

Handwritten Character Recognition Based on Zoning Using Euler Number for English Alphabets and Numerals

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Abstract: Handwritten Character Recognition has been a challenging research domain due to its diverse applicable environment. Handwriting has always been and will possibly continue to be a means of communication. There is a need to convert these handwritten documents into an editable format which can be achieved by Handwritten Character Recognition systems. This considerably reduces the storage space required. In this paper focus is on offline handwritten English alphabets and numerals. Feature extraction is performed using zoning method together with the concept of euler number. This increases accuracy and speed of recognition as the search space can be reduced by dividing the character set into three groups.

Keywords: Aspect Ratio, Euler Number, End Points, Offline Handwritten Character Recognition, Zoning

I. Introduction

Handwritten character recognition has been one of the most challenging and fascinating areas in the field of image processing and pattern recognition. Character recognition is generally defined as machine simulation of human reading. It is also known as Optical Character Recognition. It contributes tremendously to the progress of an automation process and can enhance the interaction between man and machine in a number of applications. There are several research works that have been put forward with its complete focus on new methods and techniques with an aim to cut down the processing time to as less as possible while rendering higher recognition accuracy.

Handwriting recognition is a process that needs training. Training can be carried out using a set of samples of handwriting taken from a group of writers (writer-independent training) or using samples of handwriting from an individual writer (writer-dependent training). From various experiments carried out by researchers it can be concluded that the accuracy of recognizing handwriting is higher in case of writer-dependant training because the text samples from an individual writer are used to train the recognizer.

Character recognition systems can be classified based on 2 major criteria:

a. Data acquisition process

b. Text type

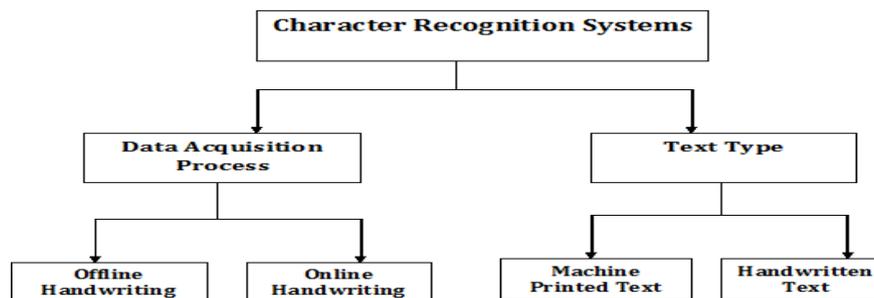


Fig 1.1: categorization of character recognition systems

Data Acquisition Process:

It signifies whether the work is on offline handwriting or online handwriting.

Text Type:

It indicates whether the text is machine printed text or handwritten text.

With respect to the mode of input, handwritten character recognition systems are based on data acquisition process. They are classified into two classes (based on the availability of dynamic information) namely:

- ❖ Online recognition systems
- ❖ Offline recognition systems

Online Recognition

Recognition of handwriting in online mode is usually accomplished using temporal spatial information obtained from the operativeness of a stylus on the surface of an electrostatic or electromagnetic tablet. Timing knowledge is accessible from Coordinate information of strokes.

Offline Recognition

Handwritten character recognition in offline mode takes as input(i.e; the writing) that is available in the form of an image captured through a scanner or a digital camera. Offline recognition utilizes only the static images that have been obtained by a camera or scanner or some other optical devices. As this type of recognition deals only with static data, certainty and accuracy of offline systems cannot reach the heights of online recognition systems, and this is due to the non-availability of dynamic information. This paves a way for off-line recognition to withhold certain exclusive advantages such as the capability to obtain information conveniently and remotely.

Recognition of offline handwriting recognition is usually standardized as a process that consists of conventional stages, resulting into a pipeline. Initially, at the beginning of the process, the text image to be recognized is obtained from a paper document and then this image is passed through a sequence of normalization and filtering operations. The main purpose of this stage is to cut down the unnecessary artifacts resulting from degradation of original document or scanning. Followed by this is the extraction of the text from background and removal of elements not being the pen strokes of the scanned image. In conclusion, the text processing pipeline has its output in the form of sequence of isolated words or character images which can then be fed to the handwritten text recognizer.

Zoning

In the field of recognition of handwritten characters, image zoning is an extensive technique for the extraction of features as it is rightly thought out to be able to manage up with the variability and differences in handwritten patterns. When zoning methods are used for the synthesis of recognition systems, irrespective of the type feature being used, these methods have been widely adopted in order to obtain valuable information on the local characteristics of the character pattern.

In general, Let 'A' be a pattern image, Z be a zoning method then ZM can be thought out to be as a partition of 'A' into M sub images (M being an integer greater than 1). These sub-images are the named zones, (i.e; $ZM = \{z_1, z_2, \dots, z_M\}$) where in each one provides local information on patterns. In the early days, methods based on zoning were extensively put into action for recognition as well as analysis of handwritten characters. In this case, the pattern image under consideration is partitioned into zones and the relevance of the information carried out from each zone is evaluated, in the context of human recognition processes.

The approach of using zoning methods has been exploited in many commercial OCR systems specifically committed to the recognition of machine printed characters, is extensively used in the context of handwritten character recognition. This is possible because of its potentiality to elicitate (extract) the required useful information for recognition aspires to reduce the effects of differences and variation of handwritten characters.

