

Chapter 1 Introduction

Writing is an art that has been used for communication not only for human to human but also used for human to machine. Handwritten recognition has an active research field since the advancement of the digitalization. There have been lots of technologies that are under the research field such as networking, image processing, artificial intelligence etc. to increase the speed, accuracy of work. Handwritten recognition is a sub module of image processing which have lots of application for automatic recognizing the handwritten number like zip code reading, bank check reading, licensed plate recognition, security based system, reading bar code and many more.

Pattern and machine recognition have many different types of application for the character recognition. Optical character recognition is mostly used for automatic pattern recognition. There are lots of application that are used in image processing such as MRI, Ultra sound, X-ray which is used to trace out the damaged bones or tissues or other kind of disease. Some more common applications like scanning of language on the airport, thumb impression, eye retina detection, zip code recognition for sorting the mail, bank check processing, and various kind of data entry. In these application accuracy and speed of recognition required at very high rate.

Handwritten digit recognition system work as an interface between men and machine. To evaluate the performance of the various handwritten digit recognition mechanism based on different features like size of the digit, writing style, space between the digits, reliability and speed of recognition. Numerals recognition is a difficult task because of the inconsistency of scanned image and this inconsistency formed by the different writing style of person, size of the numerals, shape and curve of numerals etc.

Handwriting recognition is a process that is used to identification of the hand written letter, number and characters. The problem of classification is occurred when these handwritten characters are identified by the machine and this is also practical aspects of machine recognition of handwriting, handwritten notes reading on PDA, in postal addresses on envelopes etc. The main task is that how it is converted into digital data, which is done by the help of language recognition algorithms.

There are two ways to implement these algorithms and are as follows:-

1. `On-line Text Recognition
2. Off-line Text Recognition

On-line text recognition method works on dynamic information. In other words, we can say that the method and technique that performing automatic processing of information as it is written by using digitizer or stylus that captures the every moment of pen tip, like its position, velocity, or acceleration as a function of time.

Off-line text recognition method works on static information. In other words, we can say that the information is fixed like ancient document. Now apply some algorithm on it and then converted into text format. While the on-line and off-line text recognition techniques both uses different approaches, and there is also some common problems and solutions. There have been lots of tools available in the market for online text recognition but for off-line text recognition lots of research work done so far and still in development phase. So, it is more difficult and requires more research as compared to on-line recognition. When we work on PDF, scanned document, scanned image, ancient documents, and handwritten scanned documents is really a challenging research field of character recognition. There is a main problem of recognizing the scanned image' that is written by the user and to analysis this problem five steps are as followed:-



Figure 1-Handwritten Text Recognition System

In Off-line text recognition the image of writing is converted into bit pattern by an optically digitizing device such as optical scanner or camera. The recognition is done on this bit pattern data for machine-printed or hand-written text. The research and development is well progressed for the recognition of the machine-printed documents. In recent years, the focus of

attention is shifted towards the recognition of hand-written script [2]. Off-line recognition system is used in order to solve various text oriented digitization techniques. There are lot of tasks like postal address reading, check sorting, and office automation for text entry, automatic inspection and identification.

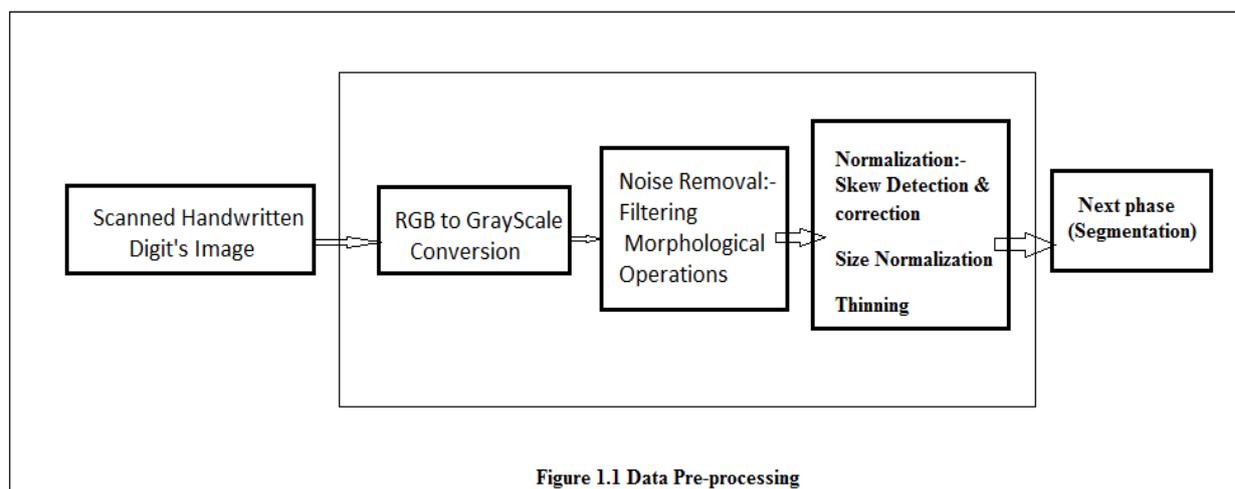
In order to convert all the above features into digital form off-line recognition system is mainly used. Off-line mechanism used for character recognition is an important tool for the creation of digital libraries. By the help of this method we can convert the image files (JPEG, BMP, PNG etc) into editable format so that they can be easily edited. Recently, content based image or video database systems make use of off-line character recognition for indexing and retrieval, extracting the writings in complex images. Also, the wide spread use of web necessitates the utilization of off-line recognition systems for content based Internet access to paper documents. Methodologies that are applied to recognize the digit by off-line recognition are as follows:-

1. Pre-Processing

Handwritten document is scanned, now the pre-processing phase generates the raw data by performing various techniques. Basically it removes the different types of errors like noise removal, curve of the digits, shape of digits, size of digits, writing style, strokes in the digits, quality of paper and ink is poor, as well hand movements etc. The main steps of pre-processing are as follows:-

Thresholding: - A grayscale or color image is compact to a binary image.

Removal of Noise:-Remove the noise by performing filtering and morphological operations. The noise is caused by the optical scanned device, gaps in between digits, loops in the digits, disconnected segments of lines and many more. There are some more common problems like distortion, corners, erosion and dilation. There are lots of imperfections in input data and that must be eliminated.



Normalization: - It is performed by using skew detection and correction, slant normalization and size normalization. The scanning processes have lots of error, the writing style is very bad, and the digits that are written in input data may be tilted or curved. These imperfections decrease the performance of algorithms, so to remove these imperfections skew detection and correction is required. Slant normalization is used to normalize all the numerals to standard form. Size normalization is used to alter the numerals size.

Thinning: - The main aim of thinning is to compress the size of the digit and extract contour information of digits. Pixel-wise and non pixel-wise approaches are used in thinning process. After performing these techniques on scanned image then we got raw data which works as an input for the next phase.

2. Segmentation

The pre-processing phase remove the various kind of error such as noise removal from the data, normalized the data and high compression of data etc. this process make the data clean. The segmentation breaks the data into sub modules to remove the overlapping of digits. It plays an important role in recognition of digits which is directly affect recognition rate. Segmentation is performed into two phases are as follows:-

2.1 External Segmentation:- This is the separation of different writing units, such as three digit number. Basically it crumbles the page layout into its logical units. Page layout analysis is completed in two phases:-first one is structural analysis and second one is functional analysis. Structural analysis segments the image into blocks of document components.

Functional analysis uses the location, size and different rules of layout.



Figure:-1.2-Sementation Process

2.2 Internal segmentation:-This is the separation of number that is written in groups. Internal segmentation breaks the sequence of digits into sub-module of individual digits.

Isolation digit means we have break the groups of number into single digit. For example:- Zip code of any city is isolated to find out the exact location. Segmentation breaks numbers of groups into individual units and then this output is used for the next phase.

3. Feature Extraction

Feature extraction is a mechanism that is used to reduce the dimensionality. When the input data in any algorithm is very large for further processing and it is suspected to be processed, then the input data renovate into a reduced demonstration set of features called as feature vector. Renovating the input data into a set of features is called feature extraction.

Feature extraction is a method for capturing the related distinctiveness of a digit object (in general the target object) from an image with static numbers of feature variables that create a feature vector. The size of the feature vector should be as small as it can possible. Several types of feature extraction are exist for handwritten digit recognition is as follows:-

3.1 Structural Feature Extraction:-it is based on the geometric and topological properties of digit. Several local & global properties of numerals can be produced by geometric and topological features by the way of tolerance to distortions and mode variations. These types of illustration have some knowledge about the object. There are lots of illustrations of structural and out of them four categories are as followed:-

Counting and extracting topological structures:- These types of structures are used to search the pre-defined structures in numerals or word. The word or numerals can be effectively represented by counting & extracting several topological features like find out the extreme points such as maximum and minimum, threshold values of cusps above and below, line end points, branch points, loops, cross points, multidirectional strokes, single stroke, stroke between two lines, horizontal curve, vertical curve, isolated points, and many more.

Approximating and measuring the geometrical properties: - The word or numerals illustrated by the many geometrical quantities like length, mass, velocity, density, height and width ratio, measurement of length between two points, different types of curve, masses of number, energy, force, potential and length of the groups of number.

Coding: - It is basically used to represent the shape of objects. To find out the different shapes of an object like triangle, circle, and pentagon are based on chain coding. In chain coding we trace the outer edge of the object and store the direction in which the edge is travelling. For example: - the directions are calculated as:-

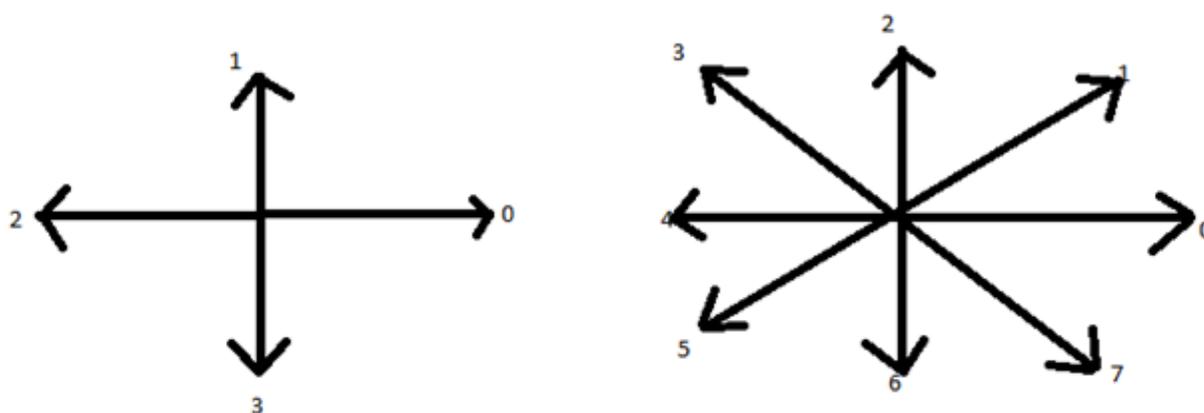


Figure 1.3 Calculation of directions

Graphs and Trees:- The topological primitives are used for separation of the words and numerals like branch points, loops, curve, strokes etc. On the basis of these primitives the graph is defined. The graph is illustrated on the basis of coordinates of numerals shapes and also on the basis of edge and vertices where edge represents the strokes and vertices show the relationship between strokes. Trees are also representing the numerals structures on the basis

of features, such as decision tree for finding blobs and stems in digits.

3.2 Statistical feature Extraction:- it is based on statistical property of the digit. It is based on the different writing styles. These types of representation are used to increase the speed and removing the complexity of the scanned image. There are three types of statistical feature and these are as follows:-

Crossings & Distances:- A popular statistical features is the number of crossing of a contour by a line segment in a specified direction. The numerals frame is divided into a set of areas in different directions and then features are extracted from each area.

Projections:- Numerals are represented by focusing the gray level image onto lines in different directions. This process create one-dimensional signal of 2-dimensional image and this is used to describe the numeral image.

Zoning:- The numerals are divided into different zoning like overlapped and non-overlapped zones. There are different types attributes are generated on the basis of zones. These attributes may be contour direction, which creates an array of braked image into diagonal and rectangular zones. The term is bending of digits that describe the curvature point, fork and terminal points etc.

