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Off-line Recognition of Unconstrained Handwritten Numerals

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Abstract

A fuzzy system for handwritten numerals recognition using a fuzzy Hough transform technique is presented. Membership values are determined as fuzzy sets which are defined on the standard Hough transform vector. Manhattan distance measurement has been used to measure the similarity of an input feature vector to a number of numeral pattern classes. The overall recognition accuracy of the system for the ten numerals is 95%.

1.1-Introduction

Different people write numbers in different shapes. Recognition of handwritten has many practical applications, including mail address and bank check reading. As in any pattern recognition problem, the different approaches to numerals recognition can be classified into two classes: the decision theoretic approach and the structural approach [1]. The decision theoretic approach includes many techniques, such as minimum distance classifier (which is used in this research), matching by correlation, optimum statistical classifier, and multilayer neural networks. In these approaches the recognition is based on the use of a decision function to separate different

classes of patterns. These decision theoretic approaches ignore any structural relationship in a pattern's shape. Structural methods, on the other hand focuses on these inherent relationships and seek to describe certain pattern classes by a formal grammar. The syntactic approach is the most famous approach of the structural class [2].

The variability in handwriting is very large to be characterized by a finite set of rules. One way to deal with variability in handwritten numerals is the use of fuzzy set theory. Fuzzy logic techniques have been used in both decision theoretic approach [3, 4], as well as structural approach [5].

For the recognition of numerals, a suitable feature vector has been extracted via the image matrix of each numeral. The feature vector should be governed by the following conditions [6]:

1- Feature vector of two different numerals should contain major differences between them so that the recognition technique can conclude these differences.

2- Feature vector of a special numeral written by different handwriting should be the same, as the recognition technique could not find a meaningful difference among them.

There are many different methods to recognize Handwritten Numeral. Sadok and Alouani [1] have used the concept of fuzzy logic in a syntactic method to recognize a handwritten numeral. Harfi and Aghagolzadeh, have used neural network to recognize the numerals over an asymmetrical segmentation pattern to obtain the feature vector[6]. AL-Taani, has proposed a structural approach for recognizing on–line handwritten numerals. The slope is estimated and normalized for adjacent nodes. Based on the changing of signs of the slope values, the primitives are identified and extracted[7]. Jaehwa P. and venu G., described a method that uses an active

heuristic function to determine the length of the feature vector as well as the feature themselves were used to classify an input pattern [8].

1.2-Handwritten Indian Numerals description:

In this paper, we consider the description of the numerals used in the eastern Arab countries usually called Indian Numerals. Before being processed by the program, the image is filtered and transformed to a binary image.

A handwritten numeral will be characterized by a certain number of features. The characteristics of each feature as well as the way these features are connected together will make it possible to identify the different shapes of the numeral. We use this terminology to characterize specific points on the outline and to label different types of lines, curves and loops. Those features are useful for handwritten numerals classification:

- Big circles which exist on numerals like ٥،٩.
- Slant lines in numerals like ٨ ، ٧ ،٤ ،٢.
- Horizontal lines in numerals like ٦ ، ٢.
- Vertical lines in numerals like ٩ ، ٦ ، ٣ ، ٢ ، ١.
- Dense circle in numeral like ٠.
- Curve in numeral like ٣.

According to those features of the outline of numerals, the decision will be taken.

2. Methodology

The central idea underlying the method used in the recognition numerals in this paper is the following: A set of features (22 in the present implementation) that can be computed from a pattern image. The bounding box of a 48 pattern of the input image is divided into 48 images to be processed.

Hough Transform is a standard technique for detecting features as lines and curves in a given image[9]. For line detection, it uses a parameterization to map an arbitrary straight line in the image plane to a point in the parameter space. In polar coordinates, a straight line can be described via the equation

$$\rho = X \cos \Theta + Y \sin \Theta \qquad 0 <= \Theta < 180 \qquad (1)$$

Equation 1 describes a mapping of a point in the Cartesian coordinate X-Y plane to the sinusoidal curve in the polar coordinates ρ-Θ plane.

Where ρ is its distance from the origin, and Θ is the angle of it's normal with the X-axis [10].

2.1 line Extraction:

Different lines in each numeral pattern are to be extracted and a number of fuzzy sets are defined to deal with the variation of styles and positions of line segments. All characteristics of the different lines in an image pattern were mapped in to the properties of these fuzzy sets**.** The fuzzy set defines different patterns of lines like (long line, short line, horizontal line, vertical line, slant line,....etc.)

