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ABSTRACT

This paper describes reviews for the handwritten Gujarati numerals recognition system. Gujarati numeral recognition is more important aspect that gets less touch. Needs several steps and database of numerals to perform Gujrati numeral recognition. The database is collected from various sources like persons of different age groups, educational groups etc. In this paper literature review describes the different techniques of Gujrati numerals recognition. Digitized image is first scanned by scanners. Then image are converted into uniform sized image and performs various pre-processing operations like median filter, wiener filter that helps to remove noise from image. Other operations such as binarization, grayscale conversion helps in to clarifying image. Classifiers are used to classify the images by using different features which are extracted by feature extraction methods. Different classifiers results may varied from one to another.it also depends on the various aspects like methods used for pre-processing, feature extraction and segmentation.

Table of Contents

List of Figures

List of Tables

Abbreviations

OCR	Optical Character Recognition
HCR	Handwritten Character recognition
SVM	Support vector machine
HMM	Hidden Markove Model

Chapter 1. INTRODUCTION

Optical character recognition (OCR) is useful in many areas of the research like pattern recognition, artificial intelligence and computer vision. Optical character recognition provide editable text from the image or printed document. One significant reason for the lack of research activity in the area of Gujarati handwritten character recognition is unavailability of benchmark or standard database [7]. Around the world there are many peoples whose mother tong is Gujarati and numerals are also a part of the Gujarati text. Now Handwriting recognition has been a popular area of research since few decades under the preview of image processing and pattern recognition. A major goal of pattern recognition research is to create human perception capabilities in artificial systems. The task of automatically reading handwriting with close to human performance is still an open problem and central issue of image processing [11].

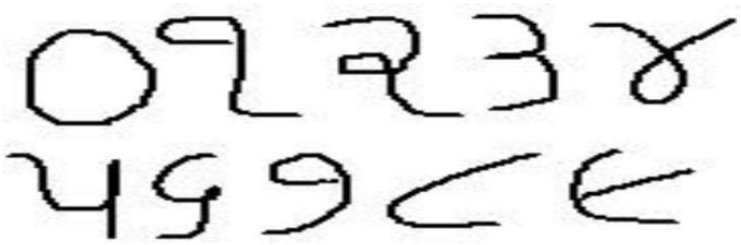

Figure 1 Handwritten numerals [8]

Several ways are available to collect the information from user like speech recording, handwritten etc. While in speech recording if speech is recorded at the crowded area then it is difficult task to get clear information from that noisy speech [6]. Information collected by handwritten document or paper provides direct information without noise. In handwritten character recognition, there are lots of problems as compared to machine printed character because of each person having different handwriting styles, the size of pen-tip and some people having skewness in their writing [5]. Recognition of handwritten characters is difficult task due to large degree of variability of human handwriting like size, shape, slant etc. **[**11, 3**]**. Gujarati numerals contains many variation as compare to English numerals that increases complexity in recognition. Because Gujarati numerals having more curves and similarities in a numerals so there higher rate of misclassification [6]. Recognition of gujrati numerals is necessary because text may contains numerals, for

example zip codes in address, bank cheque, aadhar card numbers, pan card numbers, government documents such as FIR, court files etc [9]. To read information from this kind of document we need system that can also recognize numerals. Recognition of handwritten numeral is not a single process. It is combination of many processes such as Digitization, Pre-processing, Feature extraction and Classification.

1.1. OCR

OCR is widespread technology that enables you to convert different types of documents, such as scanned paper documents, PDF files or images captured by a digital camera into editable and searchable data. Once a scanned paper document went through OCR processing, the text of the document can be edited with word processors like Microsoft Word or Google Docs. Before OCR technology was available, the only option to digitise printed paper documents was to manually retyping the text. Not only was the massively time consuming, it also came with inaccuracy and typing errors.

1.2. Types of OCR

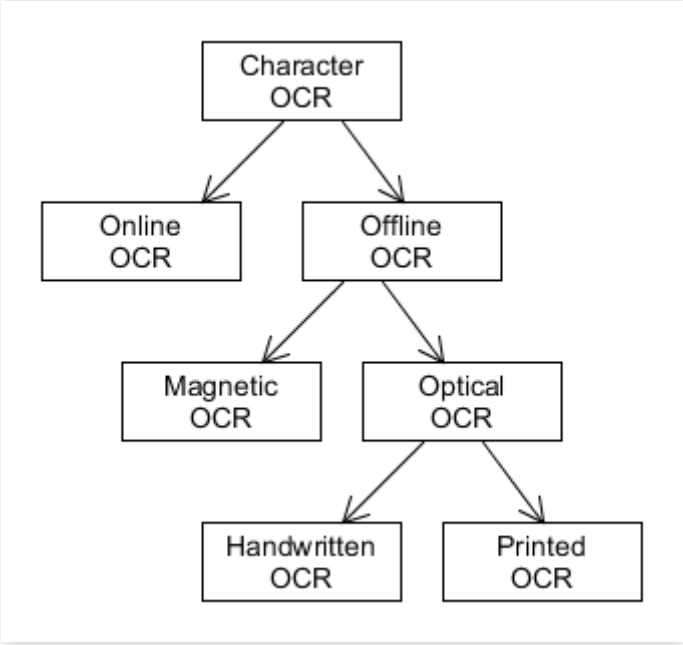

Figure 2 Type of OCR

1.2.1. Online OCR

Online system deals with x-y coordinates since the data is gathered through a device like a tablet or a smart phone. If machine recognizes the writing or text while user writes then it is known as online OCR **[**9**]**. The term real time or dynamic has been used in place of online. In online machine captures data as person writes. Online data are recognized immediately by most of the application in appropriately. Online devices Captures temporal or dynamic information of writing. This information consist of number of stroke, the direction of each stoke and speed of the within each stroke. A stroke is the writing from pen down to pen up. Online recognition may not require much pre-processing on data. And it recognize fast then offline recognition with better accuracy.

Online character recognition system needs to be fast enough keep up with writing. Online handwriting recognition requires a transducer that captures the writing as it is written. The most common of these devices is the electronic tablet or digitizer, which typically has a resolution of 200 points in a sampling rate of 100 points/s, and an indication of "inking" or pen down. The advantages of online recognition are interactivity and adaptability.

1.2.2. Offline OCR

In offline character recognition is performed after writing gets completed. It can be performed days, month, and years later. An optical scanner converts that image into a bit pattern. Offline character recognition is subset of optical character recognition

Let's say, you are trying to recognise the characters from a picture then, it is offline OCR [9]. In offline character recognition data captured after sometime of the writing is created or inputted by some user activity directly or indirectly. In offline character recognition data are recognized whenever it needs. Offline recognition need to perform pre-processing steps to make enhancement in data (image) condition to it clear for next step. The advantage of offline character recognition is that we can perform recognition at any time.