Zoning can be classified based on topologies. There are two main categories:

- ❖ **Static topology:** This topology is designed without making use of aforementioned information on the distribution of features in the pattern classes. In this topology designing of zones is performed based on experimental evidences or according to the basis of experience and intuition of the designer. In this case the zoning methods make use of simple easy grids, which are superimposed on the pattern image. These regular grids determine uniform partitions of the pattern image under consideration into identical shape regions.
- ❖ **Adaptive topology:** This topology is obtained from the outcomes of optimization procedures that are used for zoning designs. In designing such a topology, a lot of information can be used that is most useful for specific classification problem.

1.1 Problem definition

Character recognition is a process of machine simulation of human reading. It is an art of acquiring, cleaning, segmenting and recognizing characters from an image. This process converts the image under consideration into an editable format. Processing of handwritten characters automatically is favourable in many domains like signature and courtesy amount of bank check, data filled in tax, reading zip codes on envelopes. Zoning methods for extraction of features of characters is a very useful method as it concentrates on local characteristics of the characters. Thus it helps to obtain detailed information of characters thus enhancing the process of recognizing characters. Role of character recognition is critical in creating a paperless environment

by converting old handwritten documents into electronic archives. It contributes tremendously to the progress of automation process and thus improving the interaction between man and machine.

1.2 Motivation

It is not an easy task to build a program to achieve hundred percent accuracy for handwritten characters because even humans too make mistakes to recognize characters. Handwritten characters vary depending upon the writer (same or different). So there is always a need to develop an efficient handwritten recognition system. Handwritten character recognition has several potential applications which creates the need for developing such systems in an advanced manner. The process of recognition of handwritten characters is very useful in transforming old handwritten files or documents into an editable format, thus taking a step ahead in creating a paperless environment. It helps to reduce the space required to store the data and makes it flexible to use.

1.3 Objective

The objective is to recognize the objects that describe handwritten characters. The main focus is to recognize handwritten samples of English uppercase alphabets, English lowercase alphabets and English digits. The input to the system should be an image acquired by a scanner and stored in a standard format (.jpg, .bmp, .png etc). The image should be preprocessed to get rid of artifacts present in the image. Features such as euler number and end points of the character have to be calculated.

1.4 The nature of handwriting

HANDWRITING is an ability that is unique and personal to individuals. Its main goal is to exchange information i.e communicate something; this purpose is achieved by virtue of the mark's conventional relation to language. Writing is a way of storing information for later use and is considered to bring forth much of culture and civilization. Each script based on its basic form has a set of representation in the form of icons, which are known as characters or letters that have certain unique basic shapes that differentiate themselves from each other. There are rules for integrating letters to symbolize shapes of grammatical units at a higher level. For example, there are standards for combining the shapes of each letter separately so as to generate written words in cursive manner in Latin alphabet.

Writing, which has been the most common and natural mode of accumulating, collecting, storing and transmitting the valuable data through the centuries, allows interaction among humans as well as aids as an interface between humans and machines. Handwriting of one writer deviates from another as each one has his own control over the writing, thus possess different styles, own speed of writing, different positions or sizes for text or characters. An individual person's handwriting may vary widely in handwriting styles. This variation may take place due to: different moods of writer, writing in various situations that may or may not be comfortable to writer, using different kinds of hardware for handwriting, style of writing same characters with different shapes in different situations or as a part of different words.

II. Literature Survey

Manju Rani and Yogesh Kumar Meena[1] proposed an efficient feature extraction method called cross corner zoning for handwritten character recognition to improve the speed and accuracy of the classifier for pattern recognition. J.Pradeep, E.Srinivasan and S.Himavathi[2] proposed diagonal based feature extraction using zoning for handwritten alphabets recognition system using neural network. U. Pal et al [7] have proposed zoning and directional chain code features. But the feature extraction process is complex and time consuming. Simone B. K. AIRES et al[8]; proposed the perceptual zoning mechanism for handwritten character recognition. S.V.Rajashekararadhya [16] described the zone and centroid based feature extraction algorithm. This algorithm is more suitable for character having curved lines. Impedovo et al. [12,19,20] perform handwritten numeral recognition by using uniform zoning methods. Dinesh et al [6] have used horizontal/vertical strokes, and end points as the potential features for recognition and reported a recognition accuracy of 90.50% for handwritten Kannada numerals. Valveny and Lopez[23], use a zoning method for digit recognition Located on surgical sachets which pass through a computer Vision system performing quality control. In this case, the Authors divide the pattern image into five rows and three columns. The size of each row and column is determined in such away to maximize the discriminating capabilities of the diverse zones of the pattern image. However, this method uses the thinning process which results in the loss of features. Anita Pal & Dayashankar Singh[4], Multilayer perceptron has been used for recognizing Handwritten English characters. A recognition accuracy of 94% has been reported for handwritten English characters with less training time.

Output changes mainly because of the feature extraction methods. Zoning based methods are able to find the local characteristics instead of global characteristics. This will increase the efficiency of recognition of

characters. Finding features such as euler number and the end points of each character helps us to recognize the handwritten characters more efficiently. This will help us to increase the speed of processing as we reduce the search space into three groups.