4. Classification and Recognitions

After feature extraction phase the characters are classified and represented. This phase shows classification of the all character like A, if there is shape of hut then the character should be A. On the basis of classification the character are represented. There are different types of mechanism are used to classify the digit and out them four mechanism are described here.

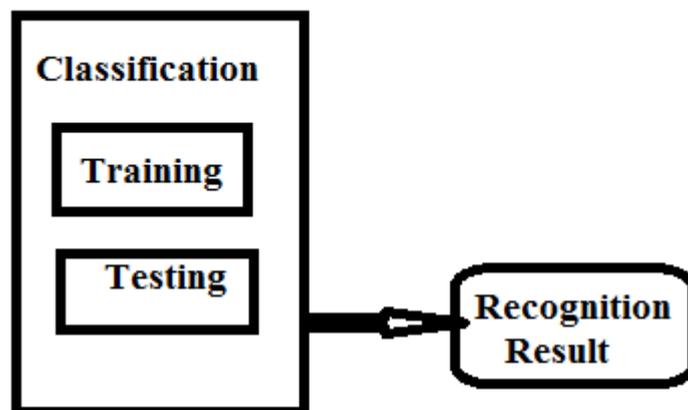


Figure 1.4 Classification

4.1 Neural Networks:- Neural network is an information processing mechanism that is motivated by the nervous system like brain, process information. It uses a different structure for information processing system. The NN is made of highly interconnected node (neurons) working in unison to present the solution of the specific problem. Neural network are trained by the several method like the people are trained to do some task. Neural network are widely used in pattern recognition and data classification, through learning process. Neural network has an ability to derive the meaningful data from any complex pattern that cannot read by either human or computer. A well trained neural network is called as expert system. It has an ability to learn how the task is performed on the basis of data that is given for the training. Neural network used two types of network. Feed forward network is single directional network, from input to output and feedback network is bidirectional network, until they reach an equilibrium point. It is very powerful and complicated networks. The mostly used feedback network is multilayer perceptron (MLP) network.

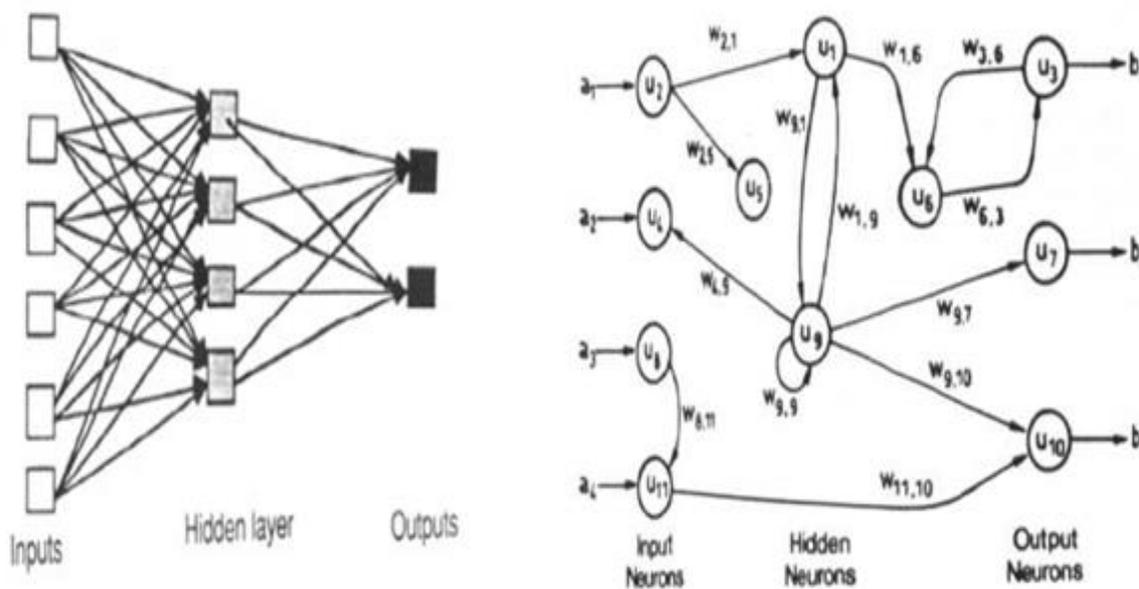


Figure 1.5 (a) Feed Forward Network (b) Feedback Network

4.2 Classifier: - Classification is a process that separates the data into two sets, training set and testing set. Each instance in the training set has a target value and several attributes. The testing set test these attributes to match the target value. Support vector classifier, combination classifier etc. are used to successfully recognition the digits.

4.3 Statistical Technique:- The theory of Statistical decision is based on a set of optimality criteria and statistical decision functions, which maximizes the probability of the observed pattern given the model of a certain class. Statistical techniques basically follow these assumptions:-

1. Distribution of the feature set is based on Gaussian.
2. Each class has an enough statistics.
3. To find the class patterns, a set of features can be extracted from the collection of images.

The digit unit from n - feature can be represented in n -dimensional vector space and the vector, whose coordinates match up to the dimension taken and represent the original digit unit. The most common statistical method that are used in digit recognition system are

Hidden markov modeling, parametric recognition, non parametric recognition, fuzzy set reasoning and clustering analysis.

4.4 Template Matching:- This is the simplest way to recognition of the digit that matched with stored prototype against the digit. Noise and image deformation directly affect the recognition rate of template matching. Direct matching, deformable and elastic matching, and relaxation matching are used to improve the classification.

5. Post-Processing

There is a lots of problem of careless handwritten text to be read by human but still human read it up to 60 to 70 percentage but in machine recognition the following operation are performed like pre-processing, segmentation and feature extraction to clean the document and finally the classification and representation of character gets all the information. Now the conversion is task is performed by the help of post-processing which converts the image into a editable format.

1.1 Problem Statement

Designing a hybrid approaches for recognition of the handwritten digit using structural algorithms. The main problem is to recognize the digits which have variety of different style of writing.

1.2 Brief of Problem to be solved

The aim of my research work is recognize the handwritten numerals by using hybrid algorithm which uses the segmenting algorithm for feature extraction and classification and decision tree was used for recognition. The main problem is that to recognize the different writing style of various people. Although every person has different writing style so it is very difficult for machine to recognize these characters. So, lots of researcher did a lot of work in this area and still going on to make it better. Here a new method is described for digit recognition and clustering and decision will be used.

1.3 Objectives

The present work has the following objectives:-

- (a) Design a handwritten digit recognition tool for recognizing the handwritten numerals based on numeral feature.
- (b) Different types of features are extracted for the scanned image.
- (c) Appropriate Classification and recognition of the handwritten digit.

1.4 Aim and Scope of the work

The main aim of this thesis work is the recognition of the handwritten digit which is not written cleanly, not is in same size, not in separate boxes and different writing style of writers. All these means the digit is not define in a fix size. In other words the unconstrained handwritten digit verification and recognition. The handwritten digit recognition system has a high recognition rate while looking for the highest consistency. The recognition rate is computed as:-

$$\text{Recognition Rate} = \frac{\text{Total number of testing characters}}{\text{Number of correctly recognized characters}}$$

The Consistency is calculated as:-

$$\text{Recognition Consistency} = \frac{\text{Total Number of testing digits} - \text{Number of misrecognized digit}}{\text{Total number of testing digits}}$$

We started our research work on hybrid feature extraction. It is essential to compose a feature extraction algorithm not sensitive to the digit's size, scaling, shifting, shape, different writing style and curve. One of major research part was to compose an effective feature extraction algorithm.

1.5 Significance of the work

As per various algorithms design so far for the recognition of handwritten integers the result is not up to the mark. There is lot of work had to be done in this field. Therefore, the significances of my research work are to improve the accuracy of handwritten text integers.

1.6 Outline of Dissertation

- ✓ Chapter I commence the research work and it envelop objective of work, aim & scope of the work, significance of the work.
- ✓ Chapter II includes the Literature Survey of the Dissertation.
- ✓ Chapter III includes the problem declaration and concept of the system.
- ✓ Chapter IV described the implementation details.
- ✓ Experimental Result & discussion are talk about in Chapter V.
- ✓ Conclusion and future scope of the work Described in chapter VI.
- ✓ Chapter VII has bibliography of the dissertation.

Chapter 2 Review of Literature

The literature review of handwritten digit recognition described in the following manners: - handwritten recognition system, handwritten segmentation methods, handwritten digit feature extraction algorithms, classification and representation for improving the recognition system's consistency.

Image processing and pattern recognition are used face recognition and many other industrial application like security check at airport through scanning, CT-Scan, MRI and many more. Faisal Tehseen Shah, Kamran Yousaf [7], they use different feature extraction technique for recognizing the handwritten digits from a scanned image. This technique provides faster image detection then the old image pixel comparison technique. In Initial phase the image is taken as an input in a specific cells format (rows*columns). So the input given by the user in multiple rows like 10, the cell must have also the width according to the requirement of the user (e.g. set it to 20*2 pixels). In the second phase, the slicing technique is used to slice the sample image of size 16*16 pixel for each digit from the scanned form. Each scanned image will make 100 images of 16*16 pixels. This step is repeated until all the 16*16 pixel images into a sample pool. This technique uses the neural network three layered architecture for training the purpose. Now, the obtain weight and bias are stored for each digit sequence. And these properties are compared to a predefined AI engine database, so the output array will automatically give the compared digits. By the help of this technique handwritten digit is easily recognized by the AI engine. A neural network gives better performance for simulation then the mat lab. They try to implement same mechanism for recognition the signatures in check processing and also try to develop a student attendance system by the help of face recognition.

All people have different writing style that is not easily understand by the machine. So In Handwritten digit recognition system pre-processing is used to refine the data such size of the data, skew detection, size of digit, thinning of digit, RGB to gray conversion etc. These imperfection are removed in pre-processing phase by using some algorithms and out of the one algorithm is proposed here by M. Blumenstein et al. [15], they use two new pre processing approaches for handwritten numeral recognition.

Detecting skew in the word and removal of underline noise techniques are described. The skew is detected by the center of mass in each half of word image. The preprocessing techniques that are described in this paper are as follows:-Removal of underlines uses three steps :-(1) Straight Underline, (2) Underline finds at midpoint of the word image and (3) Slope Underline. Baseline detection was successfully performed. Underline removal technique face some problems like underline of the word not removed properly this may cause extra noise that affect the algorithm etc. The skew recognition algorithm computed the slope successfully. Now these techniques are tested on CEDAR database of handwritten texts. Underline removal successful in 97.16% cases and skew is determined in 96.12% of cases. There is still a problem to improve the baseline algorithm to trace the abnormal horizontal strokes.

In Fatos T. Yarman-Vural and Nafiz Arica[3], the handwritten character recognition by using off-line handwriting methods. The character recognition systems classified according to the data acquisition technique. They use five stages for CR problems:-Pre-processing, Segmentation, Representation, training and recognition and post-processing. HMM is very suitable for modeling the linguistic information as well as the shape information. The best way of approaching the CR problem is to combine the HMMs at various levels for shape recognition and generating grammars for words and sentences.

In Abdeljalil Gattal and Youcef Chibani[14], They propose a handwritten digit recognition system for overlapping and joining adjacent digits. So there is a main problem to remove the overlapped digits. They provide the solution of this problem by using segmentation recognition of handwritten joint digits based on the oriented sliding window. The main work is to find out the best cutting. They adopted the segmentation verification method for finding the best cutting. Segmentation based on the interconnected point's algorithm does not correctly find the cutting path when connected digits are oriented. So the sliding window method is proposed for finding the cutting path and at the same time the IP. In this method, first detects the presence of interconnection points using a window of fixed size having the same size of the scanned image and with constant width. So the IP is positioned in between of the width. Now, the window is rotated in different angle around the IP. If oriented window is found at single IP then the cut is making between single IP with upper BP. If there are two IP then hypothesis is applied. To avoid the under segmentation the hypothesis 3 is applied. For the recognition they used multiclass SVM classifier. The verification method reduces the confusion between under segmented and isolated digits. NIST SD19 database is used to measure the performance of the segmentation. The NIST SD19 database is module into two

parts: the first part (5000 digits) used for learning and second part (600 digits) used for testing. The result shows that the orientation angle affects the overall recognition rate. An oriented sliding windows method uses few rules and gives better segmentation in many cases.