Further offline character recognition is divided into two parts.

1. Machine printed character recognition

Machine printed characters are printed by the machine like computer or type writer. Machine printed character recognition uses intelligent document recognition technology to read the pattern of the text on the physical paper and convert them accurately in digital format. Apart from that, companies are using it to digitise all paper works so that they can become paperless and more efficient. They also use it to preserve the physical paper texts in digital form for future reference.

Figure 3 Machine printed characters

Traditional machine printed character recognition where one character is read at a time, machine printed word recognition where one word is read at a time, and intelligent character recognition where the handwritten text is interpreted accurately and transformed into digital format. Machine print character recognition is used widely in data entry and data processing businesses for reading machine print documents such as bank statement, official documents and likewise. It is used in reading number plates so that all the information of a particular vehicle can appear instantly on the machine.

2. Handwritten character recognition

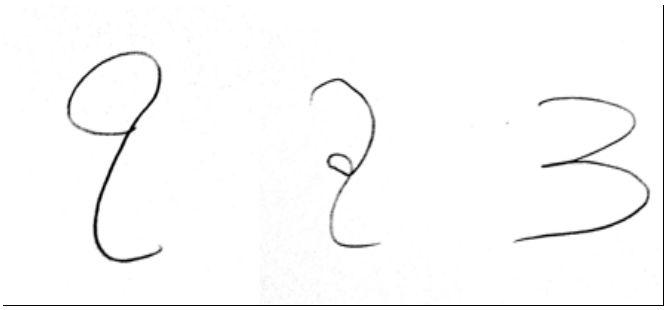

Figure 4 Handwritten numerals

Handwritten character recognition systems obtains text from the handwritten paper documents or images and make it in editable formats such as word document. As compare to machine printed character recognition, the work done in handwritten character recognition is very limited as mentioned in [12]. Also handwritten character recognition have huge amount of variety in data because in every persons handwriting

differs from another person in various ways like size, shape etc. This make handwritten character recognition character difficult.

Handwriting recognition entails optical character recognition by principally. We also follows the similar steps for HCR as followed in OCR. To perform HCR we need to perform steps like segmentation, pre-processing, the accuracy of HCR depends upon this steps also. Two way are available to recognize handwritten characters. One is OCR and second is intelligent word recognition. Handwritten character recognition works based on the handwriting samples which are stored in database and algorithm used to perform recognition.

1.3. OCR Process

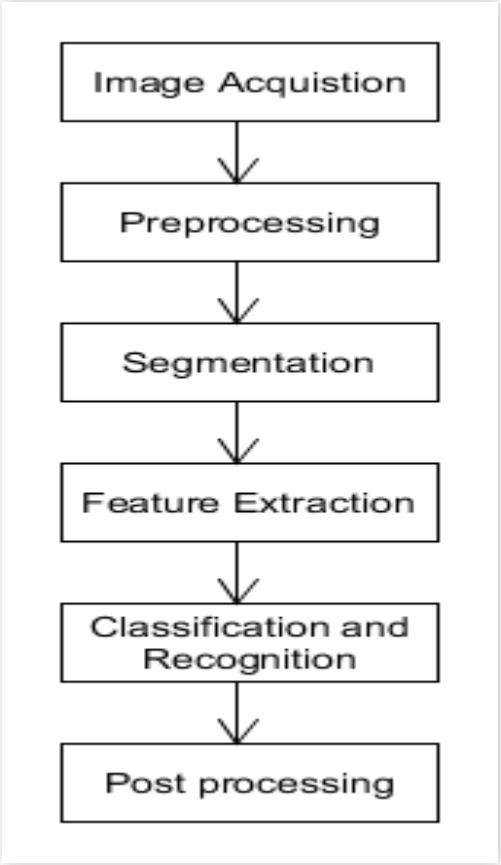

Figure 5 OCR Process

1.3.1. Image Acquisition

Image acquisition includes gathering images (data) form the source for recognition. We can take image data from every individual, internet etc. Recognition accuracy rate also

depends on image (data) condition due to variations in writing style of individual who belongs to different age group, gender, educational levels. The samples for recognition is taken from the person and database created manually. Generally dataset is divided into two parts training and testing dataset [9].

I. **Training dataset :**

Training dataset are used at the time of training algorithm. Training dataset is a taken from the overall dataset. If the training data is better than classifier or algorithm performs better

II. **Testing dataset**

Model is trained by the training dataset, after that testing dataset to test the model or algorithm. Testing dataset is also part of overall dataset.

1.3.2. Pre-processing

Pre-processing of an image comprises of improvement in its appearance and effective representation of input image suitable for required application. Pre-processing includes Binarization, median filtering, resizing and thinning operations etc. First, these images are converted into binary images using Otsu's thresholding algorithm. Median filter is applied in order to remove salt and pepper noise from the image and to fill holes in object region. All the numeral images are resized to the size of 16*16 pixels with nearest neighbourhood interpolation algorithm. After resizing, one pixel wide thinned image is obtained using morphological thinning operation.

Pre-processing steps helps to make image clear for the next recognition steps. The size of different noise removal filter mask make different in output.

1.3.3. Segmentation

Image segmentation is the division of an image into regions or categories, which correspond to different objects or parts of objects. Every pixel in an image is allocated to one of a number of these categories.

1) **Structural Segmentation Techniques**:

The structural techniques are those techniques of image segmentation that relies upon the information of the structure of required portion of the image i.e. the required region which is to be segmented.

2) Stochastic Segmentation Techniques

The stochastic techniques are those techniques of the image segmentation that works on the discrete pixel values of the image instead of the structural information of region.

3) Hybrid Techniques

The hybrid techniques are those techniques of the image segmentation that uses the concepts of both above techniques i.e. these uses discrete pixel and structural information together.

Segmentation methods which are used to perform segmentation on the image

1) Threshold based segmentation
2) Edge based segmentation
3) Region based segmentation.
4) Clustering techniques
5) Matching

There are three properties of image segmentation **I)** ROI should be a subpart of the full image, R1, R2 …Rn R where R is full image and R1, R2.. are the ROI or segmented parts of image. **II)** Multiple regions cannot have redundant features of an image. **III)** ROI should contain invariant image features like colors invariant, size and shape invariant **[13].**

Segmentation plays an important role in numeral recognition because not every time numeral as single image. To extract numeral image from the given document or image segmentation is required because it may contains characters. Segmentation also used for to extract the ROI (region of interest) from image.