III. System Design

3.1 Work process of the system

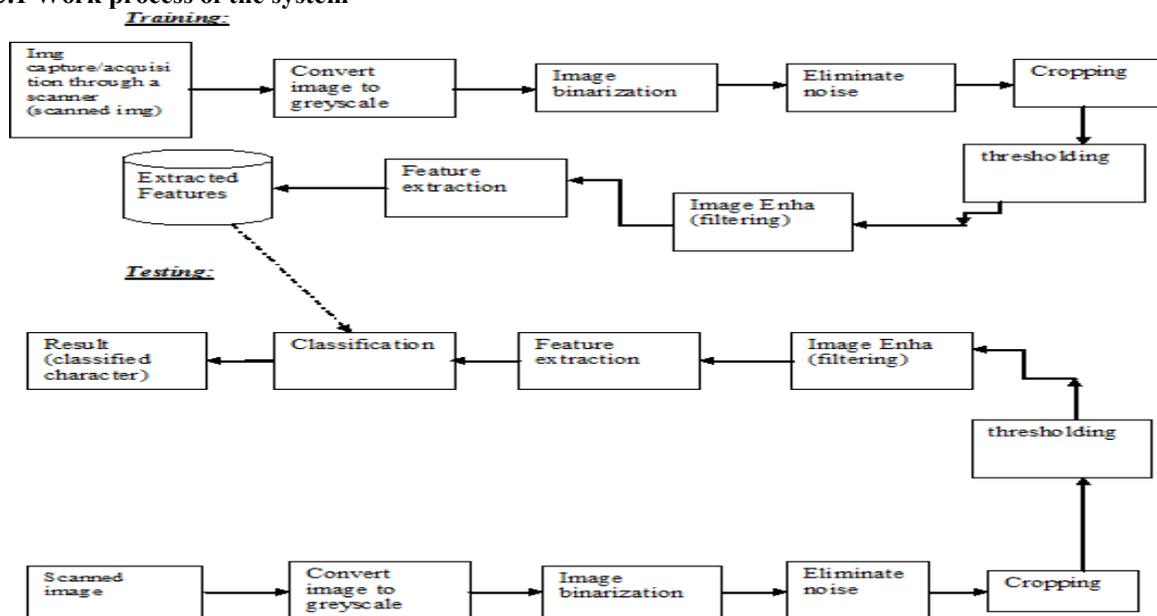


Fig 3.1.1: Block diagram of the proposed system

The system design is as follows:

❖ Image acquisition

In the beginning phase of this process character images are acquired through a scanner and stored into a file. The images can be stored in any format like .jpg, .png etc. These acquired scanned images are in an editable format.

❖ Pre-processing

These images are subject to certain preprocessing operations in order to get rid of unnecessary artifacts in the image that may be available due to image degradation or introduced while scanning the image. This enables to enhance the quality of the acquired image.

Preprocessing of the image is carried out in the following way:-

Binarization

Image under consideration is converted into a gray scale image. This grayscale image is subjected to binarization. Binarization is performed using otsu's method. This converts the gray-scale image into black and white image where in the pixel values of the image are either 0 or 1. Such an image is referred to as a binary image.

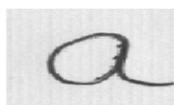


Fig 3.1.2: Original character



Fig 3.1.3: Binary character

Noise removal

In order to remove noise from the image i.e particles other than the necessary character, dilation is used which takes one of its arguments as the structuring element. Usually erosion is used for such purpose but because the background of the image is white in colour in case of our images, dilation is a preferred choice.

Cropping and Resizing

Once the image is free from noise, the extra portion present in the image other than the portion occupied by the character needs to be eliminated so that only the character can be processed. This process is known as cropping. In case of cropping an image, initially the top-leftmost black pixel of the character is first identified, and stored in a temporary variable. Similarly the top-rightmost black pixel, bottom-leftmost black pixel and bottom-rightmost black pixel of the character are identified and stored. These values are fed to the cropping function in order to extract only the character from the image. After cropping the character image, the image is resized to a standard size of 150*150. Resizing function allows us to specify number of rows and columns that are fixed for any character image. So in this case the image is set to have 150 rows and 150 columns. This is taken to be a standard size for all the images to be considered.



Fig 3.1.4: Original Image

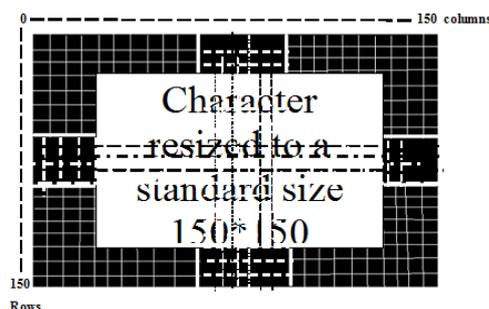


Fig 3.1.5: Resized Image

Thresholding

The resized image is then subjected to thresholding. As the image is in matrix form, firstly maximum values from each column are extracted and stored as a row vector and then maximum value from this row vector is found. Thresholding is performed by subtracting the image matrix from the maximum value.