In Marwan A. Ab-Zanona et al. [11], Arabic handwritten numerals are difficult to recognize. To resolve this problem, they use morphological operations on the Arabic numerals and then implement the neural network to obtain the features of segmented numerals and recognition. The numerals are written by the hand having different style, to make them isolated numerals are not an easy task. The morphological operations are applied to isolate the Arabic numerals by using radon transform. This paper applied the spatial dividing of number image and images are resized in 32x24 pixels. Now this image is divided into 8x8 size of 12 segments and from these segments 5 statistical features is calculates and 60 features set is intended for each segment. The Linear vector quantizer neural network is used for recognition. The implementation is done on MATLAB and enhances the accuracy to by 98% over the testing data set.

For character recognition neural networks are mostly used. B. El Kessab et al.[9], the neural network is train and tested on the MNIST database. Gradient algorithm is used for learning process and in this process the synaptic weight is modified which is based neurons connections. MLP (multilayer perceptron) is used as a classifier and that recognize the white and black pixels of image. MLP (multilayer perceptron) a three layer architecture of neurons; retina is match up with the input image at first layer. Hidden layer is match up the characteristics that are extracted from the subsystems. And last layer is used as output layer. The extraction method is used to extract the features of the digits. The scanned image of handwritten digits is split into five characteristics zones (North, South, East, West and Central Zone) and these regions are identified by dilatation of the image into four direction. The neural network is used to classify the data. This method tested on MNIST handwritten isolated database which uses 6000 learning images and 1000 images in test. The multilayer perceptron and back propagations is used for the classification of MNIST isolated digits. This extraction method achieve 80.00% recognition rate on 60,000 test database.

Farsi handwritten digit recognition problem is resolve by Marzieh Moradi et al.[10] and the uses field programmable gate array(FPGA) a new method that is implemented for feature extraction. This is specifically works on Farsi handwritten digit recognition. The feature extraction used statistical and the number of intersection approaches to extract the features.

The FPGA is basically works on addition and subtraction operations and execution of these approaches are parallel. To implement these operations they use VHDL language. Two layer MLP (multi layer perceptron) is used for the classifications. The features are extracted from the normalized from of 40 x 40 pixel handwritten data images from standard Hoda database. VHDL language is used for implementing Farsi handwritten digit recognition. Theses method provides god recognition rate.

The unconstrained digits are difficult to recognize. Rafael M. O. Cruz et al.[6] gives a system that uses multiple features extraction methods and classifier ensemble for the unconstrained handwritten digit recognition. They use the six features extraction algorithms:- Structural characteristics, modified edge maps, image projections, multi Zoning, concavities measurement and MAT-based gradient directional features and among four are published on the basis of previous work and two of them proposed by the author. Structural characteristics algorithm having extracting histograms and profile, then merge in a single feature vector. Modified edge maps used NxN image scaled and compressed into 25x25 matrix. To compute the edge map sobel operator is used. All these feature (25x5=125) combine into a single feature vector. Image projection algorithm is used calculate the radial and diagonal projection. Each projection has a value that are normalized to a range [0, 1], that is calculated by division of maximum value. Multi Zoning algorithm has an NxN matrix that divides the image into several zones and then features are extracted. Concavities measurement follows these steps to calculate the concavities. An 18x15 matrix is made by the scaling of image. Then the image is separated into thirteen zones and each zone has a 13-dimension feature vector. Combination of each feature vector has a 78 features. MAT-based gradient directional features algorithm is used to compute the gradient components of grayscale image. For the classification ensemble system is used which is a combination of classifiers. A 3-layer MLP are use for training purpose with back propagation algorithm. The different feature extraction algorithms show a great rate of digit recognition. The performance of any algorithm is decreased because of the some misclassified digit, irregular writing style or distortions. A rejection strategy is used for misclassified digit and tries to recognize the misclassified digit to improve the performance of feature extraction algorithm.

Structural features are used for handwritten digit recognition. Miran Karic and Goran Martinovic[1], Improving the performance of the recognition of handwritten digit by using concavity-based structural features. They use the existing concavity features and introduce a new one. The gradient and chaincode features are used as complementary features and both

provide better recognition results of handwritten digits. The feature extraction mechanism used the primary feature that is chaincode and gradient. Binary images are the input image for the feature extraction. Gradient features sets are computed by using sobel operator mask. The binary image mapped into a pseudo-gray image and then 3x3 Gaussian lowpass filter is used to make the image blur. Gradient features are extracted from eight standard directions into a 5x5 grid. Chaincode feature are computed on the basis of character contour. Concavity features are performed on the binary images. Concavity feature 1 uses a star operator that is used for shooting the ray in eight directions and this ray hits on numerals or border of image. Concavity features 2 procedures the distance from the numerals convex hull to numerals pixels. The new concavity features 3 are depend upon the measurement of the numeral concavity area in a binary image. Now the convex hull is computed and then subtracting numeral image from convex hull, so the concavity areas are obtained. For the classification k-NN classifier and the support vector classifier are chosen with radial basis function kernel and the polynomial kernel. The results are obtained on MNIST, USPS and DIGITS databases. They proposed concavity feature extraction method in conjunction with gradient features gave the highest recognition accuracy in majority of experiments.

Persian handwritten digits recognition based on statistical attributes is proposed by Omid Rashnoodi et al. [13]. The novel method is proposed and use median, central moments and variance that is obtained from the digit image as feature set. Each instance uses 140 dimensions for feature set. PCA (Principle components analysis) is used to reduce the dimension of features. The PCA is mostly used because it uses liner transformation and the data that has any liner correlation is automatically detected. Here the PCA is used to produce solid and complete feature vector that has been used as an indexing for the fast retrieval in the image database. For the classification these algorithms are used:-Support vector machines (SVM), K-nearest Neighbor (KNN) and sequential minimal optimization. The SVM and multiple binary SVM resolve the two class (Binary) and multi class classification problem respectively. K-Nearest Neighbor Classifier provides consistently high accuracy. The mat lab is used to implement the proposed work and they uses Tabiyat Modares University database of farsi handwritten digits. When these techniques applied for classification then the SMO classifiers has high performance then SVM, K-NN. The SMO is basically used to perform testing on data set and get 92.38% recognition rate, SVM has 91.34 and K-NN has 92.04% recognition rate.

The handwritten digits are difficult to recognize when it was written in different application such as digit written in Arabic. The problem is that recognize the Arabic digits when it is used in different applications. J.V.S. Srinivas and P.Premchand [18] proposed a system that is recognize handwritten digits that are represented in black & white rectangular pixels. They use Elman neural network to display the digits. It is simple supervised and feed forward multilayer neural network which has an output layer, hidden layer, input layer and context layer. They use Semeion digit dataset. This data set has 1593 handwritten digits that are written by approximate 80 persons. Now these dataset were scanned and expanded in a 16x16 rectangular box in a gray scale of 256 values. Boolean conversion is performed on the pixel of image using a threshold. Elman sequential algorithm is performed for feature extraction and to trained the Elman network gradient descent back propagation and optimization method is used. The back propagation algorithm is controlled learning algorithm, which is used to compute weights like given input, network output should equal with preferred output. The adaptive learning rate is better in comparison with non adaptive algorithm to train a network.

The recognition of hand written numeral is a main problem cause of the variability in writing style. Sometimes the scanning device creates many errors and some other error like the size of the digit, shape, slant etc are difficult to recognize. V. Vijaya Kumar et al. [26], described a new approach to recognize the handwritten digits. This paper describes the methods that divide the digit into two parts. One part that contains the blobs without stems and the second part contain the stem only. A new method is used to find out the blobs that is morphological area filling method. This method removes the problem of find the size of blobs and structure of the digits. Connected component is a new process that identify the stems and blobs in digit. Basically this method removes the complexity of recognition system to finding the horizontal and vertical line then removes these lines. The digit which having stems is extended into blobs by using morphological connected component approach. The decision tree is used to define the structure of the digits. For example: if there is only one blob in the digit then it should be 0. If the image pre-processing process is not performed carefully then this may cause extra blobs problem. To resolve this problem, thinning or skeletonization methods are applied. So, most of the digit are easily recognized by the help of blobs and stem. The recognition rate is achieved up to 90.00%. They leave some problems on these methods that do not work on large gap digits, digits with extra strokes and partial digits.

The identification of object, eye, nose, face, retina, words etc is the part of pattern recognition. The visual pattern recognition is process that is used to read contour, color, forms etc. so there is a problem to identify these attributes is very difficult task. The digit recognition is used to solve this problem by using feature extraction and classification. The feature extraction and classification is basically based on heuristic principle and problem-based knowledge but the Kai Labusch et al.[17] proposed a system that need not heuristic principle and problem-based knowledge. They use the combining unsupervised learning of a sparse code with local maximum operation for features extraction. The spare coding mechanism and local maximum operations are used for feature extraction.

The unsupervised sparsenet algorithm is used in learning process to represent the patches of digit images. The preprocessing is performed on input image. Then the feature extraction method is performed in two phase: first one is used to find out the coefficient of image by the help of learning basis and second step is performed by using local maximum operation. The learning basis functions are applied to each patch vector of Images. The PCA and sparse coding is used as generative image patch model. PCA and sparse coding is applied to the images patch vector that can determine the parameter by using generative image patch model. The coefficient of image is obtained from the training data by using sparsenet algorithm. The input images patches have the coefficient image which contains the coefficient of basis functions. The basis function objective is used to minimize the sparsenet coefficients. To find out the final feature of image vector a local minmax operations are performed and these features are used for the classifier. Now the SVM training and learning of function basis are performed on final feature vector. Classification is performed by using MNIST data and provides significance performance. The combination of maximum operations and sparse feature demonstration shows the really good performance.

Handwritten Character recognition system is increased day by day and lots of research has done in this field and still going on for future enhancement such as mathematic equation. Mathematic equation has word, digit and special symbol which are a very interesting and challenging task for the recognition. In mathematical equation symbol or expressions are arranged from left to right. Sanjay S. Gharde et al.[31], proposed a system that is used to recognize the mathematical equation. In this system the following process are followed: First of all the mathematical equation is scanned and in the preprocessing phase, noise removal algorithm is used to remove the loops, dots, extra strokes, curves etc.

Skew correction and detection, binarization, normalization algorithms are also used to make the equation neat and clean. Segmentation process is used to segment the operations, operand using labeling and bounding box algorithms. If the image is colored then it is necessary to convert into grayscale image. Feature extraction algorithms are used to find out most suitable information about the character. Here projection histogram algorithm is used which compute the number of pixels in different direction and having value "1". Horizontal, vertical and left & right diagonal are the basic histogram. By using these algorithms features are extracted of character which is used for the classification. In the classification character is recognized according to predefined rules of text. Here the support vector machine is used for classification. The classification and recognition performed on 237 symbols which have been extracted from 28 different equations. By using this mechanism the recognition rate is achieved upto 98.26%. The implementations of some more complex equation is quite difficult and tries to make some computational task on the basis of these equations in the future.

The license plate recognition is an application of digital image processing in which digit recognition system is used for the recognition. Milan Tuba and Snezana Zekovich [42], proposed a system for handwritten digit recognition that is based on the Hu moment. Template based recognition is a tough task for recognizing handwritten digit. Hu moments are unchangeable to many transformations such as scaling and rotation. The algorithms how acceptable recognition ratios in initial phase, not including any preprocessing steps although preprocessing increase the recognition rate. The calculation of the moment Invariants is based on Summed area tables (SAT). A Hu moment set has 7 moments.

This set is non-changeable for the translation, mirroring, rotation and scaling. This is an important property for extraction method for shape contour. Contour is a list of pixels that shows curve on image. A filter is used for the edge detection that find out the edge pixels to separate the image in different segments. The contour matching with other contour is based on the characteristics of the contour moments. The proposed algorithm used the modular architecture of the feature extraction and digit classifications.

This algorithm is implemented using digit analysis and its Hu moment that is invariant as digit descriptor. Different types of digits can be written in different angle for the purpose of classification. Then the Hu moment are computed and then compare with the sum of distance Hu moment from the average of digits. The Hu moment can be used to recognition the digit

at the first step. This method achieves a good recognition rate. The Future work is needed to enhance the accuracy with larger number of inputs.