1.3.4. Feature Extraction

Feature extraction is a crucial step of image recognition if feature extraction is not done properly then it may be possible that then recognition gives low accuracy rate. The main objective of feature extraction is to extract all the essential characteristics of the numeral image. Each numeral image has some set of features which are extracted. The selection of the appropriate feature extraction method is probably the single most important factor in achieving high recognition performance. So, the extracted features should be able to classify each numeral uniquely [3].once feature extraction gets complete then features are converted into classifier acceptable format [7].

Feature extraction methods are grouped into three types of classes: structural, statistical and hybrid [4]. Here structural techniques uses qualitative mesurement, statistical techniques uses quantitative mesurement and hybrid technique is combination of both structural and statistical features used for recognition [3]. Shapes of Gujarati numeral are close to one another. Therefore the complexity is high for recognition of Gujarati characters.

1.3.5. Classification and Recognition

There are different classifiers are used to classify and recognize the pattern of given images. Classification phase is the decision making phase of the numeral recognition system [3].This phase uses features which are extracted during feature extraction step. There are many classifiers are available for recognition like neural network, SVM, KNN etc.

Every classifier produce the different accuracy result based on previously performed steps. Example of classifiers neural network, support vector machine, hidden markov model nearest neighbour etc. Since all classifiers are two class classifiers, test feature vector is classified in either of two classes by each classifier. By voting strategy it calculate number of times image is classified in each class. At the end testing point is designated to be in a class with maximum numbers of votes.

1.3.6. Post Processing

The text obtained by OCR systems often suffers from low accuracy owing to irregularities in images, poor scans or simply the nature of arrangement of letters in a word. For example, reading “lea” instead of “tea”, “ia” in-stead of “is”, “m” instead of ”rn”, to name a few. These erroneous characters severely hamper the quality and readability of a converted document. The main goals of OCR post-processing methods are error detection and correction. Different approaches are used for the OCR post-processing which are manual error correction, dictionary-based error correction, and context-based error correction.

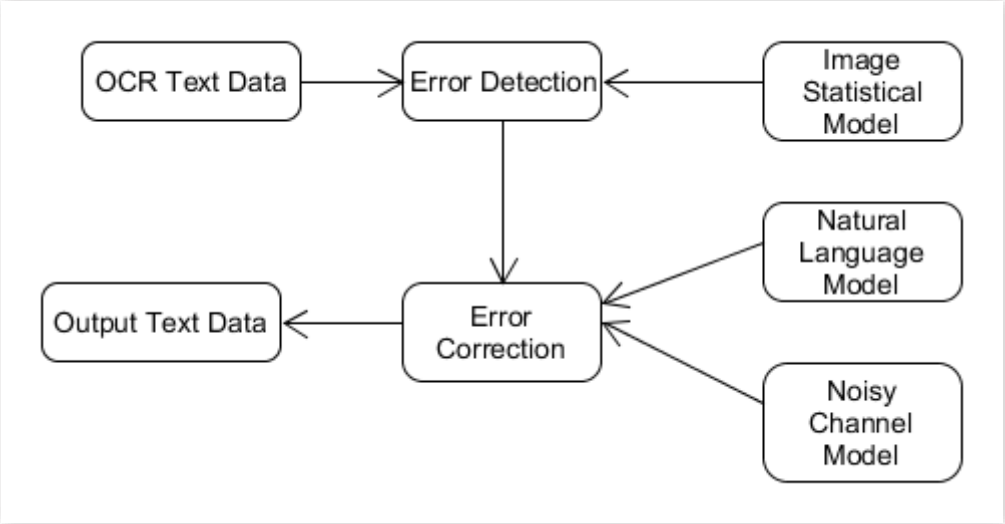

Figure 6 Post-processing process

Printed books may contain many challenges when they are converted into text such as different fonts, colors, and touching character at the edges. This makes the text segmentation not an easy task. In addition, after scanning the document the obtained images may contain blur or curved lines. These challenges may produce a text document with many errors [14]. In order to minimize these errors, the OCR post-processing methods are used In OCR text correction is an important and challenging problem that needs to be addressed to facilitate digitization.

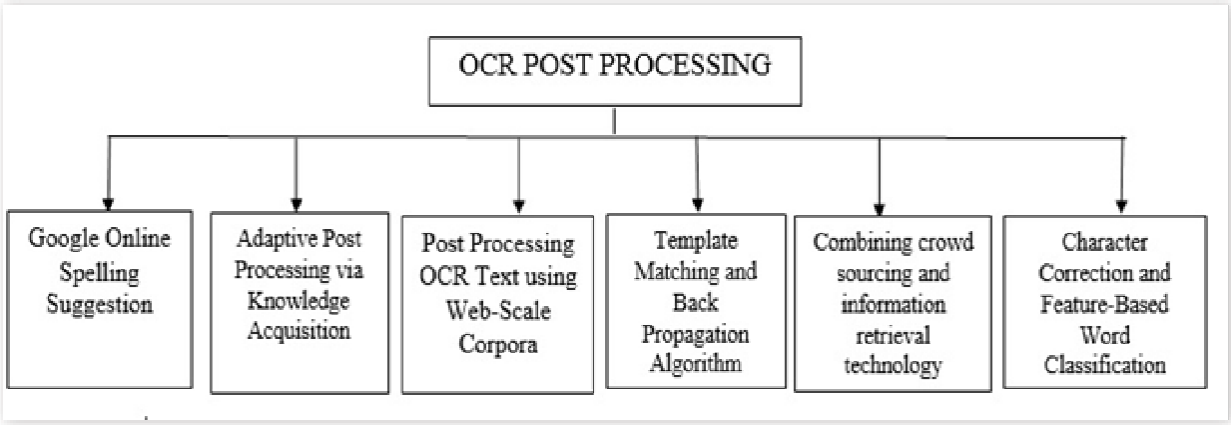

Figure 7 OCR post processing techniques

Here this diagram describes about some post-processing techniques.

Chapter 2. Literature Review

2.1 Pre-processing Literature Review

In [1] this paper Author have worked on feature extraction where she attempt to apply a technique based on affine invariant moments for feature extraction. For the classification SVM is used with number of 800 samples. In this the different feature set has provided different accuracy rate. The overall recognition rate is 90.55%.

In [2] this paper Author have used Projection profile based technique is used .here four profiles x-profile, y-profile, diagonal-1 profile, diagonal-2 profile can be used as abstracted feature for identification of digit. A feedforward back propagation neural network is used for the classification of the image. 3260 samples are used for training or testing purpose. Overall accuracy obtained is 91.0%.