2.2 Circle Extraction:

Similar basic fuzzy sets are defined on the (a,b,c) accumulator cells for circle extraction using the transform

$$c= (X-a)^2+(Y-b)^2 \qquad (2)$$

where (a,b) denote the center of a circle and c, its radius .The fuzzy sets defined for circle extraction include (large circle, small circle, dense circle, sparse circle,....etc). From the fuzzy sets membership functions definitions, it is seen that a non-null support of the fuzzy set implies the presence of the corresponding feature in a character pattern.

The advantage of using fuzzy set membership functions is that the search space is shortened and only the outputs of i^{th} high membership values are considered for the search.

2.3 Similarity Measurements:

The recognition of the numerals requires estimation of *Manhattan distance* between the reference image to all other known images in the data base. Each pattern is represented by the feature vector F_i, i=1,2,3,...p.

Then the *Manhattan distance* between Fj and other feature vectors is calculated by the absolute values of the distance between all the P pattern from i^{th} input pattern, where summation is done over all the feature elements subscripted by j.

The effect of *Manhattan distance* on the recognition accuracy is based on the minimum value of this distance.

3. The Proposed System

The proposed method for recognizing the handwritten numerals is shown in figure 1. The process can be divided into the following stages:

1- Splitting

2- Image centering

3- Digitization

4- Feature vector extraction

5- Symmetrical segmentation pattern

6- Recognition of numeral.

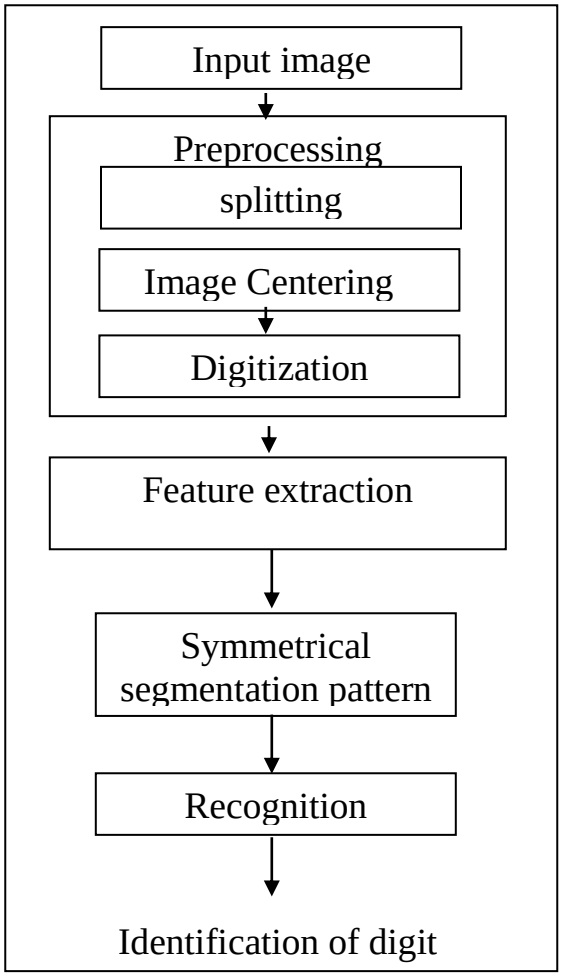
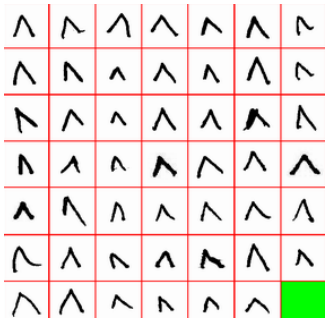


Figure -1 Block diagram of the proposed system

3.1 Splitting

The input image is entered to the system as a collection of 48 samples of each Arabic numeral (Figure.2), written by 48 different persons. In this stage, the entered image is split into 48 images each for a single numeral.



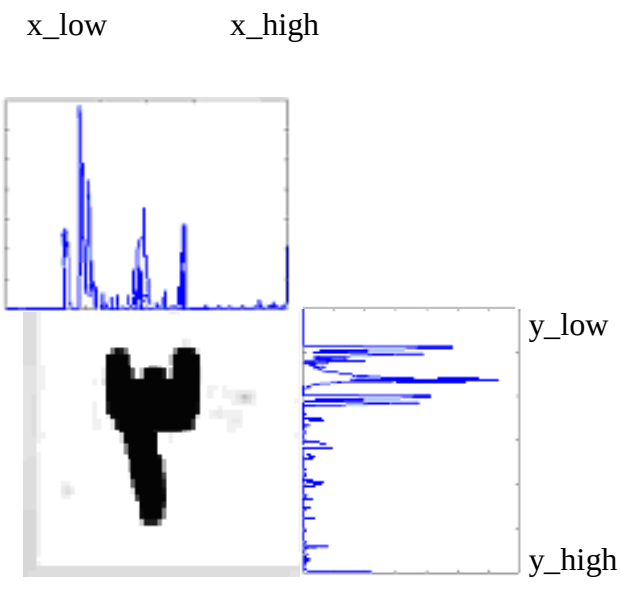
(Figure 2-a) Input Image

(Figure 2-b) Split Numeral

3.2 Image centering

To recognize a hand-written numeral regardless of position and size, some sort of transformation has to be applied. Alternatively, the position and size of the original numeral can be adjusted to standard values, and then applying the classification to the adjusted image. This process of adjustment is called normalization.