A human can read handwritten digit easily and make the reorganization for the future. When we have a large number of database and the work is done manually. It may consume a lot of time as well as money and does not promise of accuracy. So this task is done with the help of machine then the results are acceptable. The number recognition decreases the processing time with high accuracy which can be done with the help of computer applications. In number recognition is required everywhere for example in passport number, driving license number, zip code analysis and many more. The number recognition is difficult because of the variation in the size and shape. So, Salameh A.Mjlae et al. [43], proposed a system for the Indian number recognition. They describe this system in three phases:-pre-processing, feature extraction and number recognition. The pre-processing phase improves the visibility and readability of the input image of Indian number by removing the unwanted information. The binarization, skew correction, slant normalization, size normalization and thinning operations are performed in pre-processing phase. The feature extraction method is used reduce the dimensionality of the number.

Here a new feature extraction method is described which divide the handwritten Indian number image into 16 sub block and 24 partition lines. The vector set of 41 attributes is maintaining that represent the 16 block and 24 partition lines and out them one attribute is used to test the closed loop. For recognition of Indian number the decision making operation are used to classify the number by comparing its vector set attributes with its predefined attribute of the same class. They use five classifiers: - DROP1, DROP2, DROP3, DROP4, and RNN for the classification and this classifier show satisfactory accuracy. The highest classification accuracy found in DROP3 classifier.

In Yann LeCun et al. [25], they give a learning algorithm for the classification for the handwritten digit recognition. There are different types of learning algorithm were used for classification and the performance optimized on standard database. The accuracy, training time, recognition and requirements of memory had been also analyzed. Different kind of database has been used for the training and testing such as zip code Database, NIST (National Institute of Standards and Technology), and Modified NIST. There are several classifier are used for the classification of the handwritten digit. Baseline Linear Classifier, Baseline

Nearest Neighbor classifier, fully connected multi layer neural network, LeNet1, KeNet4, Boosted LeNet4, tangent distance classifier etc are used for the classification and recognition. The performance of classifier depends upon the many facts and these facts are:- high accuracy, low space need, low run time, and appropriate training time.

Chapter 3 Problem Investigation & Present Analysis of System

3.1 Problem Investigation

This dissertation deals through recognition of handwritten English numerals stand on numeral features. That means recognition of a given input numeral has been done by extracting some different features from that input numeral. In the direction of recognize handwritten English numeral, the input images are obtained from papers having English number by using scanning device which is called as input device such as –Scanner. So the main problem is that to extract the feature of a digit image which is handwritten and the handwriting is different of every person so the recognition of digit image is very tedious task.

Now images are scanned and stored in some image format like jpeg, jpg, png, bmp and more. This image consequently passes through these steps: Pre-processing, segmentation, feature extraction, classification and recognition.

This dissertation proposes a new feature extraction algorithm for handwritten English numerals. The algorithm works on shape theory which is a structural approach. Before this every one work on whole image of digit but in this algorithm the segmented image digit is divided into the four regions and each region draw a shape. So here we work of a part of an image. So work on a part of image is very easy but matching these regions is tedious task. All these parts are converted into bit pattern (0 and 1). Now calculate the pixel intensity of each part by examining the 0 and 1's. 0 means “off” pixels and 1 means “on”. On the basis of the pixel intensity we calculated the average intensity which describes the range. Now total the all range of each part we get a range which is used in classification.

Classification is based on the shape of each part. The decision tree is used for digit classification. In this technique we use some condition and these conditions classify the digit. On the basis shapes all numerals are divided into two groups and further dividing into sub groups. The shapes of each part have a range of pixel intensity and by comparing these ranges of pixels and these ranges classify the digits.

3.2 Analysis of concept with present investigation

Before we start we have look on the digital image processing which describe what image means and what information we want to extract from an image.

3.2.1 Image Processing and Pattern Recognition

In the recent era and decade ago, the images carry the information and play an important role in transferring information. A single image can carry thousand of information about the sizes, shape, positions and relationship among objects. The persons are good enough to find out these information's from an image on the basis of their good sense of humor and mental skill. A human can get 75% information in the pictorial form. Digital Image Processing include progression whose inputs and outputs are images, and in count, include progression that take out characteristics from images, up to and as well as the detection of individual images. The main aim is to take the text information from an image. There are several processes performed to acquire the information from an image like preprocessing of the text, segmentations which separating the characters, the feature extracting algorithm which make the information to machine readable and at last the recognition of an isolated character are the compass in digital image processing.

Pattern recognition is a sub part of image processing which covers a variety of research field like fingerprint recognition, face recognition, signature recognition, and many more. Here we work on digit recognition which is also a part of pattern recognition.

3.2.2 Tools Used

In this paper the java platform is used. The Mat Lab was extensively used and good results but java provides better results than mat lab that's why java is used. It provides the following benefits:-

1. Java provides better security
2. Java provides portability
3. It is simple to implement
4. It is free ware for all users

3.2.3 Digit Recognition

The computer changes the world of human, because they almost all work on computer. The computer can reduce their working time as well as provide accurate results. For example: the automated cash machine, the data, characters, digits etc. are commonly used in normal life. The number automation deals with postal code, demand draft number, account numbers and car plates' number. The number recognition that deals with automatic system is the main aim of this work. A lot of research work has been done on Digit recognition, lots of engineering's, scientists, and researcher did research on digit recognition and urbanized several approaches in image processing and pattern recognition. So, this is used in many fields like banking application for cheque number recognition, post offices application for automatic recognition of zip code, RTO offices application for automatic car plates and many more applications.

There are two types of techniques used to recognition the digit [5].

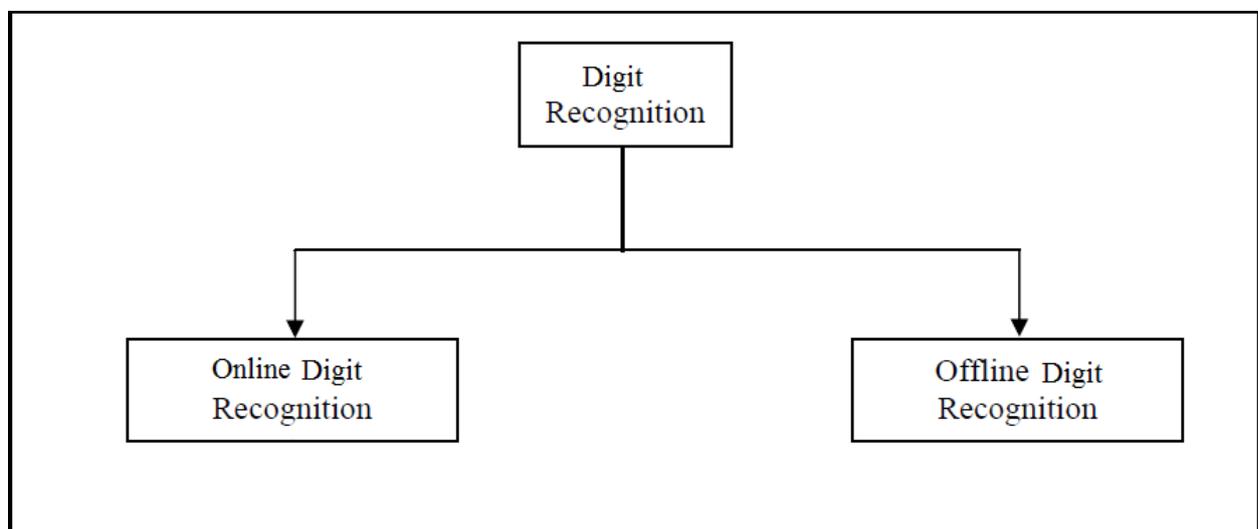


Figure 3.1: Classification Of Digit Recognition

Online digit recognition [5], there is actual time recognition of digit. Online systems acquire the location of the pen tip as a function of time openly from the edge. Online handwritten numeral recognition, the handwriting is confined & stored in digitalized form by dissimilar means. Generally, a unique pen is used in juxtaposition amid an electronic surface. As the pen be in motion across the plane, the 2-D coordinates of consecutive spot are represented as a function of time.

Here we use an offline recognition technique which is based on structural approach. This works on static information like ancient document. There are two approach applied in offline recognition: Statistical approach and Structural based approach [5]. The structural based approach is used in this dissertation and it means it works on the structure of the work like shape, curve etc.

In this work, the developed application is used to recognize the digit which may be used in several fields. The application mainly concerned on segmented digit, the input given in an image format (jpeg, png, bmp, jpg) which will be converted into editable format. This application recognizes the English numerals from 0 to 9. The application acquires the input digit image then the digit image goes through different stages for the betterment like image binarization, smoothing, noise reduction, skeletonization, skew detection & correction and segmentation. After the segmentation the digit images goes in the feature extraction and classification and then in the recognition phase and in the recognition phase a structural based approach has been used which is decision tree.

The following terms are used in my research work:-

1. Performed Pre-processing Steps on digits
 - a. Binarization
 - b. Noise Removal
 - c. Skeletonization
2. Segmentation Technique
 - a. Line Segmentation
 - b. Word Segmentation
 - c. Character Segmentation
3. Feature extraction Mechanisms
 - a. Feature extraction algorithm
 - b. Performing pre-processing steps (If Required)
4. Classification of digits

3.2.3.1 Performed Pre-processing Steps on digits

The pre-processing steps are performed on any objects to make it smoother, less noise, correct skew, thinned, etc. and these steps were performed because of different writing style. Here we used mainly binarization, noise removal and skeleton.

Binarization is used to convert the image into gray level. Without gray level conversion the feature extraction algorithm is not applied because there are different color of every image and color is also feature of any image so, it is meshed the entire features. The very first step is that gray level conversion of an input colored image to work on it. Binarization means it convert the gray scale image into an image that contains 0 and 1 pixel called as binary image. The threshold value is used to separate the foreground from background. The threshold value is calculated either globally or locally. The global threshold value was used to separate the foreground from background. There are many technique are used for binarization but the Otsu's Method mostly used.

Noise removal is process to reduce the noise on scanned image. The noise is taken place on scanned image due the quality of paper or some time scanning device. The mostly low-pass filter is used for noise removal.

Skeletonization/Thinning is used to reduce the size of objects. It basically removes the irregularities in digits. The thinning process reduces the many pixels of any object to single pixel. It helps for recognition algorithm to identify the digit in simpler way because now only one pixel is used for work, this increase the efficiency of the algorithm.

3.2.3.2 Segmentation Technique

It is a mechanism that is used to molders an image of digits into isolated digits. Digit segmentation is an important aspect for recognition that improves the efficiency of algorithm. It comprises word, line & numeral segmentation. Segmentation distributes the image into sub-image in the basis of their pixels attributes. Segmentation is based on contextual or non-contextual. In this paper the contextual based which used the texture based segmentation.

3.2.3.3 Feature Extraction Mechanisms

The segmented English numerals are transformed into actual treasured vector called feature structure of 0's and 1's that distinguish the important information of the pattern. Each numeral has various features, which play a vital job in pattern recognition. The handwritten numerals have several features particularly. Feature extraction illustrates the similar contour information that contained a pattern which is used for classification. The clustering algorithm is used for feature extraction. The segmented image is divided into four regions that shows different contour. On the basis of these contour the image is classified. For Example: - When the algorithm is applied onto a segmented image then it provides the following contours.