In [3] this paper Author have used two feature extraction method to extract the feature from the image Hough transformation and projection profile.MLP and SVM classifiers are used for classification on dataset of 1200 samples of digit image and recognition rate is 98.73%.

In [4] this paper Author describes about Structural, statistical and hybrid feature extraction methods are used to extract feature from the image. SVM classifiers is used with different kernel functions to recognize the image.Approx 500 data samples are used and 88.66% accuracy rate is obtained.

In [5] this paper Author have extracted features like zone density feature and background directional distribution. Image classification and recognition is done by using SVM classifier. Total 22546 data samples are used with different size. They obtained 98.99 accuracy rate.

In [6] this paper Author have used thin Binarization and stroke orientation estimation to extract the features from image, SVM and multilayer SVM is used to recognition with dataset of 12889. Overall accuracy rate is 99.56%.

In [7] this paper Author have extracted feature using chain code based methods where author supposed to find centroid point. Neural network with back propagation is used for classification and recognition of Gujarati numerals. Data set consist of 12000 numerals and obtained recognition rate is 95.62%.

In [8] this paper Author have used Chain code and stroke estimation methods for feature extraction. SVM is used for classification and recognition of the image. 2000 data samples are used for testing and training purpose from that obtained accuracy is 95%.

In [9] this paper Author converted image into binarized image and generate feature vector from that image based on pixels value. They have used feed forward neural network with back propagation. They have collected 3900 input samples of handwritten digits from various age groups. Highest accuracy rate obtained by them is 88.76%.

In [10] this paper Author have used invariant moment and row moments feature to uniquely identify the image features. For the classification of the image they used k-Nearest Neighbour classifier and minimum hamming distance classifier. They uses 400 data samples to training and testing dataset and obtained accuracy is 67%.

2.2 Common methods based on literature review

2.2.1. Pre-processing methods:

Conversion to Gray scale: RGB image contains lots of data which may not be required for processing. When we convert a RGB image into Gray scale we discard lots of information which are not required for processing.

Noise removal: Median filter is applied in order to remove salt and pepper noise from the image and to fill holes in object region. All the numeral images are resized to the size of 16*16 pixels with nearest neighbourhood interpolation algorithm. After resizing, one pixel wide thinned image is obtained using morphological thinning operation **[**7**]**. Mean filtering is most commonly used as a simple method for reducing noise in an image.

Binarization: Otsu's thresholding method is used to convert binary image from gray-scale image. In Otsu's thresholding method two classes namely black and white. Where white is a numeral and black is numeral **[**6, 3, 5**]**. Another technique for binarization is using optimum threshold of 0.2 binarization level so that image is converted into two tones.(0 for background and 1 for foreground).[4]Due to binarization there is chance that image is broken down into several parts and lose some information [1].

Thinning: Once the binarization is get completed then the thin version of the image is used for feature extraction. Thinning can be done by using different algorithms [6,4].Thinned image have background pixel in black and foreground pixel white and lesser then background.

Erosion/Dilation: Erosion increases the background and decreases the foreground so it can be used to disjoint the object and dilation decreases the background and increases the foreground. This both are used to maintain the pixel of foreground and background in image so that classifiers can classify image with more accuracy.

Image cropping : Image size can make impact on accuracy result because different size of image can be recognized differently so it may possible that similarities between the numerals can increased complexity in recognition so before recognition, we should convert image into optimum size image different image resizing provides different accuracy result**.**

2.2.2. Feature Extraction

Features can be specific structures in the image such as points, edges or objects. Digital image can have different type of features that helps to identifying image uniquely such as moment feature, invariant features etc. Many methods to extract those features. The selection of the appropriate feature extraction method is probably the single most important factor in achieving high recognition performance. So, the extracted features should be able to classify each numeral uniquely [5-2]. This stage is the main stage of HNR (Handwritten Numeral Recognition) because the output highly depends upon the extracted features. The widely used feature extraction techniques are Zoning, Projection profiles, Hough transform, Chain code, Fourier descriptor etc. [5]. A feature vector is just a vector that contains information describing an object's important characteristics.

Chain Code: They have used different structural and statistical features. These features are extracted from each stroke. The size of stroke and speed of stroke may vary from user to user that may lead to wrong feature extraction. Proposed features are a size and speed independent. Each stroke drawn by the user is divided into equal zones according to its length and width. Percentage wise distribution of active pixels from each zone is calculated and considered as features. Figure 2 illustrates the zoning of digit 3 with a percentage of active pixels in each zone. Zone of starting and ending of every stroke is considered as features. Stroke's directional feature describes curvature. The chain code is used to get directional detail of a stroke [8, 7].

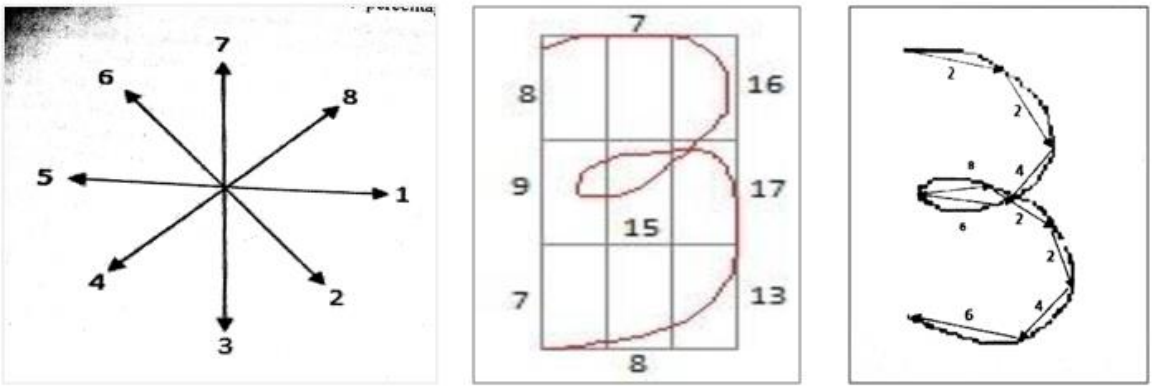

Figure 8 chain code based feature extraction

Projection Profile: Projection profile is a method which is used to extract feature from the given image. Your accuracy rate is mostly depends on how much your feature vector is strong. most of the Gujarati numeralsare based on very sharp curves, and for handwritten numerals also these curves may be very irregular. In this case it is very difficult to extract different objects or components which constitute unique features for each of the individual Gujarati numerals.