The normalization process only trims the image to the area of the writing. From figure 3 the process first obtains the column and row summation of the image, which are the x and y profiles. The point with the maximum value of each profile is set as the center point. Next, from the center point, it searches left/up until a point in which its value is lower than a specified value and then sets it as the lower point of the profile. Again from the center point, it searches right/down for the higher point of the profile. The new rectangle is formed as (x_low, y_low, x_high, y_high).



(Figure -3) Image centering

3.3 Digitization

A heuristic algorithm generates a matrix of 1's and 0's for each image according to the gray level of image. Each black pixel is represented by a 1 and each white pixel by a 0 [11].

Figure-4 shows gray scale levels of the image of the numeral 4 which is used to fix the threshold value as a result of all of the images.

253	253	253	253	253	253	253	253	253	253	253	253	253	253	253	253
253	253	253	253	253	253	253	253	253	253	253	253	253	253	253	253
253	253	253	253	253	253	253	253	253	253	254	255	254	253	253	253
253	253	253	253	253	253	253	254	255	255	247	219	240	255	253	253
255	255	255	255	255	255	254	255	173	114	87	0	63	119	231	255
255	255	255	255	255	255	135	9	8	0	0	0	0	0	210	255
255	255	255	255	255	132	0	0	0	0	0	0	0	107	255	255
255	255	255	255	130	0	0	0	0	0	0	132	182	249	255	255
255	255	255	202	0	0	0	0	5	116	169	255	255	255	255	255
255	255	255	125	0	0	0	0	2	35	153	234	255	255	255	255
255	255	255	255	99	0	0	0	0	0	0	57	239	255	255	255
255	255	255	255	249	168	39	18	9	0	0	0	138	255	255	255
255	255	255	255	255	255	252	255	174	0	0	0	138	255	255	255
255	255	255	255	255	255	255	174	30	3	0	0	138	255	255	255
255	255	255	255	255	242	168	5	0	0	0	48	232	255	255	255
255	255	255	255	251	58	0	0	0	0	43	235	255	255	255	255
255	255	255	255	176	0	0	0	0	163	255	255	255	255	255	255
255	255	255	220	4	0	0	0	160	255	255	255	255	255	255	255
255	255	255	189	0	0	0	151	255	255	255	255	255	255	255	255
255	255	255	60	0	0	0	188	255	255	255	255	254	249	255	255
255	255	255	60	0	0	0	0	96	163	154	155	143	76	160	165
255	255	255	60	0	0	0	0	0	0	0	0	0	0	0	16
255	255	255	207	83	21	4	0	0	0	0	0	0	0	0	0
255	255	255	255	255	255	154	145	61	0	5	5	2	2	0	11
254	254	254	254	254	254	255	255	245	236	237	247	152	140	164	242
253	253	253	253	253	253	253	253	254	255	255	255	255	255	255	255
253	253	253	253	253	253	253	253	253	253	253	253	253	253	253	253
253	253	253	253	253	253	253	253	253	253	253	253	253	253	253	253
253	253	253	253	253	253	253	253	253	253	253	253	253	253	253	253

(Figure-4) Gray scale levels of number 4 image

3.4 Feature Extraction

The main purpose of the feature extraction process is to reduce the number of inputs into the classifier while maintaining the important features or properties of the image. The more meaningful of the features that are extracted, the better this feature extractor is. Additionally, the features must satisfy other desirable requirements such as fast processing speed, low computational cost and low complexity of the feature extraction techniques. Thus, simpler and more powerful features cannot be easily found.

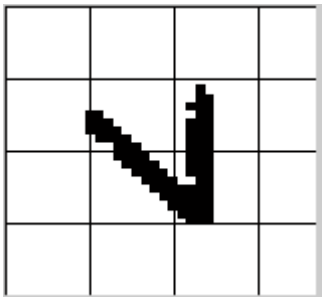
Once the input image is split into smaller units, these units are sent to a module which extracts features of the data, essential to the employed shape classification algorithm.

The actual features, however, are lines of different lengths, orientations, and circles of different sizes. The local feature vectors will produce same length vectors associated with each sample.