Morphological operation

In order to proceed with ease for further processing, the character in the image needs to be enhanced. This can be achieved by certain morphological operations. One such operation is dilation. Dilation can be performed either on a grayscale image or a binary image. A structuring element function is used before performing dilation in order to create a morphological structuring element of the type specified by shape and radius. There are two types of structuring elements: flat and non-flat. Flat structuring element includes shapes like diamond, disk, rectangle etc. while non-flat structuring element includes shapes like arbitrary and ball. Output of this function is taken as input to the dilation function along with the image to be dilated. Thus the output of the dilation function enhances the image under consideration for further processing.

❖ Feature extraction

Now the image can be used to extract its features. The method used for feature extraction is zoning. Image zoning is a widely used feature extraction method that helps us to obtain information about local characteristics of the image under consideration.

Initially the image is thought of to be divided equally into 3*3 i.e; 9 zones.



Fig 3.1.6: character 'A'



Fig 3.1.7: character 'A' divided into 9 zones

As there are 3 zone rows and 3 zone columns, and the image is resized to a fixed size of 150*150, each zone will be constituting 150/3 i.e; 50 rows and 50 columns.

Creation of zones: As binarization is performed in initial steps the background of the character is black. So to create the zones the pixels at 50th row, 50th column, 100th row and 100th column are set to 1 (i.e; white) which will form 9 zones as follows,

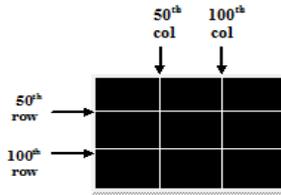


Fig 3.1.8: Creation of 9 zones

These 9 zones are then plotted using the subplot function on one window itself with 9 plots representing 9 zones of the character image considered.

Euler number: Concept of euler number is used which will help to classify the characters. Euler number is defined as the number obtained by subtracting the number of the number of holes in the image from the number of objects in the image. Therefore in case of handwritten character recognition euler number is the difference between number of characters in the image and the number of holes present in the character.

Euler number = number of characters in the image – number of holes in the character
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Eg:

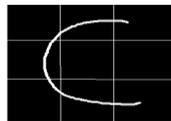


Fig 3.1.9: Character 'C'

In this case the image is of uppercase 'C'. here number of objects is 1 and number of holes is 0. Therefore, **Euler Number = 1 – 0 = 1**

But using euler number alone for classification of English alphabets (26 uppercase, 26 lowercase) and digits was not sufficient as more than one character had the same euler number.

For eg:- characters 'A' and 'D' in uppercase have euler number 0, characters 'M' and 'N' in lowercase have euler number 1, digits '6' and '9' have euler number 0.

End points: And thus the concept of finding the end points of characters was added to eliminate the problem arising from using only the euler number. End points of each character were noted down as to which zones they lie into.

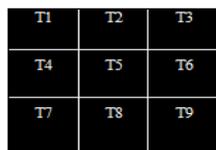


Fig 3.1.10: Zones named from T1 to T9

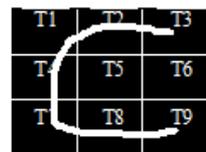


Fig 3.1.11: End-points of character 'C'

In the above fig we can see character 'C' divided into 9 zones. We can infer from the fig that the end points of character 'C' lie in zones T3 and T9.

❖ Now the combination of euler number and end points was used to recognize the characters uniquely. But this attempt too failed, as there were few characters which had the same combination for euler number and end point.

For eg:- uppercase alphabet 'H' has euler number 0 and 4 end points and 'K' has euler number 0 and 4 end points with its end points lying in the same zones as that of 'H'.

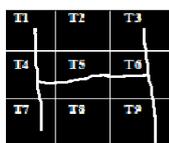


Fig 3.1.12: character 'H' with its end points in zones T1,T3,T7 and T9

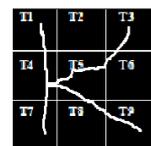


Fig 3.1.13: character 'K' with its end points in zones T1,T3,T7 and T9

Aspect ratio: To overcome this problem, aspect ratio in each zone was calculated. Based on the aspect ratio, zonemap of the character was created which identified the character uniquely. Thus 5 types were created depending upon aspect ratio:-

Type 0:- if aspect ratio = 0, it indicates no end point exists in the zone.

Eg:-



Fig 3.1.14: One of the zones out of 9 zones

It does not contain any pixels of the character so this zone will be assigned value 0.

Type 1:- if aspect ratio = 1, it indicates the presence of an end point in the zone.



Fig 3.1.15: Case 1



Fig 3.1.16: Case 2

Case 1: In this case the pixels of character do not touch the bottom, top and the right side of the zone and hence values of bottom, top and right are changed. This case is used to indicate the presence of an end point and the respective zone is assigned value 1.

Case 2: In this case the pixels of the character do not touch bottom, top and left side of the zone and hence values of bottom, top and left are changed. This case too is used to indicate the presence of an end point and the respective zone is assigned value 1.

Type 2:- if aspect ratio ≥ 4 , it prints value 2 for that zone in the zonemap.

Eg:



Fig 3.1.17: Example for aspect ratio ≥ 4

Type 3:- if $0 < \text{aspect ratio} \leq 0.25$, it assigns value 3 for that zone in the zonemap.