There are four projection profile pattern is available

a)Horizontal

b)vertical

c)diagonal 1

d)diagonal 2

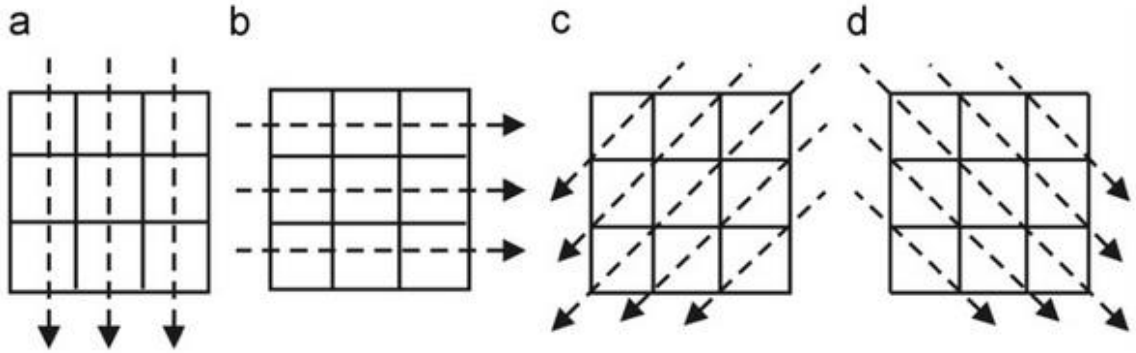

Figure 9 Projection profile patterns

The vector of these four profiles, that is [X-profile, Y-profile, diagonal1 profile, diagonal2 profile], can be used as an abstracted feature for identification of a digit. The feature vector or profile vector is generated. For Gujarati numeral recognition profile vector is created for all the digits which are converted into 16 x 16 pixels after pre-processing. The orientation or the skew which exists in the writing of most of the writers is the next thing to remove from the digits before their identification.

We can use this projection vertical profile patters for text-line recognition and horizontal profile pattern for word segmentation also. We have achieved maximum accuracy of about 93.12% and 72.5% by SVM and MLP classifiers and with four view projection profiles technique; we obtained the 96.04% and 98.73% recognition

2.2.3. Classifiers

There are different classifiers are used to classify and recognize the pattern of given images. Every classifier produce the different accuracy result based on previously performed steps. Example of classifiers neural network, support vector machine, KNN etc.

1. SVM (Support Vector Machine):

Support Vector Machine (SVM) [17] is supervised Machine Learning technique Support vector machine creates a hyperplane in n-dimensional place separates two classes. Support vector machine places hyperplane at a distance from where the nearest point of both the classes have the largest distance. This distance is known as ‘‘margin’’. Support vector machine gives efficient results if all parameters are set properly. Therefore it is important to understand various parameters which play an important role in SVM. LIBSVM implements the “one against one” approach for multi-class classification. They are one against all and one against one. One against one compares each group with all rest of the groups and one against all compares each group with a group consisting of all rest of the groups. Further SVM can be also be used with kernel technique. Here different types of nonlinear or even linear kernels can be used to separate groups in parts. Two known nonlinear kernel are polynomial, and Gaussian.

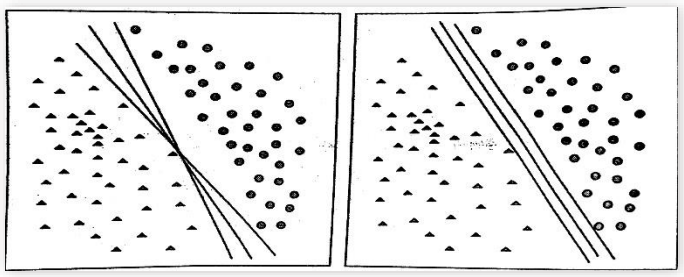

Figure 10 SVM data classification

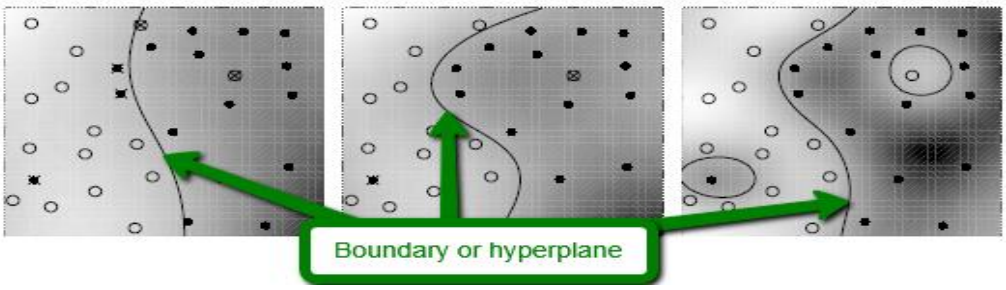

Figure 11 SVM hyperplane

Advantage and Disadvantages of SVM

Advantages:

1. SVM's are very good when we have no idea on the data.
2. Works well with even unstructured and semi structured data like text, Images and trees.
3. The kernel trick is real strength of SVM. With an appropriate kernel function, we can solve any complex problem.
4. SVM models have generalization in practice, the risk of over-fitting is less in SVM.

Disadvantages:

1. Choosing a "good" kernel function is not easy.
2. Long training time for large datasets.
3. Difficult to understand and interpret the final model, variable weights and individual impact.

2. Neural network

A more widely used type of network is the recurrent neural network, in which data can flow in multiple directions. These neural networks possess greater learning abilities and are widely employed for more complex tasks such as learning handwriting or language recognition. There many type of neural network like feed forward neural network, Artificial neural network etc [7]. The purpose of a neural network is to learn to recognize patterns in your data. Once the neural network has been trained on samples of your data, it can make predictions by detecting similar patterns in future data.

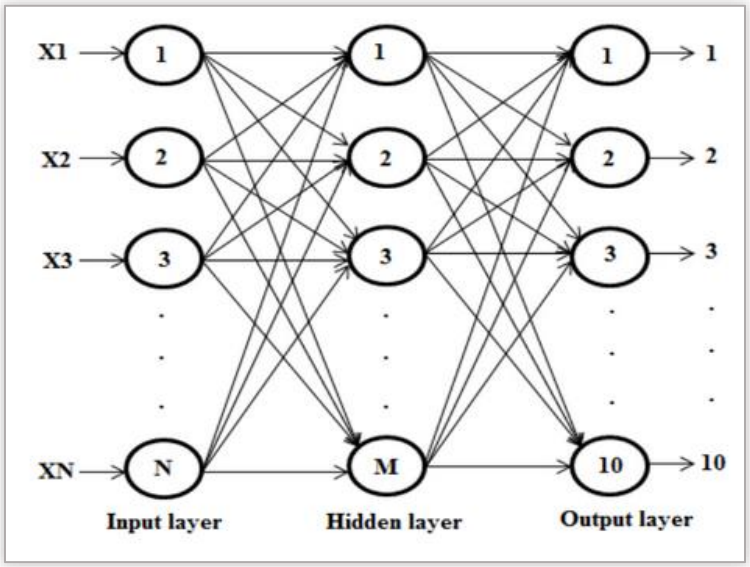

Figure 12 Neural Network Architecture

Neural network classifier with back propagation algorithm is used for recognition and classification of handwritten Gujarati numerals. Three layered feed forward neural network is used with one input layer, one hidden layer and one output layer. Mostly used neural network is artificial neural network. In is artificial neural network each neuron is connected to other neurons with certain coefficients. During training, information is distributed to these connection points so that the network is learned.