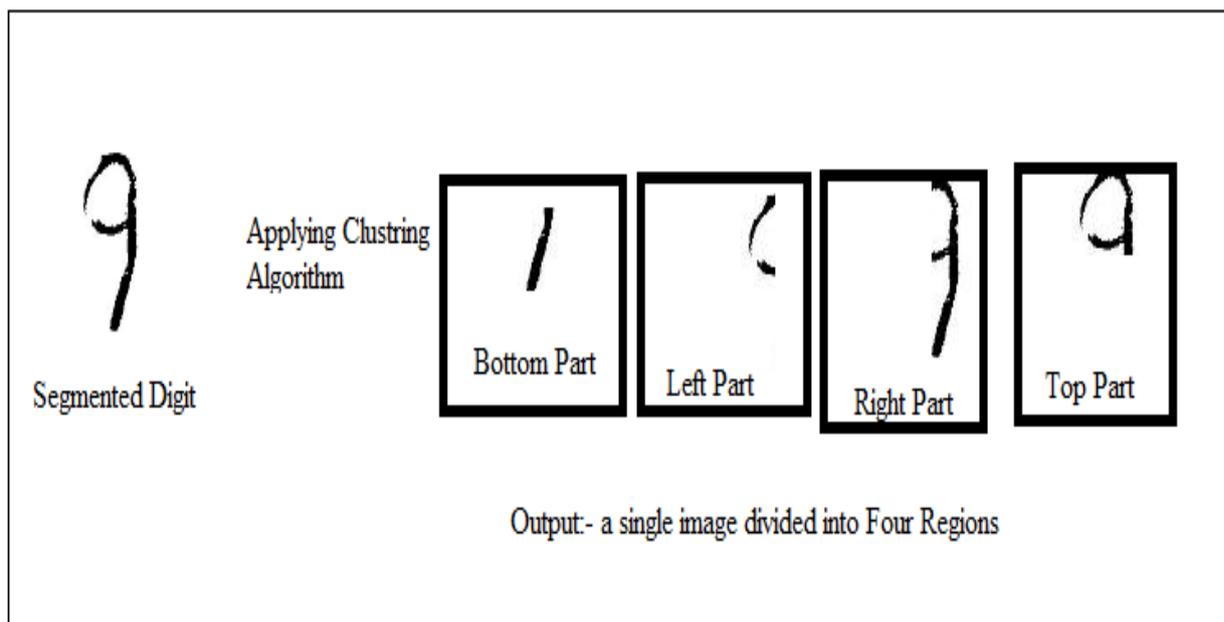


Figure 3.2 : - Image divided into four regions

So the feature extraction is a formula that was used to determine related contour information in the form of pattern so this formula makes the classification easier. There were lots of problems faced for recognizing the pattern and among all of them the feature selection was the most commonly raised. After applying the feature extraction algorithm pre-processing is performed if required.

3.2.3.4 Classification of Digits

It is a decisions making stage of the system. The decision is made on the basis of previous stage feature extraction information. Classification is apprehensive through making decisions regarding the class association of a pattern in problem. The job in any condition is prepared a decision rule and regulation that is used to calculate and also reduce the probability of misclassification comparative to the influence of feature extraction algorithm. Pattern are hence distorted via process of feature extraction into spots in a dimensional feature space which is denoted by d . Classification has many problems to recognize the digits because it has different features.

Chapter 4 Procedures and Implementation of Methodology

The handwritten digit recognition system which acquire the input image pre-process the image, segment the image, extract the feature of the image and classify the digit that is based on feature extracted. So there are many algorithms are used to perform these tasks out of them five algorithms are described here. Two algorithms are previously used and last three algorithms are newly designed. The algorithm which are used as follows:

1. Binarization Otsu's algorithm
2. Segmentation based on (Spectral features)
3. Feature Extraction algorithm based on dividing
4. Bit conversion and intensity calculation Algorithm
5. Decision tree algorithm

On the basis of these algorithms the digit is recognized. The overall system structure is as follows in figure 4.1.

4.1 Binarization Otsu's Algorithm

The first step after image acquire is the pre-processing and in the pre-processing the first step is binarization because binarization is an important part of our system without binarization gray level conversion is not possible. The gray level conversion is performed before binarization. The binarization is performed convert the image into 0's and 1's form. The threshold value is used to calculate for binarization. The algorithm we used for binarization is described below:

- ✓ Divide the pixels into two clusters according to the threshold
- ✓ Now the mean value is calculated for each cluster
- ✓ Find the difference between means and square the means
- ✓ Multiply by the number of pixels in one cluster times the number in the other

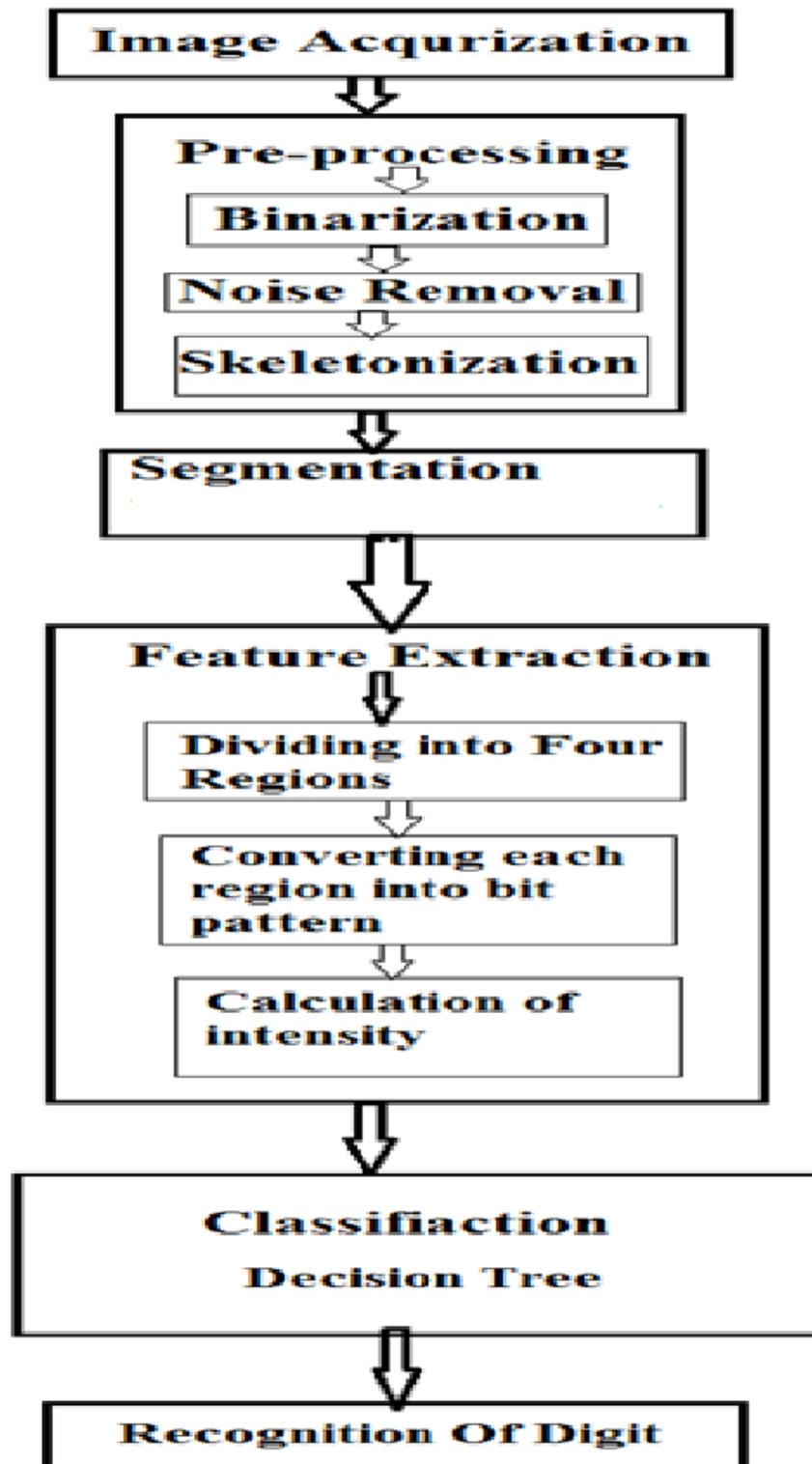


Figure 4.1: Digit Recognition System

Mathematics that is used behind Otsu's algorithms

Let q_1 and q_2 stand for the estimate of class probabilities defined as: 1

$$q_1(t) = \sum_{i=1}^t P(x)$$

$$q_2(t) = \sum_{i=t+1}^I P(x)$$

Sigmas are the individual class variance that is defined as:

$$\sigma_1^2(t) = \sum_{i=1}^t [i - \mu_1(t)]^2 \frac{P(i)}{q_1(t)}$$

$$\sigma_2^2(t) = \sum_{i=t+1}^I [i - \mu_2(t)]^2 \frac{P(i)}{q_2(t)}$$

And the class means:

$$\mu_1(t) = \sum_{i=1}^t \frac{iP(i)}{q_1(t)}$$

$$\mu_2(t) = \sum_{i=t+1}^I \frac{iP(i)}{q_2(t)}$$

P is the image histogram. The difference of total variance and within class variance:

$$\sigma_b^2 = \sigma^2 - \sigma_w^2(t) = q_1(t)[1 - q_1(t)][\mu_1(t) - \mu_2(t)]^2$$

Finally, this expression can safely be maximized and the solution is t that is maximizing $\sigma_b^2(t)$.

4.2 Segmentation based on texture (Spectral Features)

Segmentation has been performed to isolate the digits. This is performed because the feature of an individual image can be easily extracted. Grey level values are not enough for the segmentation for the highly-textured images. For Example:-

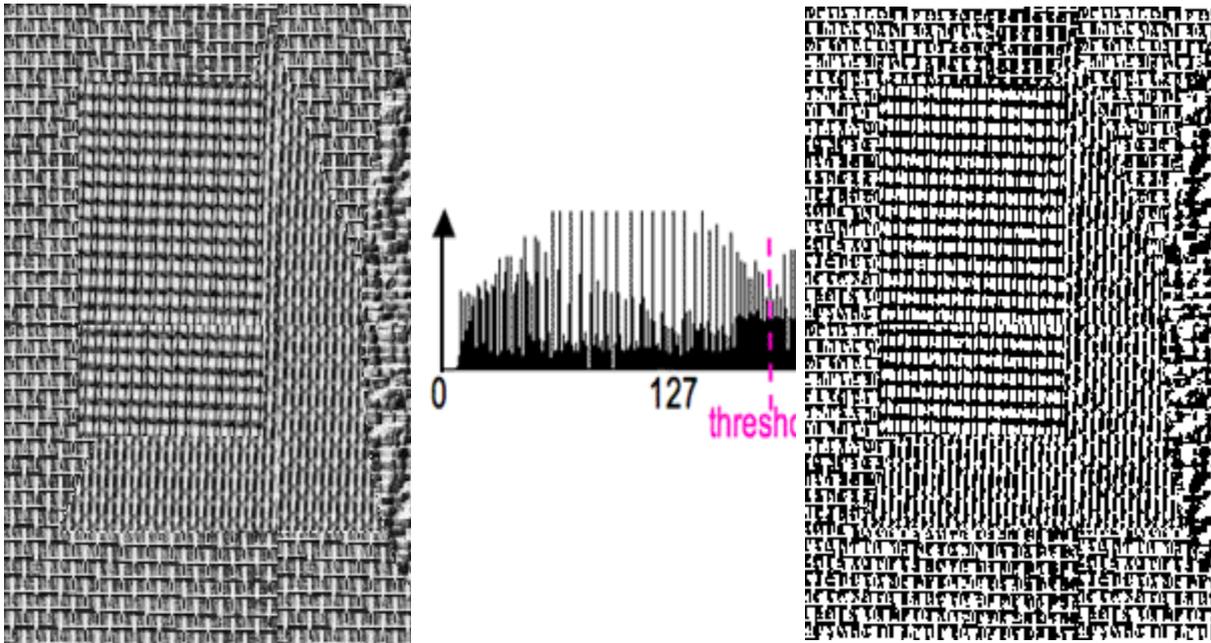


Figure 4.2 (a) Textured Collage (b) Grey-Level histogram (c) Segmentation by Thresholding

There are two regions: first one has a black object and second one has a white background. These regions are found via simply calculating the thresholding which are worthless. Headed for something meaningful regions having dissimilar types of harmonized textures, precise texture features have to be utilized like, for example, local spatial gesture statistics:

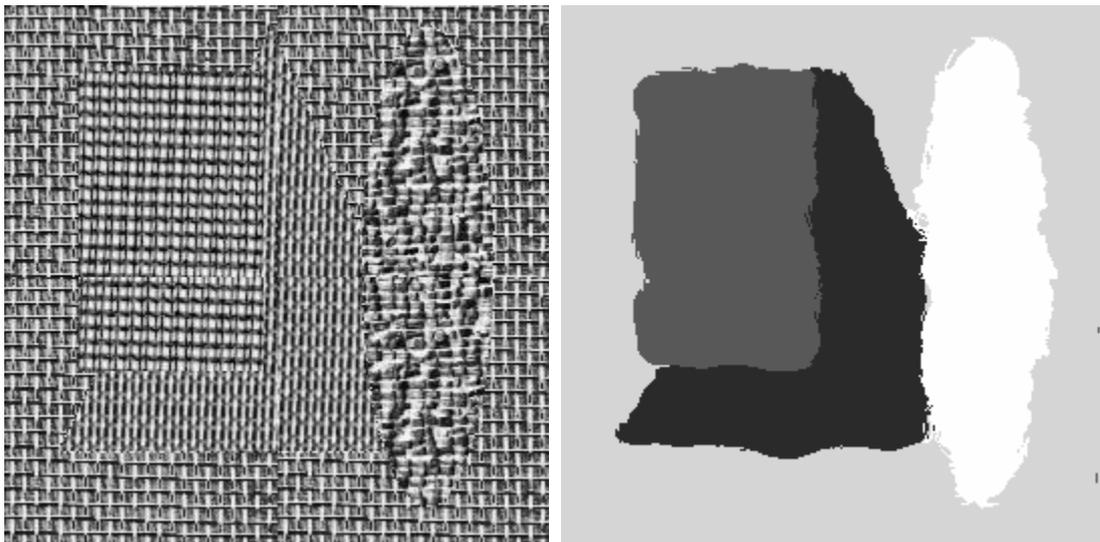


Figure 4.3: (a) Textured Collage (b) Segmentation using local features

Texture is spatial assets that describe groups of pixels. A local determination of texture is consequently computed above a neighborhood. For example: the easiest statistical calculation is the variance of grey levels within a square of $n \times n$ neighborhood axis on a pixel:

$$\sigma^2 = \frac{1}{n^2} \sum_{\xi=-n/2}^{n/2} \sum_{\eta=-n/2}^{n/2} (f(x+\xi, y+\eta) - \mu)^2; \quad \mu = \frac{1}{n^2} \sum_{\xi=-n/2}^{n/2} \sum_{\eta=-n/2}^{n/2} f(x+\xi, y+\eta)$$

The "variance" image shows the scaled standard deviations σ for each pixel; bright parts within this image imply high local variance of grey levels. The natural textures, easy statistical measures are of miniature use. If two textures of interest are sporadic, then they can be divided by the help of frequency domain via match up to the spectrum of petite sample received from these two patterns. The segmentation that is based on spectral uses the angularly included power spectra of a region into image. The calculated of spectral is following:

1. Radial integration totals power values in a ring has radius r and width Δr .
2. Angular integration totals power values inside a sector that is describe by a radius r , an orientation θ , and an angular width $\Delta\theta$.
3. The texture scale is based on ring measurement: an attentiveness of power at small or large radii means common texture, correspondingly.
4. The texture orientation is a sector-based measurement: a texture slanting in a direction φ results in high power for a sector at angle $\theta = \varphi + \pi/2$.

The complete segmentation is called when these requirements are fulfilled.

1. The entire pixels have to be allocated to regions.
2. Each pixel has a single region merely.
3. Each region is related to set of pixels.
4. Each region has to be identical by value to a specified predicate.
5. Any combined pair of adjoining regions has to be non-uniform.

4.3 Feature Extraction algorithm based on dividing

Every digit has some features, which play significant job within pattern recognition. Each digit has several scrupulous features. Feature extraction illustrates the appropriate shape information enclosed within a pattern thus the job of classifying the pattern is made simple through a proper procedure. Feature extraction stage in handwritten digit recognition system investigation these digits segment and choose a set of features to facilitate for exclusively identify that digit segment. Mostly, this stage is heart of Handwritten Digit Recognition system as output depends on these features. So the feature extraction is a formula that was used to determining related contour information in the form of pattern so this formula makes the classification easier.

The feature extraction technique is implemented using a new feature extractions approach. This algorithm is implemented for feature extraction discussed below with diagram. The algorithm we used here divides the single image into four parts which is called as feature of this image. The numerals are divided into four regions by using the following algorithm which is called as four region algorithm. The following steps are used to divide the segmented image into four regions:

- Selected image (72x72): Here the selected image is zero. So height and width coordinates are calculated.



Figure 4.4 Segmented Images

- Now, we divide the image into four parts which is start with the coordinates X,Y(0,0) like

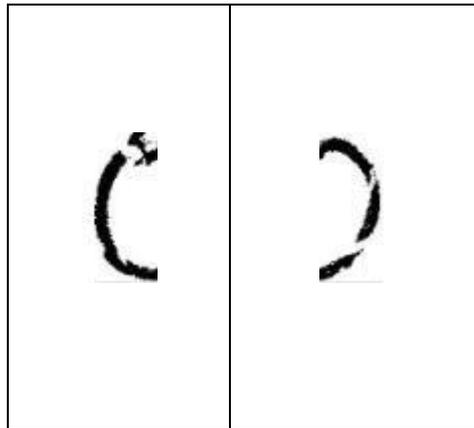


Figure 4.5:- Left and Right Part

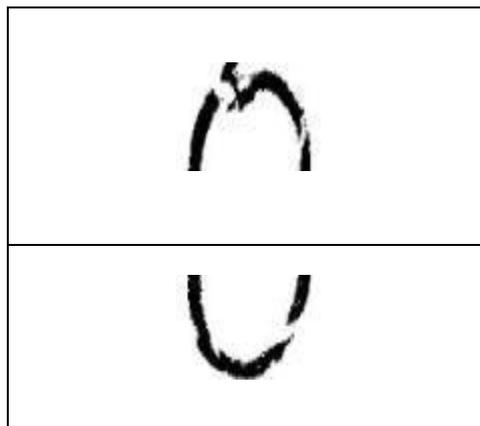


Figure 4.6:- Top and Bottom Part

- In order to get these four part of a image (72x72) we used java by applying these logics:-
 - `Img = imag.getSubImage`
(0, 0, 71, 36) for the top part of image
 - `Img = imag.getSubImage`
(0, 36, 71, 71) for the bottom part of image
 - `Img = imag.getSubImage`
(0, 0, 36, 71) for the left part of image
- `Img = imag.getSubImage (36, 0, 71, 71)` for the right part of image
- After applying this algorithm we got the following patterns which are as shown in table. Each part make an pattern which are as follows:-

S.No.	Left Part	Right Part	Top Part	Bottom Part
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				

Table 1:- Four Regions of every Digits

By analyzing these regions we find out following characteristics:

- Holes/Circle
- Vertical up & down cavities
- Horizontal left & Right cavities
- Right Curve
- Left Curve
- Upper Curve
- Bottom Curve

These following tasks will be done in using this application and diagrammatic view of my application is as follows:



Figure 4.7:- Handwritten Digit recognition System

For image scanning click on the scan image:



Figure 4.8:- Browsing the image Which is divided into four regions

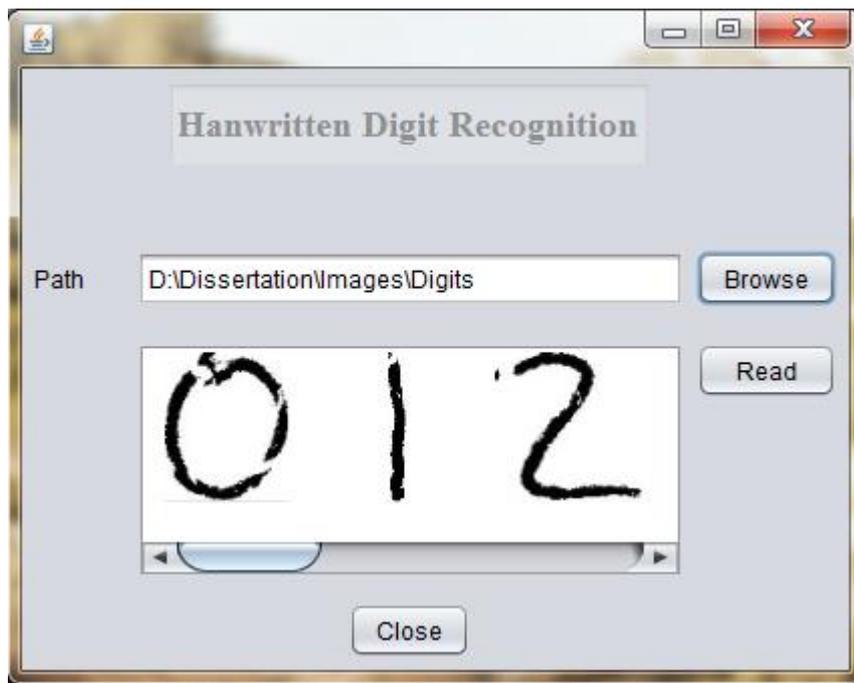


Figure 4.9:- The segmented images are selected

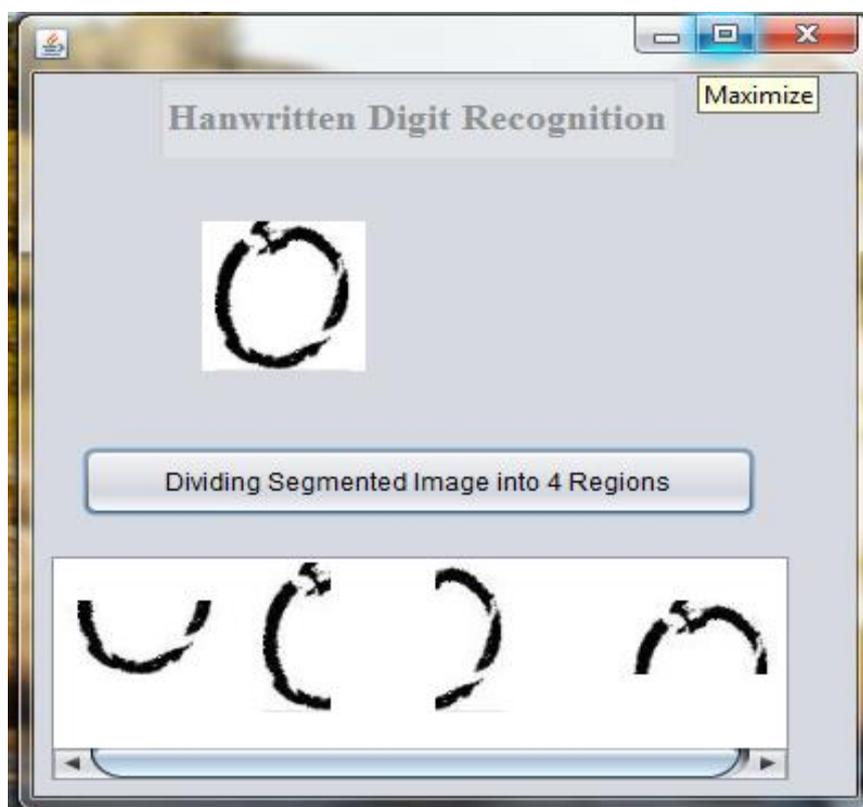


Figure 4.10:- After applying the dividing algorithm we got four regions

4.3.2 Similar regions

Now on the basis of these four regions a decision tree will be made. First of all, the similar regions are identified. The followings regions are identified which is shown in the following table:-

S.No.	Digit	Part	Attribute
1	3,5	Bottom	Right Curve
2	1,7,9	Bottom	Vertical Line
3	2,3	Top	Right Curve
4	2,6,8	Right	Right Curve
5	0,9	Left	Left Curve

Table 2:- The similar Attributes in each parts of digit

4.4 Bit Conversion and Intensity Calculation Algorithm

To matching these image first need to convert these parts of image into bits and for conversion following algorithm will be used:

- ✓ If we require the pre-processing of image to enhance contrast, noise removal
- ✓ Now segmentation is performed which divide the image into regions and contains the pixels range of the region that is similar and different.
- ✓ A descriptor is needed to calculate the all four region that is left part, right part, top part and bottom part of the image.
- ✓ If required, then perform Re-Segmentation of the image, where the regions are merged can be representing the same object.
- ✓ If needed, then we can eliminate the regions that are useless for the work.
- ✓ Accumulate the image's regions' descriptor used for auxiliary processing.