Eg:



Fig 3.1.18: Example for aspect ratio > 0 but ≤ 0.25

Type 4:- if $0.5 \leq \text{aspect ratio} < 4$, it assigns value 4 for that zone in the zonemap.

Eg:

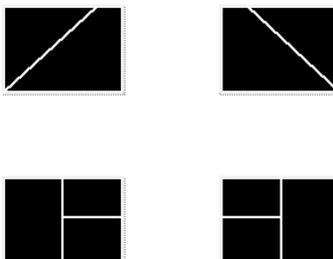


Fig 3.1.19 Examples for aspect ratio ≥ 0.5 but < 4

❖ Thus the combination of euler number and zonemap of characters are used to recognize the characters without ambiguity.

5.2 Applications

Character recognition is a basic, fundamental topic but most challenging and an active area of research in the field of pattern recognition with wide range of useful applications. Recently character recognition has gained a lot of attraction in this field as its applicability has spread out to a number of different fields.

Handwritten Character Recognition is convenient for applications like resolution of handwritten postal address, historical document recognition, cheque processing in banks, on-line signature verification, almost all kind of form processing systems and many more. Character recognition system may be viewed as a factor which is a key determinant for digitizing and processing existing paper documents to create a paperless environment.

Character Recognition system is also useful in handwritten word recognition. The current exploration looks deeply into developing constrained systems for limited domain applications such as sorting of cheques, reading of postal addresses, automation in office for text entry and tax reading. As there is a scope to use the entire word at once, there is a clear feasibility for exploitation of correlations between adjacent characters. One of the possible option to do this is to make use of a dictionary of possible words and contextual knowledge of syntax, which has been seen to succeed in case of reading handwritten address information of postmarked mail.

Script recognition is another potential application of Character Recognition systems. Based on the potentiality of Character Recognition systems their applications have been extended in newly emerging areas, such as development of multimedia database, systems which require data entry to be handwritten and electronic libraries. When various applications of these systems are considered, it can be noted that most of the applications require handwriting recognition systems in offline mode. In effect to these demands, off-line handwriting recognition gains a lot of importance and thus proceeds to be an active area for intensive research towards the exploration of effective and new techniques that would contribute to the improvement of recognition accuracy.

IV. System Requirements

4.1 hardware requirements

- ❖ Scanner With 600DPI Resolution
- ❖ Intel i7 920 CPU running at 2.66GHz and 4GB RAM

4.2 software requirements

- ❖ Matlab 6.1 or Higher Version
- ❖ WIN OS

V. Implementation

5.1 Algorithm (training)

Input: Scanned character image

Output: Features extracted

Method:

- Step 1: Collect samples(images) of handwritten English characters.
- Step 2: Scan the collected samples(images).
- Step 3: Convert the image to a grayscale image.
- Step 4: Perform binarization.
- Step 5: Eliminate noise from image.
- Step 6: Crop the image.
- Step 7: Resize the image to a standard size
- Step 8: Perform thresholding.
- Step 9: Enhance the image for further processing.
- Step 10: Perform zoning on the character image.
- Step 11: Divide the character image into 3*3 i.e;9 zones.
- Step 12: Determine the euler number of the character.
- Step 13: Unique euler number generates a separate class.
- Step 14: Assign the characters to the class based on its euler number.
- Step 15: Find the end points of the character.
- Step 16: Calculate the aspect ratio of each zone to determine the presence of end point.
- Step 17: Store end points in the form of a zone map in the class file.

5.2 Algorithm (testing)

Input: Scanned character image

Output: Classified character

Method:

- Step 1: Select the image to be tested

- Step 2: Convert the image to a grayscale image.
- Step 3: Perform binarization.
- Step 4: Eliminate noise from image.
- Step 5: Crop the image.
- Step 6: Resize the image to a standard size.
- Step 7: Perform thresholding.
- Step 8: Enhance the image for further processing.
- Step 9: Perform zoning on the character image.
- Step 10: Divide the character image into 3*3 i.e;9 zones.
- Step 11: Determine the euler number of the character.
- Step 12: Find the end points of the character.
- Step 13: Calculate the aspect ratio of each zone to determine the presence of end point.
- Step 14: Based on the euler number check the character class for a matching zonemap.