Advantages of using artificial neural network is Storing information on the entire network: Information such as in traditional programming is stored on the entire network, not on a database. The disappearance of a few pieces of information in one place does not prevent the network from functioning and second is ability to work with incomplete knowledge: After ANN training, the data may produce output even with incomplete information. Here the disadvantage is that loss of performance here depends on the importance of the missing information. In multi-layer artificial neural network.

2.3. Comparative study of Gujarati Numerals Recognition results

Sr No.	Author Name	Dataset Size	Method	Accuracy	Year
1	Vasant, A., Vasant, S., Kulkarni, G.	7*5 14*10 16*16 Total =39000	Neural Network	87.29% 88.52% 88.76%	2012
2	Desai, A.	199 Writers	Support Vector Machine with Gaussian kernel, kNN	86.66%	2015
3	Naik, V., Desai, A.	2000 Samples 200 writers Tested by 50 writers	Support Vector Machine with linear, polynomial, and radial basis function kernels	92.60% 95% 93.80%	2018
4	Nagar, R., Mitra, S.	22546 data samples written by 1049 persons	Neural Network, Support Vector Machine	92.28% 98.97%	2015
5	Garg, M., Ahuja, D.	1200 samples by 24 writers	Support Vector Machine, MLP	96.04% 98.73%	2013
6	Desai, A.	2650 digits	Neural Network	82%	2010
7	Sharma, A., Adhyaru, D., Zaveri, T.	1200 Samples	Neural Network	96.37% 95.62%	2017

Table 1 Comparative study of Gujarati numeral

Chapter 3. IMPLEMENTATION

3.1 Code

Here we have implemented our pre-processing steps in python. Python provides various different libraries and namespaces for image processing.

Source Code:-

```
import cv2

import numpy as np

import matplotlib.pyplot as pt

import pandas as pd

from skimage import color, data, restoration,filters,morphology

from scipy.signal import convolve2d as conv2

from scipy.misc import imread

from PIL import Image


img=Image.open('7.png')

img=cv2.imread('7.png',1)

img=cv2.resize(img,(300,300))

cv2.imshow('Originalmage',img)


""" gray Conversion"""

gray=cv2.cvtColor(img,cv2.COLOR_BGR2GRAY);

cv2.imshow('gray Image',img)


"""Median filter"""

md=cv2.medianBlur(gray,27);

cv2.imshow('Median blur',md)


"""Weiner Filter"""
```

```
f0=pt.figure(0)
f0.canvas.set_window_title('Weiner Filterd Image')
image = md
print(image)
psf = np.ones((5, 5)) / 25
image = conv2(image, psf, 'same')
image += 0.1 * image.std() * np.random.standard_normal(image.shape)
deconvolved = restoration.wiener(image, psf, 1, clip=False)
"""cv2.imshow("ooh",deconvolved)"""
pt.imshow(deconvolved, cmap='gray')
"""
pt.subplot(2,1,1), pt.imshow(deconvolved,cmap = 'gray')
pt.title('Original Image'), pt.xticks([]), pt.yticks([])
pt.subplot(2,1,2),
pt.hist(deconvolved.ravel(), 256)
pt.title('Histogram'), pt.xticks([]), pt.yticks([])"""
f1=pt.figure(1)
f1.canvas.set_window_title('Original Image Histogram')
img = cv2.imread('7.png')
pt.subplot(2,1,1), pt.imshow(img,cmap = 'gray')
pt.title('Original Noisy Image'), pt.xticks([]), pt.yticks([])
pt.subplot(2,1,2), pt.hist(img.ravel(), 256)
pt.title('Histogram'), pt.xticks([]), pt.yticks([])
f2=pt.figure(2)
f2.canvas.set_window_title('Otsu s threshold Binary Image')
print(md)
print(deconvolved)
a=deconvolved.astype('uint8')
print(a.shape)
```

```
img=a
print(img)
blur = cv2.GaussianBlur(img,(7,7),0)
ret3,th3=cv2.threshold(blur,0,255,cv2.THRESH_BINARY+cv2.THRESH_OTSU)
pt.imshow(th3,cmap='gray');
crop_img = th3[3:700, 10:700]
cv2.imshow("cropped", crop_img)
imgr=cv2.resize(crop_img,(500,500))
cv2.imshow("resized", imgr)
print(imgr)
f7=pt.figure(7)
f7.canvas.set_window_title('thiin Image')

isa=cv2.imread('7.png',1)
image_binary = th3 < 0.5
thins=morphology.thin(image_binary)
pt.imshow(thins,cmap='gray')
kernel = np.ones((1,1), np.uint8)
i=thins.astype('uint8');
print(i)
img_dilation = cv2.dilate(i, kernel, iterations=1)
print(img_dilation)
cv2.imshow('Dilation', img_dilation)
pt.show()
```

3.2. Methods and Screenshots

Image Grayscale:

Figure 13 grayscale image

There are only 256 gray colors. The main characteristic of grayscale images is the equality of the red, green, and blue colors levels. The luminance of a pixel value of a grayscale image ranges from 0 to 255. The conversion of a colors image into a grayscale image is converting the RGB values (24 bit) into grayscale value (8 bit).So that it gets easy for further processing.