3.5 Symmetrical Segmentation Pattern

Elongated and skewed handwritten numerals can extensively affect the feature vector. Therefore a symmetrical segmentation pattern presentation is to be found.

With some modification to the current pattern of the numeral, a 16-segment pattern was used, and a counting of the enclosed pixels in every segment was performed (Figure-5).



(Figure-5) Symmetrical Segmentation Pattern

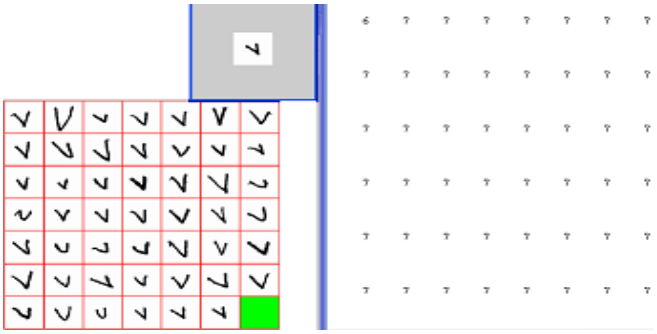
Then a ratio between the numbers of pixels in every segment to the whole number of pixels inscribed in the image has been found.

This pattern in addition to a feature vector was used in the recognition step.

3.6 Recognition of Numerals

Now it is possible to recognize the numerals using two structures: The feature vector and the symmetrical pattern of every numeral.

Each numeral has different shape which was captured by the set of primitives. Each numeral can be described by a specific array of features. Also each numeral has different symmetrical shape. Both have been used to determine to which numeral the primitives collected belong. Figure-6 shows 48 sample of the handwritten numeral 7 as a data base for this numeral with the output result of recognition from the system implemented.



(Figure-6) Recognition Result of the Numeral 7

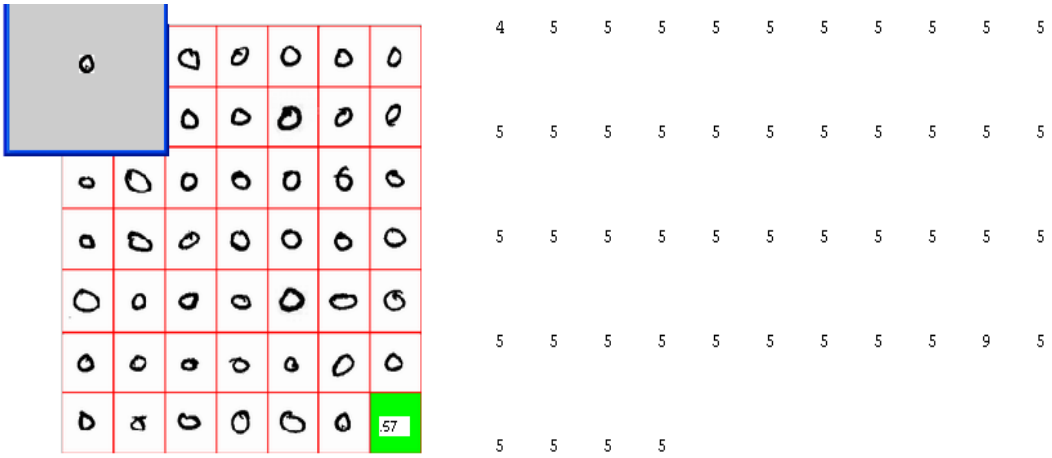
3.7 Simulation Results

The proposed method was simulated to determine its performance. In the training procedure, 480 handwritten numerals from 48 different writers were used. The recognition rate of numerals is shown in Table 1.

Table 1 - Recognition Accuracy of Numerals

Numeral	Accuracy %
0	86.7
1	75.4
2	98.1
3	94.3
4	96.2
5	96.2
6	96.2
7	88.6
8	94.2
9	96.1

Figure 7 shows the results of processing of the numeral 5 as given by the program. The recognition accuracy for this numeral is 92.23 %.



(Figure-7) Results of processing for numeral 5

Conclusions

An OCR system using fuzzy logic has been implemented for Indian numeral recognition from a large number of handwritten numerals.

The proposed recognition system performs rotation and scaling – in variant. Therefore, it achieves high flexibility for the hand writer to make sketches freely.

The feature vector and the mapping vector, which characterizes the numeral is used as input to the recognition system. The output of the system is a decision about the foreign numerals. The advantage of fuzzy sets in Hough transform is that it does not reject any feature in the numeral pattern. Also, the output fuzzy sets enable the system to consider shapes which are suitable candidates for final selection from numerals database by using Manhattan distance as a similarity measurement.

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