. This is represented by taking the example of Hindi numeral four in figure 7.

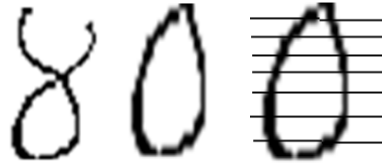


Figure 7: Hindi numeral four with F7=1

(8) **Horizontal crossing up of image (F8):** It checks Horizontal crossing of the upper half portion of the 2-D array of image after complete scanning if the two horizontal crossing is greater than six times for the half upper portion then it is taken as 1 otherwise 0. This feature is used in the recognition of Hindi numerals four and five. This is represented by taking the example of Hindi numeral five in figure 8.



Figure 8: Hindi numeral five with F8=1

(9) **Triple Horizontal Cross (F9):** It checks Horizontal crossing of the whole 2-D array of image after complete scanning if the three horizontal crossing is greater than six times for the half upper portion then it is taken as 1 otherwise 0. This feature is used in the recognition of Hindi numeral seven. This is represented by taking the example of Hindi numeral seven in figure 9.

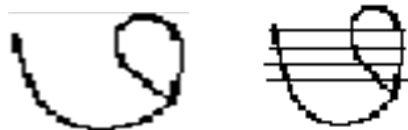


Figure 9: Hindi numeral seven with F9=1

(10) **Distance (F10):** It checks the distance row wise from the below half portion of 2-D array of image and if the distance is in increasing order to the last row of the image then it is taken as 1 otherwise 0. This feature is used in the recognition of Hindi numerals one and nine. This is represented by taking the example of Hindi numeral nine in figure 10.



Figure 10: Hindi numeral nine with F10=1

VI. Feature Set

This feature set is a collection of various features used to recognize or feature combination which is necessary to recognize each numeral individually. This is represented by taking the example of Hindi Numeral four.

A. Recognition of Numeral Four: To recognize Hindi numeral four a feature set of three features is required (F3, F7 & F8). If all these three values are equal to one (F3=1, F7=1 & F8=1) then the tested sample is recognized as Hindi Four.

Three features are used to recognize this particular numeral four.

- I) Open from above
- II) Double horizontal crossing in the above half of figure
- III) Double horizontal crossing in the below half of figure



Fig. 11. Scanned image of hindi numeral four

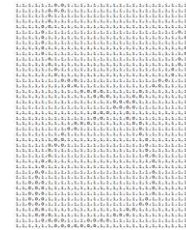


Fig. 12. Digitization of hindi numeral four

- I) Open from above

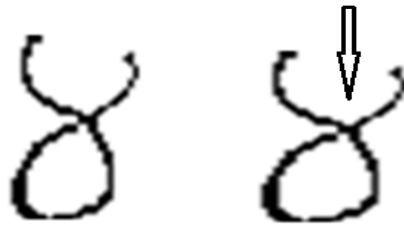


Fig. 13. Hindi Numeral four Open from above

- II) Double horizontal crossing in the above half

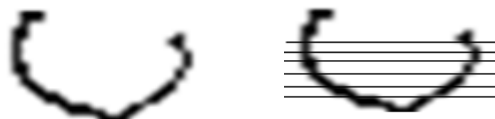


Fig. 14. Double horizontal crossing in the above half of four

- III) Double horizontal crossing in the below half



Fig.15. Double horizontal crossing in the below half of four

VII. Results and Observation

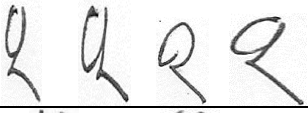
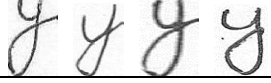
Data used for the present work were collected from different individuals. We considered 500 numerical samples of Devnagari for the experiment of the proposed work and accuracy of individual numeral is shown in Table 1.

Table1. Recognition results of individual numerals

Numeral	Accuracy	Numeral	Accuracy
0	100%	5	92%
1	92%	6	100%
2	100%	7	96%
3	94%	8	100%
4	96%	9	98%
Overall Average Accuracy			96.80%

From experiment we noticed that mainly the error occurred because of the similar shaped numerals. Since the shape of the handwritten Numerals in this pair is very similar, most of the Pair is misclassified. Some pair of Devnagari Numerals which forms the main confusion pairs of numerals is listed in table 2. Maximum error occurred between 3 and 2, 1 and 9, 4 and 5.

Table2. Main Confusing pairs among Devnagari numerals

Class	Classified as	% of error
	2	6%
	9	8%
	4	8%

We compared our current results with those existing pieces of work. Details comparative results are given in Table 3

Table 3. Comparison results for Devnagari Numerals

Sl. No	Method proposed by	Accuracy obtained
1.	Hanmandlu and Ramana Murthy [1]	92.67%
2.	Ramteke et al. [8]	92.28%
3.	Bajaj et al. [9]	89.68%
4.	Bhattacharaya et al.[10]	95.64%
5.	Our Proposed method	96.80%

VIII. Classification

Decision based classifier is used to recognize the Hindi numerals. By using nested if else statements this classifier is implemented in Matlab. Values of various features are collected in feature variables in the form of 0 and 1(0 represents the feature is false for a particular image and 1 represents true). If first condition is true for an input image then the image is recognized otherwise it will check other conditions. If none of condition is not true for an input image then it results that image is not recognized or not present.

IX. Conclusion

India is a multi-lingual and multi-script country comprising of twelve different scripts. But not much work has been done towards off-line handwriting recognition. In this paper a work on Devnagari numeral recognition is presented by using structural as well as statistical feature extraction method and then by applying decision based classifier without using any pre-processing technique except binarization. Dimension features are obtained based on the structure of Hindi numerals. From the experiment encouraging results are obtained. This work will be helpful for the research towards the recognition of other Indian script numerals.

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