Median Filter:-

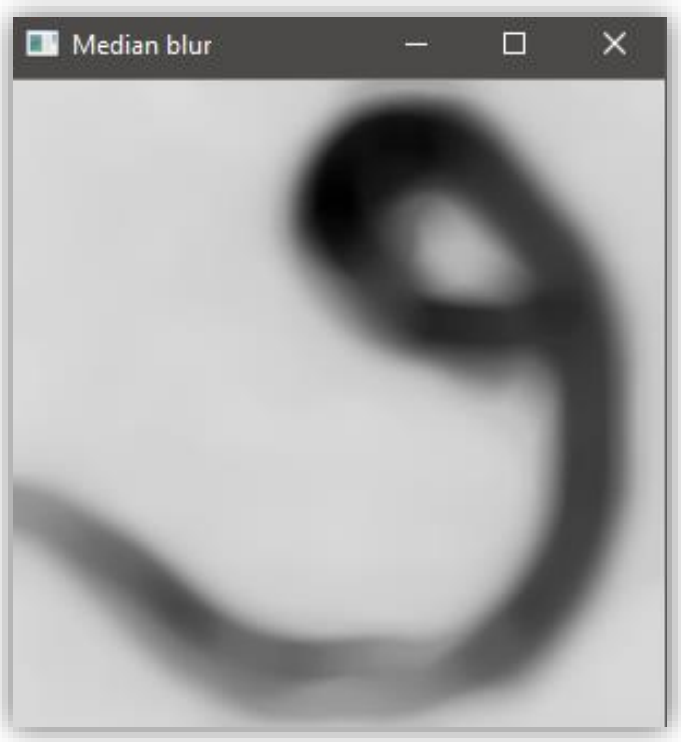

Figure 14 Median filtered image

The Median Filter is a non-linear digital filtering technique, often used to remove noise from an image or signal like paper noise and salt noise. Such noise reduction is a typical pre-processing step to improve the results of later processing.

Weiner Filter:-

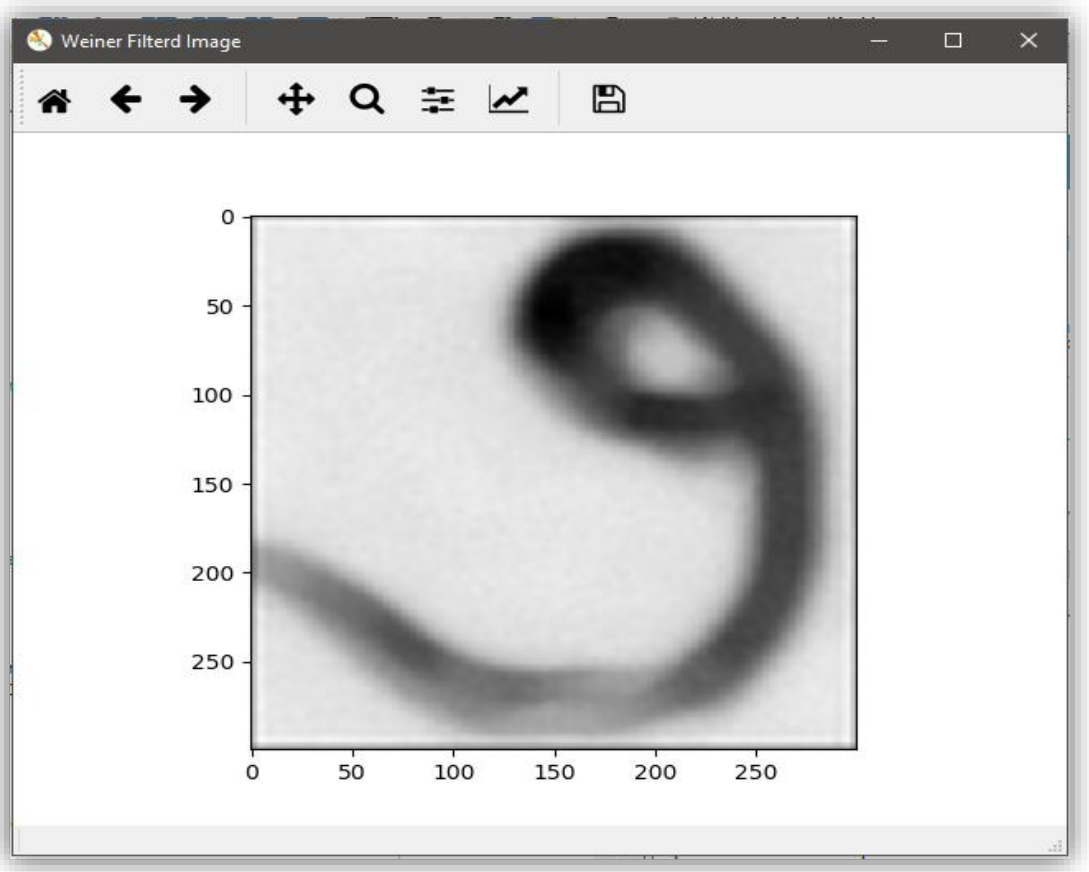

Figure 15 Weiner filtered image

The Wiener filter. The Wiener filter is the MSE-optimal stationary linear filter for images degraded by additive noise and blurring. ... Wiener filters are usually applied in the frequency domain. Given a degraded image x (n, m), one takes the Discrete Fourier Transform (DFT) to obtain X (u, v).

Binarization using Otsu method:

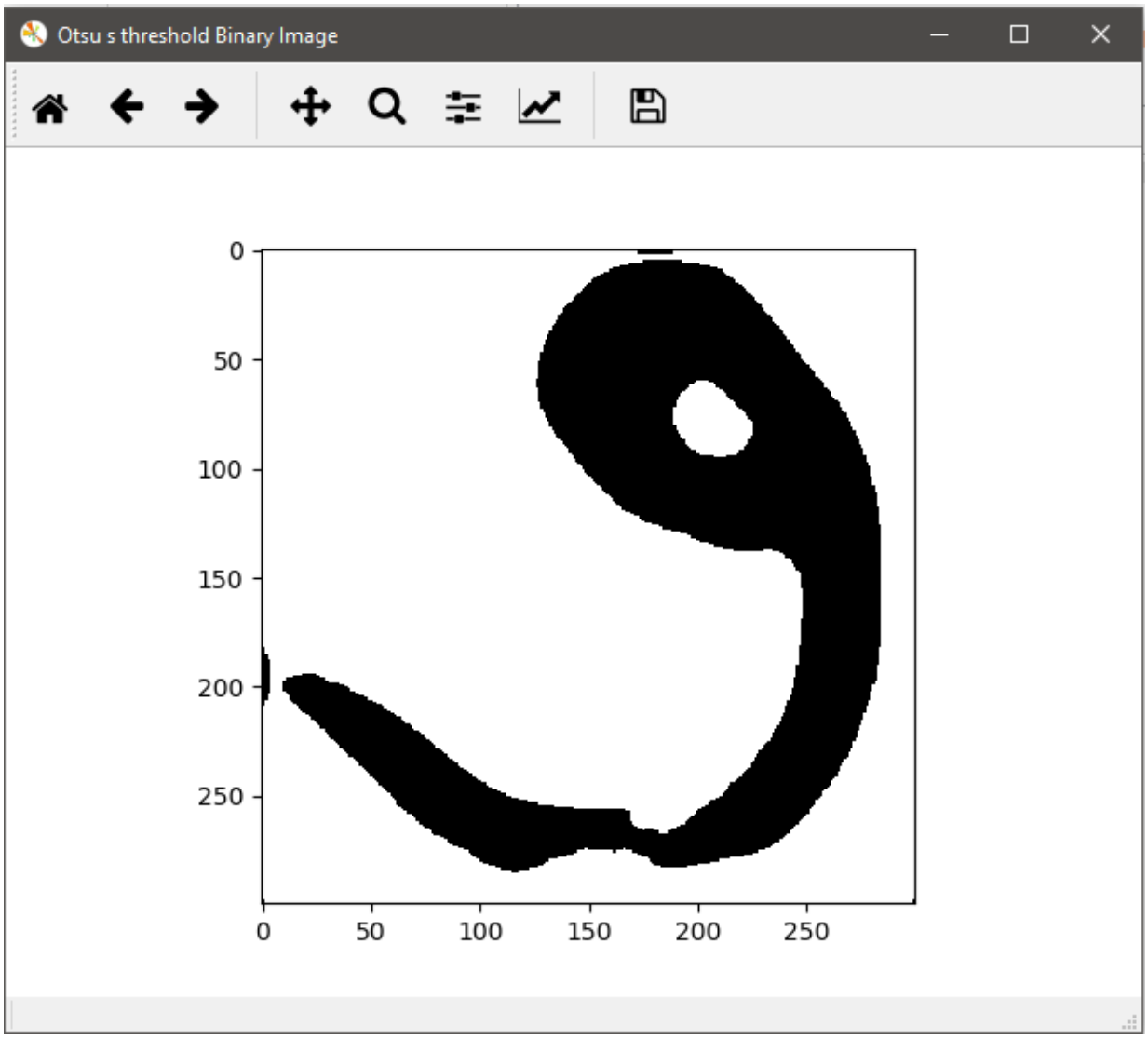

Figure 16 Binarized image

Otsu method is used to automatically perform clustering-based image thresholding or, the reduction of a gray level image to a binary image.

Crop image to optimum size:

Figure 17 cropped image

Cropping image to optimum size gives a new shape and number of pixels is get decreased so that it gets beneficial for next method performance.

Thinning:

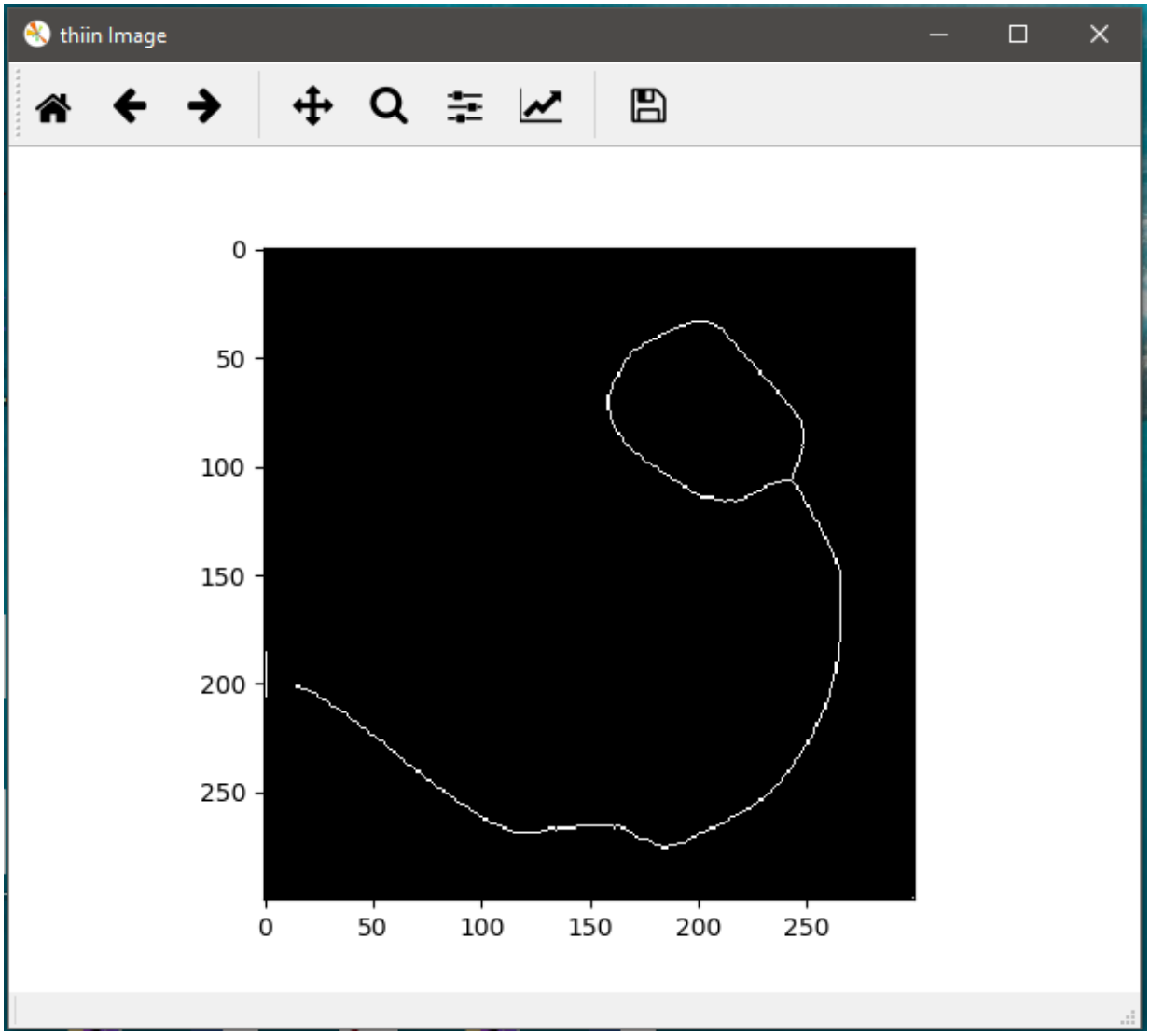

Figure 18 Thinned image

Thinning is a morphological operation that is used to remove selected foreground pixels from binary images, somewhat like erosion or opening. It can be used for several applications.

Chapter 4. Conclusion

Handwritten numeral recognition is process to recognition by machine. This helps a common men day to day life. Using HCR we can perform the work of days in hours. This provides and intelligence to the machine. Here it comes with many problems such as accuracy, joint characters and different handwriting styles etc.

There are several factors are available that can affects this factors as we discussed. Still accuracy is and data variation is still problem. The Using SVM we can obtain good accuracy.

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