VI. Results

6.1 Snapshots for uppercase english alphabets



Fig 6.1.1 Graphical user interface with main menu

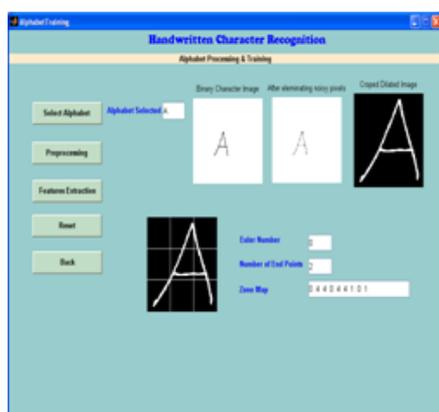


Fig 6.1.2: Alphabet processing and training



Fig 6.1.3: Alphabet recognition



Fig 6.1.4: Word preprocessing

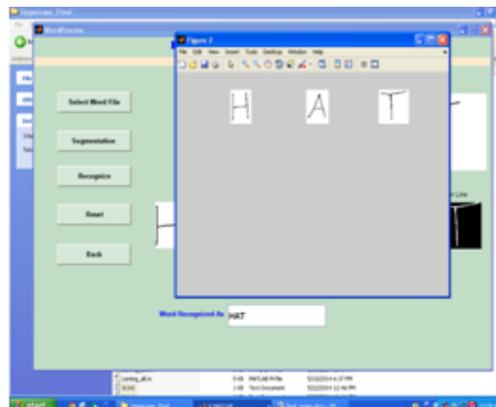


Fig 6.1.5: Word segmentation into individual characters

6.2 Snapshots for english digits

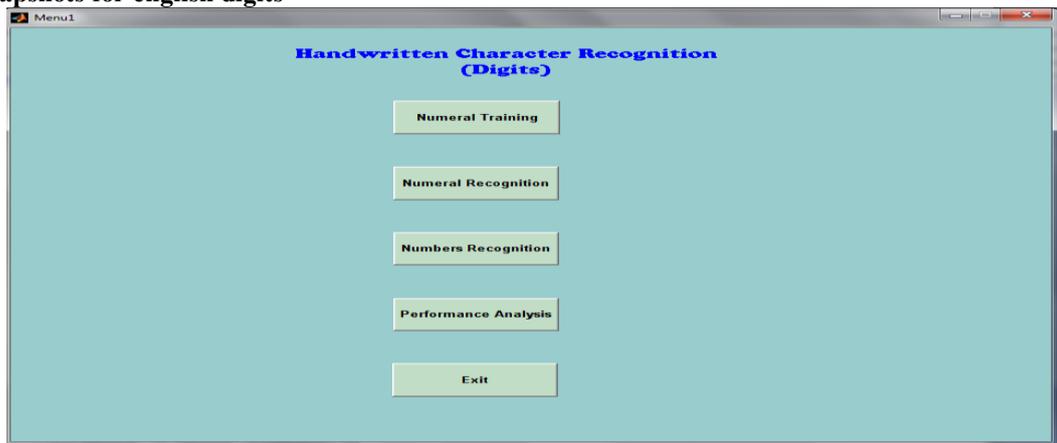


Fig 6.2.1 Graphical user interface with main menu



Fig 6.2.2: Numeral processing and training

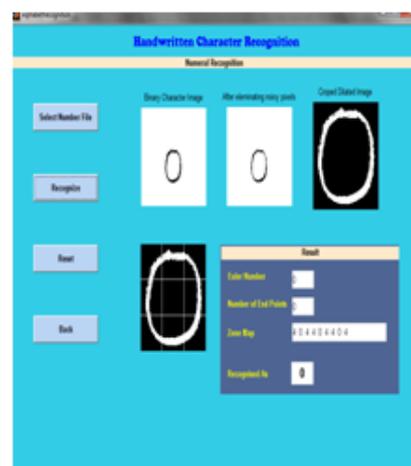


Fig 6.2.3: Numeral recognition

6.3 Snapshots for lowercase english alphabets

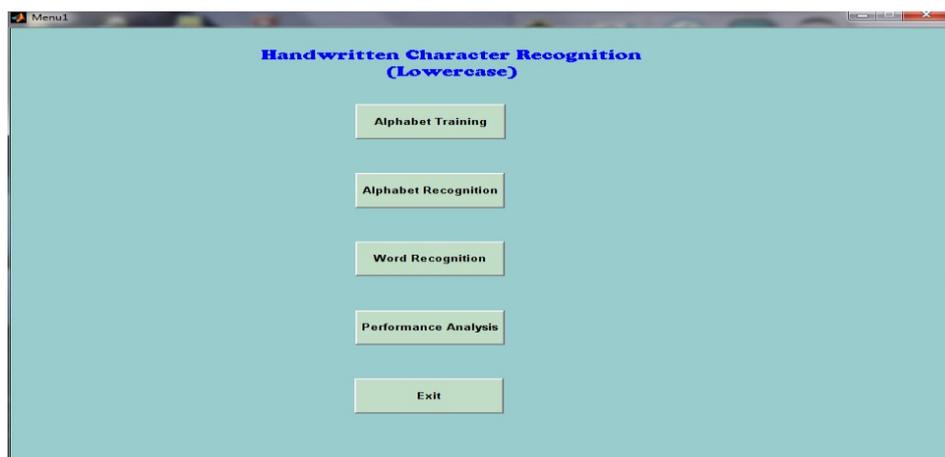


Fig 6.3.1: Graphical user interface with main menu

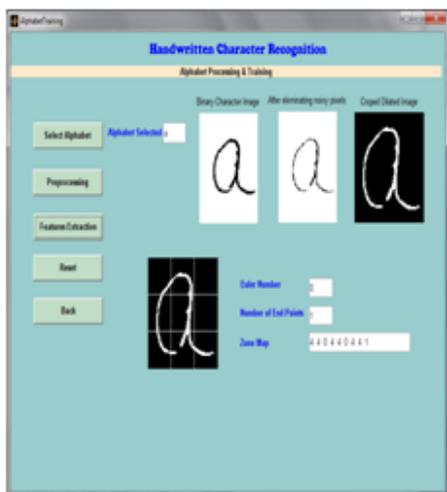


Fig 6.3.2: Alphabet processing and training

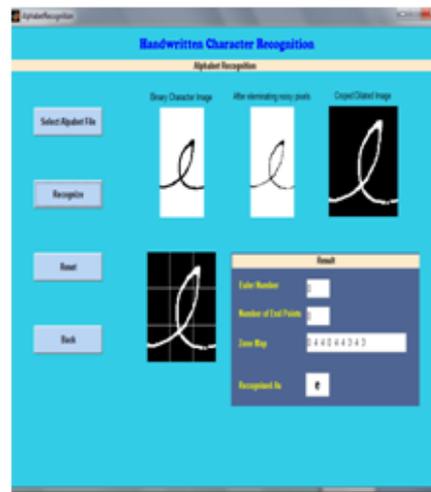


Fig 6.3.3: Alphabet recognition



Fig 6.3.4: Word preprocessing



Fig 6.3.5: Word segmentation into individual characters

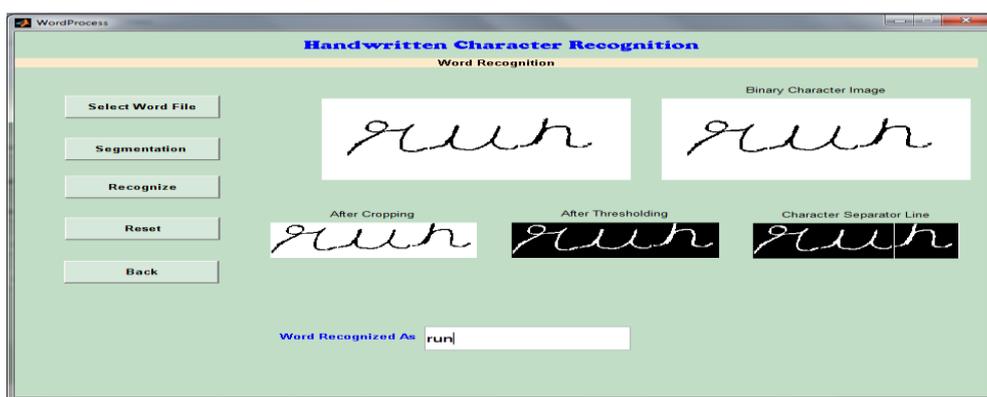


Fig 6.3.6: Word recognition

VII. Performance Analysis