The calculations of these four regions are calculated by using pixels average value and then total of these values.

$$\text{Pixels avg value} == \frac{\text{Total Pixels in image}}{\text{Total true pixels}}$$

Now by applying this method we got approximate avg. pixels value for each part which is shown in the table:-

Digit	Left Part	Right Part	Top Part	Bottom Part
0	2	2	2	2
1	9	9	9	9
2	2	3	3	2
3	6	3	4	4
4	5	3	3	4
5	6	3	5	4
6	2	5	6	2
7	3	4	3	5
8	2	4	2	3
9	8	3	3	7

Table 3: Avg. Pixels value of each part

Now, after this we calculate the total pixels of each image. Total Number of avg. pixels in four parts == LeftPart+RightPart+TopPart+BottomPart

So the total number of avg. pixels in digit 0 is 8 such as:-

Total number of avg. pixels of digit 0's four parts == 2+2+2+2 == 8

By using this we got a range of pixels. Like this we find out all these digits range which is shown below:

Digit	Tot. of avg. pixels of each part
0	8
1	36
2	10
3	17
4	15
5	18
6	15
7	15
8	11
9	21

Table 4: Total of avg. pixels of each part

After applying this algorithm we got a range of every English numeral, so by using this range the classification and recognition of digit has been done. The bit conversion and intensity calculation algorithm has been performed only once further it will not require because it gives us a range for particular digits.

4.5 Decision Tree Algorithm

The classification and digit recognition has been done through decision tree algorithm. The classification phase is an important phase which is used to compare the extracted feature with scanned image. So here classification has been done using the attribute of image which is based onto the each region of image. The algorithm we used for classification is as following:-

1. First on the basis of the right curve if it is found on each part then two groups are made.
 1. (0, 2, 3, 5, and 8)
 2. (1, 4, 6, 7, and 9)
2. First group which have the following digits: 0, 2, 3, 5, and 8 is further divided into two parts on the basis of right curve found at bottom part. 3 and 5 these digits make a parts and the second part have the 0, 2, and 8.

3. First part (3, 5): if right curve found in the top part then the digit is 3 otherwise the digit is 5.
4. Second part (0, 2, 8): if we found upper curve at top part and lower curve at the bottom part which have 0 and 8 digits and the other part have the digit 2.
5. Sub module which has 0 and 8: have the left curve in left then it is 0 otherwise it is 8.
6. Second group having the following digits: 1, 4, 6, 7 and 9 again divided into two sub module.
7. A Module which has horizontal line/cavities at the right part is first sub-module (1, 4 and 7). Second sub-module has 6 and 9 digits.
8. First sub-module which have (1, 4 and 7) again divided into two sub parts in which one part has the vertical line at top, bottom, left and right part is recognized digit 1 and the other sub part have (4 and 7). If we found horizontal line at top and vertical line at bottom then it is 7 and otherwise it is 4.
9. Second sub-module which have 6 and 9: if we found circle at top and left curve at the left then it is 9 otherwise it is 6.

On the basis of this algorithm the following tree has been made.