Dataset description: Dataset consists of total of 1550 number of samples of uppercase English alphabets, lowercase English alphabets and English numerals. Three sets of uppercase English alphabets are tested, three sets of lowercase English alphabets are tested and three sets of English digits are tested for recognition. Images of different formats are considered to enhance the flexibility of the project. Images from different writers are used. Thus slight variance in writing styles is also taken into account.

$$\text{Accuracy (Recognition rate) } = \frac{\text{Number of characters recognized correctly}}{\text{Total number of characters}}$$

Analysis performed for uppercase English alphabets:
Total number of characters trained=130
Total number of characters tested=520
Total number of characters recognized correctly=474
Total accuracy=91.15%

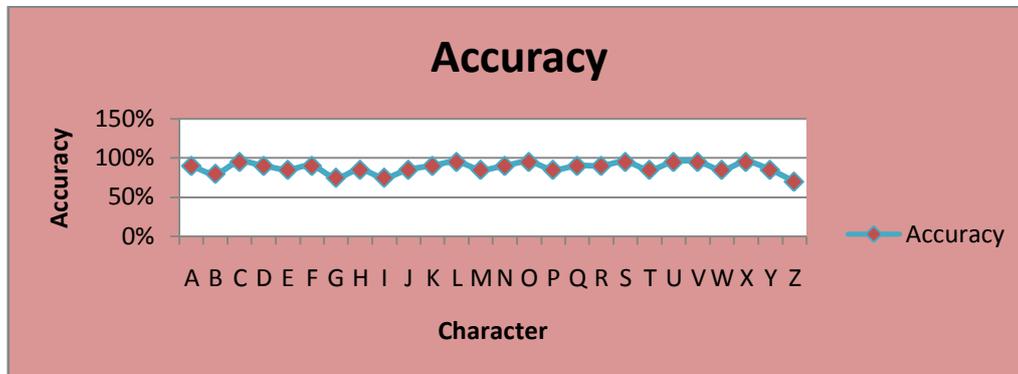


Fig 7.1: Analysis representing accuracy levels for uppercase alphabets

Analysis performed for lowercase English alphabets:
Total number of characters trained=130
Total number of characters tested=520
Total number of characters recognized correctly=471
Total accuracy=90.57%

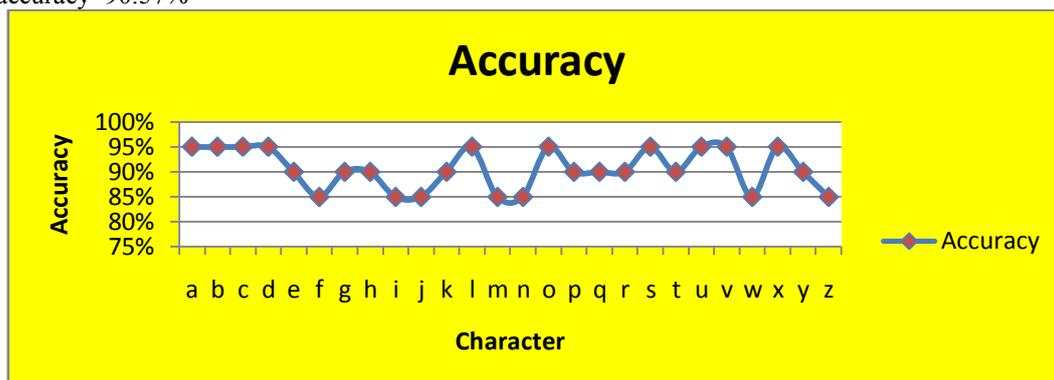


Fig 7.2: Analysis representing accuracy levels for lowercase alphabets

Analysis performed for digits written in English:
Total number of characters trained=50
Total number of characters tested=200
Total number of characters recognized correctly=182
Total accuracy=91%

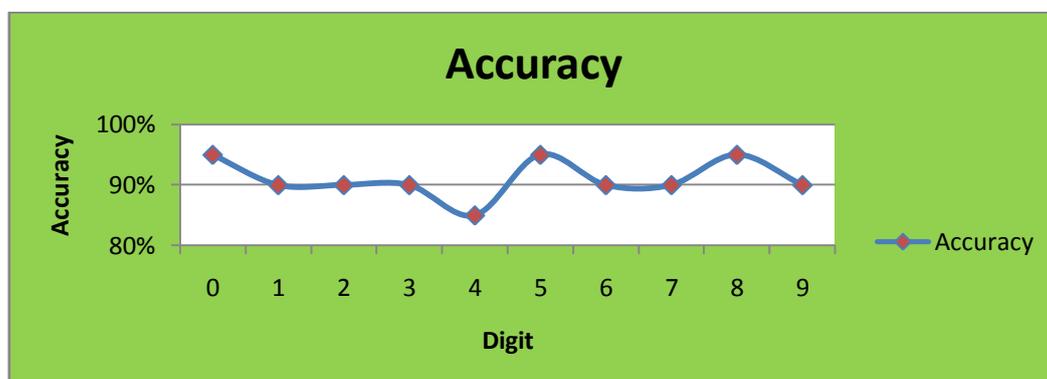


Fig 7.3: Analysis representing accuracy levels for digits

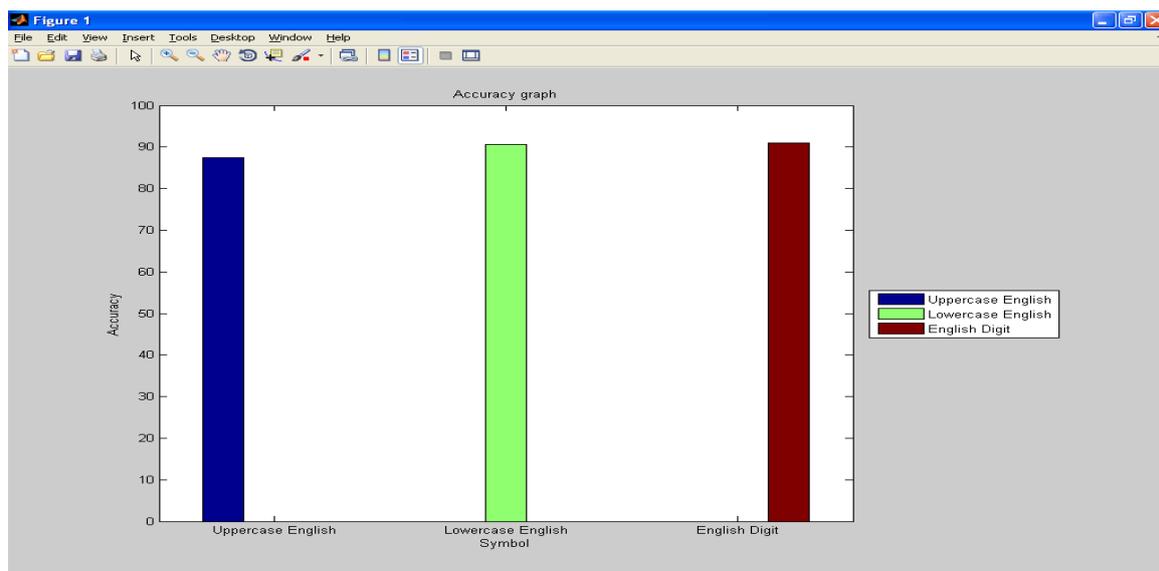


Fig 7.4 : Graph showing total accuracy for uppercase alphabets, lowercase alphabets and digits.

VIII. Conclusion

It is quite evident from the experimental results that the analysis performed on handwritten English alphabets (uppercase and lowercase) and digits highly depends on the style of an individual writer. The accuracy differs when different writers are considered. As well, if the writer writes in a standard way then it is more easier to recognize by the above proposed method.

Future Scope

This work can be extended to writing involving different directions like handwriting towards left or right or slant. As the variability in directions are involved it is challenging to take up this as a task. In case of words, if the same writer writes the characters with variation in size then it is difficult to recognize it as a single word. This issue needs to be addressed in future.

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