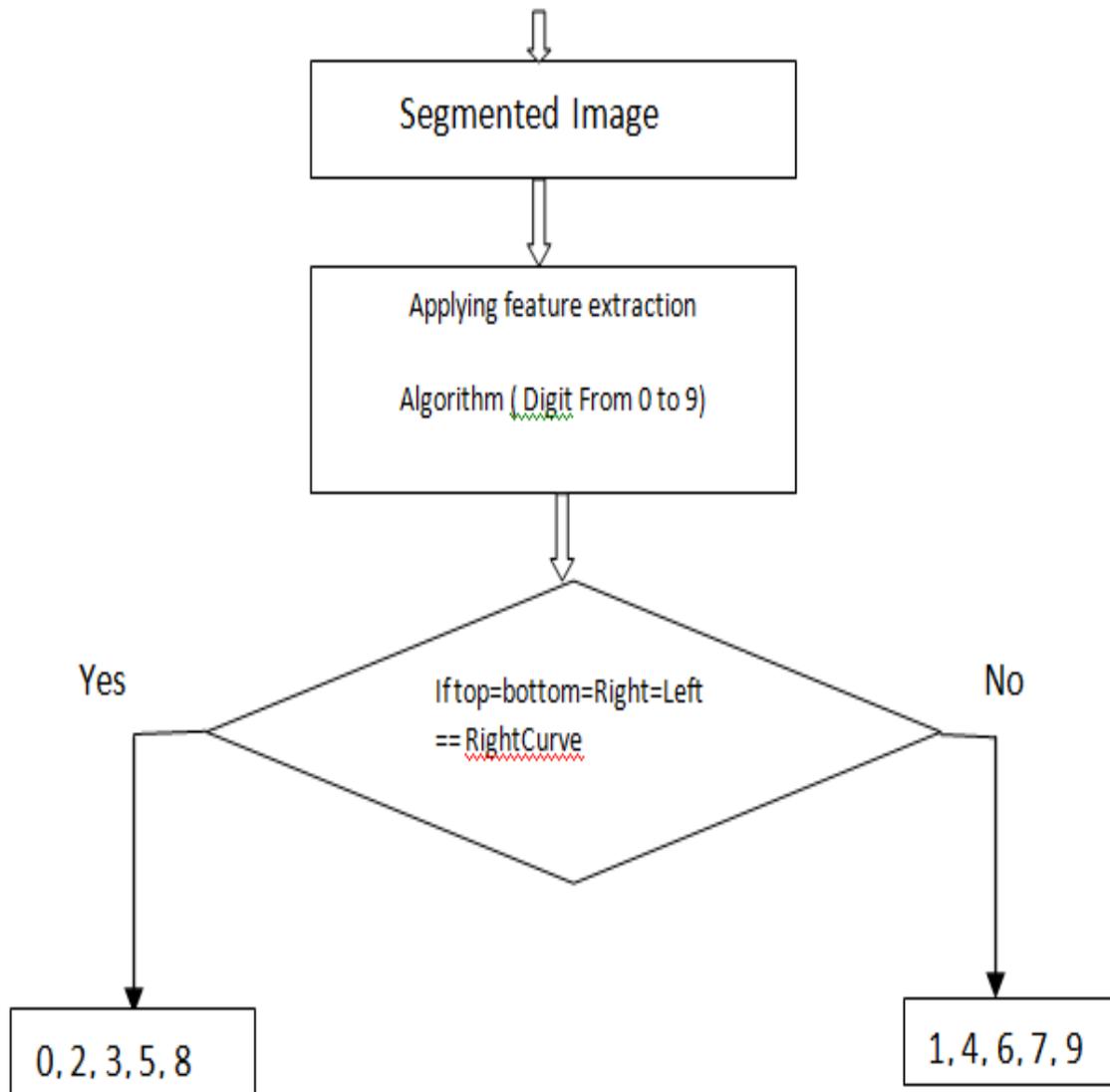


Figure 4.11:- Dividing into two Groups

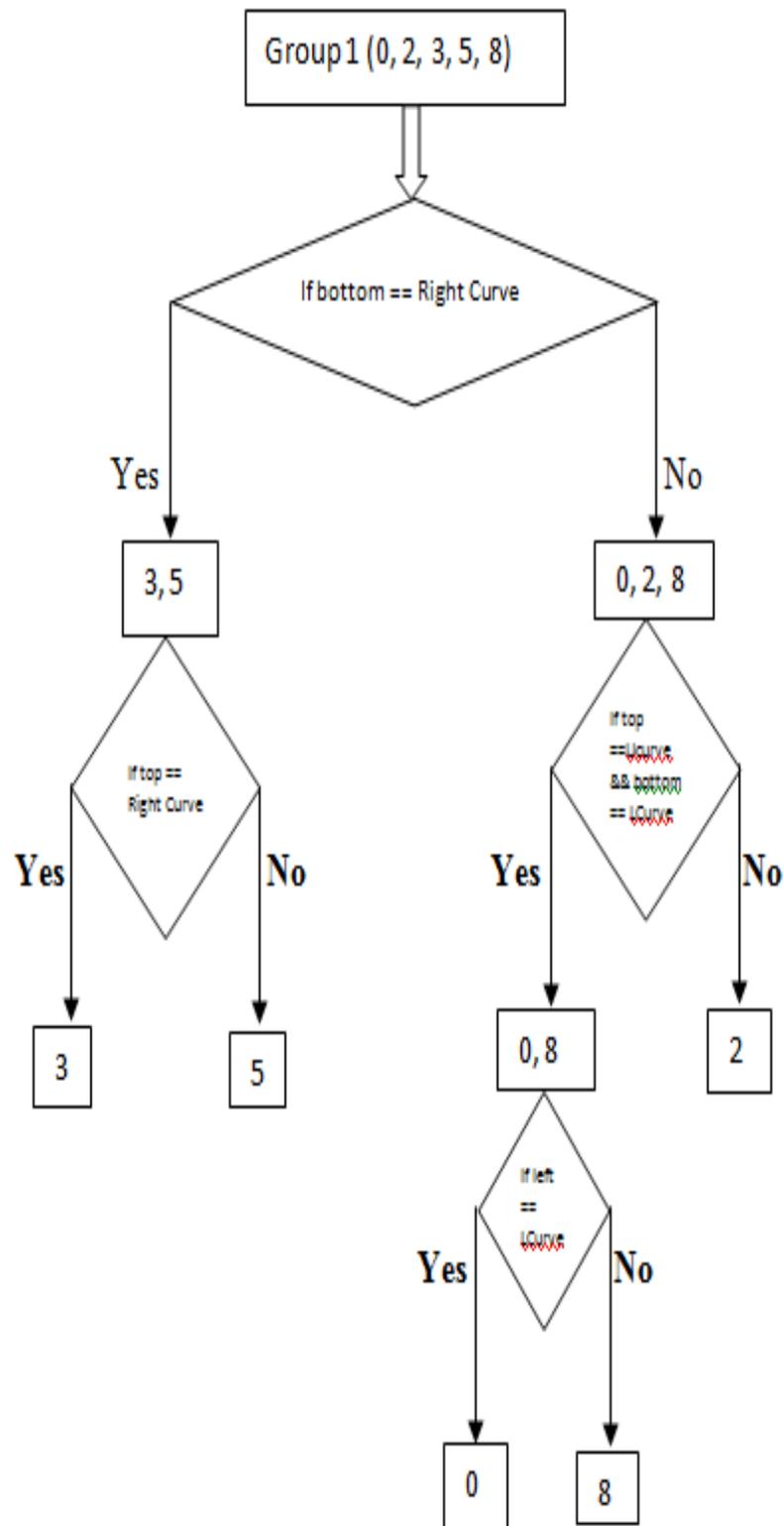


Figure 4.12:- Group 1 Digit classification

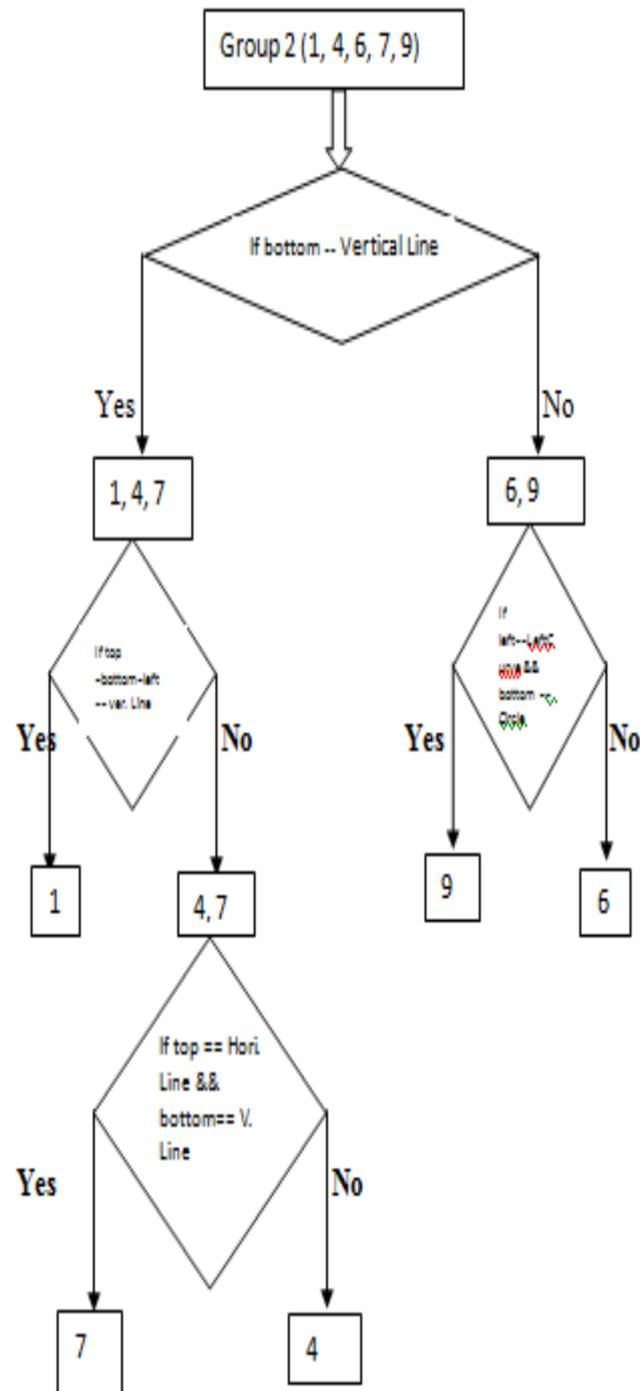


Figure 4.12:- Group 2 Digit classification

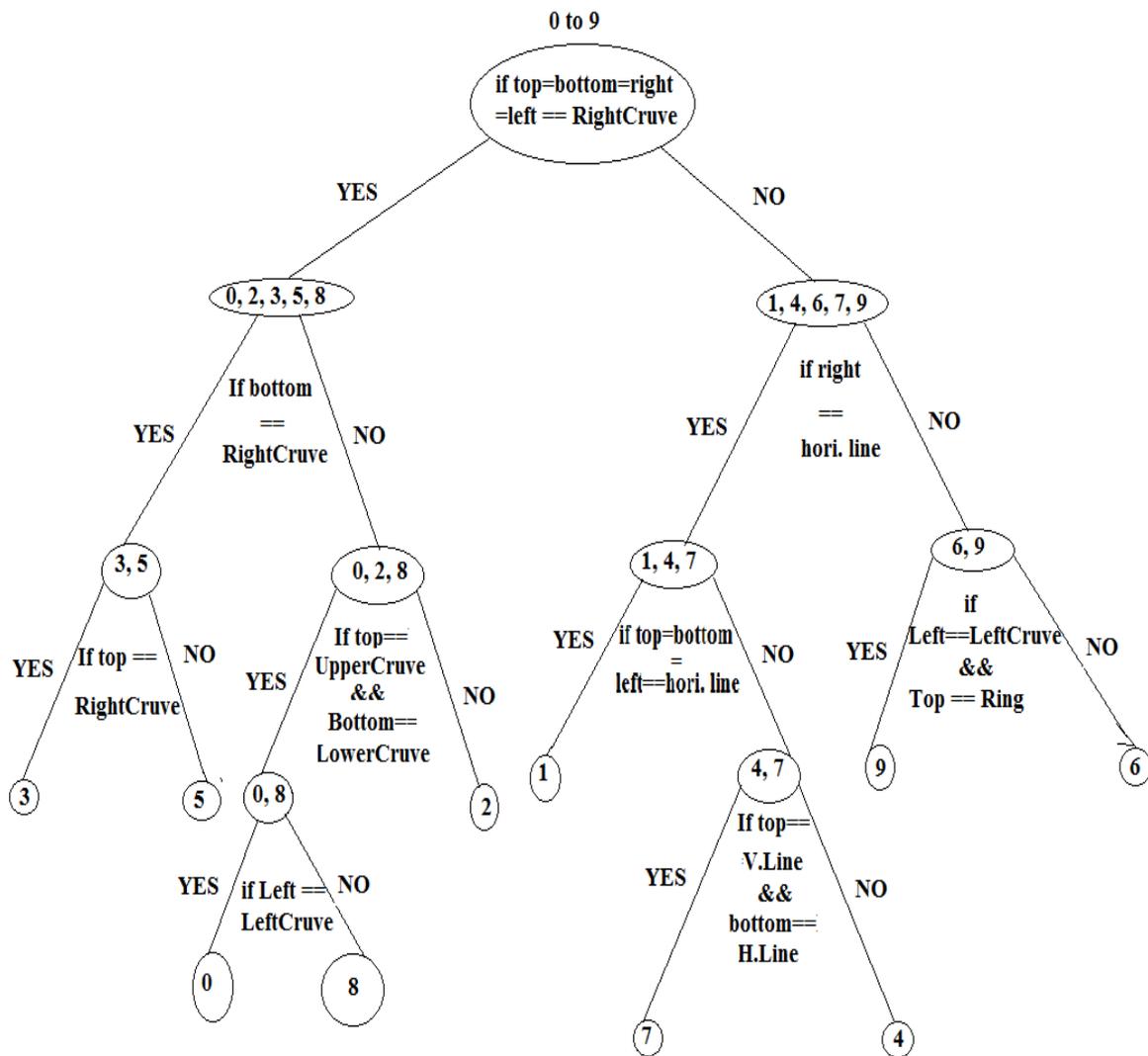


Figure 4.13:- Digit Classification and recognition Decision tree

After this algorithm applied the sample data is used to test the system by using this decision tree algorithm and results are compared with preferred results. Difference in between any two values shows an error. The correctness can be calculated as follows:

$$\text{Correctness (\%)} = \frac{\text{No. of digit found correctly} * 100}{\text{Total number of samples}}$$

Chapter 5 Result and Discussion

The digits are classified and recognized by the help of decision tree. There are some common bit patterns which are used to classify the digits into two groups. The region which have the right Curve in the top part, bottom part, left part and right part make a group (0, 2, 3, 5, and 8) called as first group. The group which does not have any curve in any parts (1, 4, 6, 7, and 9) called as second group. First group which have the following digits: 0, 2, 3, 5, and 8 is further divided into two parts on the basis of right curve found at bottom part. 3 and 5 these digits make a parts and the second part have the 0, 2, and 8. First part (3, 5): if right curve found in the top part then the digit is 3 otherwise the digit is 5.

Second part (0, 2, 8): if we found upper curve at top part and lower curve at the bottom part which have 0 and 8 digits and the other part have the digit 2. Sub module which has 0 and 8: have the left curve in left then it is 0 otherwise it is 8. Second group having the following digits: 1, 4, 6, 7 and 9 again divided into two sub module.

A Module which has horizontal line/cavities at the right part is first sub-module (1, 4 and 7). Second sub-module has 6 and 9 digits. First sub-module which have (1, 4 and 7) again divided into two sub parts in which one part has the vertical line at top, bottom, left and right part is recognized digit 1 and the other sub part have (4 and 7). If we found horizontal line at top and vertical line at bottom then it is 7 and otherwise it is 4. Second sub-module which has 6 and 9: if we found circle at top and left curve at the left then it is 9 otherwise it is 6.

Now all these curve of each image part is converted into bit patterns and calculate the pixel intensity of each part. After getting the intensity of each part, we total the intensity of each digit's part which gives us range and on the basis of this range the recognition of digit were taken place. In this paper we used differently handwritten data set sample by 30 peoples. Out of them five data set sample are shown below:-

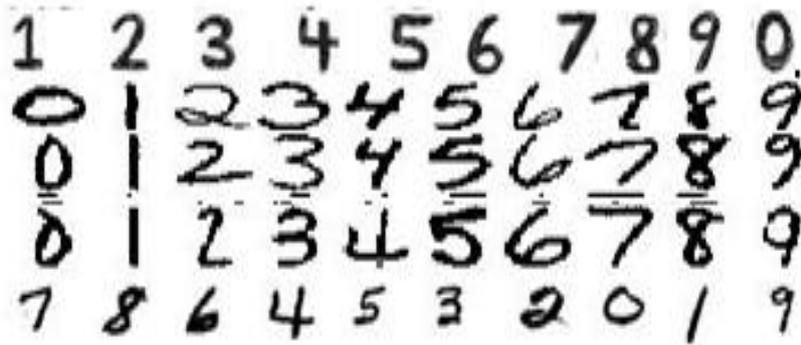


Figure 5.1: Data set sample From 5 Different Persons

The recognition of each digit which is successfully done was shown in table.

Digits	Success rate of recognition (%)
0	94.59%
1	97.85%
2	81.23%
3	92.17%
4	83.25%
5	95.67%
6	98.00%
7	95.49%
8	99.98%
9	97.99%

Table 5: Recognitions of handwritten digits for 30 users

5.1 Comparison with Existing Method

We compare the proposed algorithm with existing method of V Vijaya Kumar et.al [26]. By the comparing results some of digits show great results and two digits not show good results.

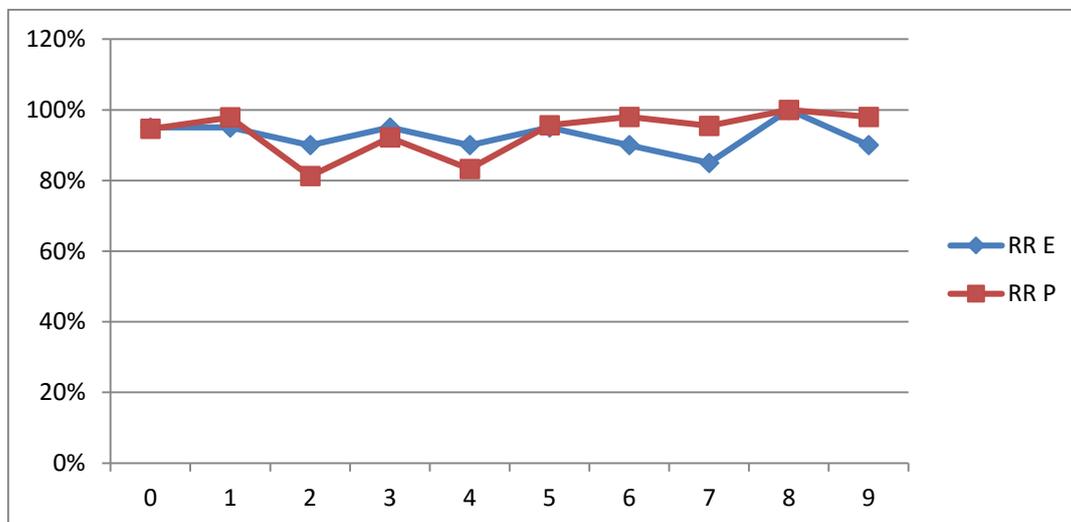
Digits	Recognition Accuracy of decision tree algorithm of V VIJAYA KUMAR et.al[26]	Recognition Accuracy of proposed algorithm

0	95%	94.59%
1	95%	97.85%
2	90%	81.23%
3	95%	92.17%
4	90%	83.25%
5	95%	95.67%
6	90%	98.00%
7	85%	95.49%
8	100%	99.98%
9	90%	97.99%

Table 6: Comparison of existing method with proposed method

5.2 Comparison Graph of the Algorithm V Vijaya Kumar et.al [26] and the proposed Algorithm

Here graph showing the square variation of the performance of recognition of the existing algorithm of V Vijaya Kumar et.al [26] and proposed algorithm There is small variance exist.



RR E = = Recognition Rate of Existing Algorithm

RR P = = Recognition Rate of Proposed Algorithm

Figure 5.2:- Showing the square variation of the performance of recognition of the existing algorithm and proposed algorithm.

Chapter 6 Conclusion and Future Work

Handwritten digit recognition based on digit feature is discussed in this paper. Regions based feature algorithm and density based algorithm are executed. This algorithm shows a good recognition rate of the English numerals in comparison with previous algorithms that performed morphological operation on digits. A tool is made by using this algorithm which is implemented in java. A decision tree is used for classification.

This algorithm uses a novel technology of regions which shows a great efficiency in the digits recognition because it work only on some part of image not on whole image which shows the faster recognitions. Regarding this specifics rules are describe in second section. All digits average success rate is above 91.21% which is a good recognition rate. This mechanism may decrease the proficiency of the algorithm when it found a rough written digits or digit with extra storks. This work can be implemented in the future.

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