HANDWRITTEN CHARACTER RECOGNITION USING MACHINE LEARNING APPROACH

By

Mr. Shivangkumar R. Patel
(130320702512)

Guided By

Ms. Jasmin Jha
B.E. (C.E.) and M.Tech. (Web Technologies)
Asst. Prof., PG Department, L.J.I.E.T.

A Thesis Submitted to
Gujarat Technological University in Partial Fulfilment of the Requirements for the Degree of Master of Engineering in Computer Engineering

May 2015

L.J. Institute of Engineering and Technology,
LJ Campus, Nr Sarkhej-Sanand Circle, S.G. Highway,
Ahmedabad-382210, Gujarat, India

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CERTIFICATE

This is to certify that the research work embodied in this thesis entitled **"HANDWRITTEN CHARACTER RECOGNITION USING MACHINE LEARNING APPROACH"** has been carried out by **Mr. Shivangkumar R. Patel (Enrollment no. 130320702512)** studying at L.J. Institutes of Engineering and Technology (032) for partial fulfillment of Master of Engineering degree to be awarded by Gujarat Technological University. This research work has been carried out under my guidance and supervision and it is up to my satisfaction.

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COMPLIANCE CERTIFICATE

This is to certify that research work embodied in this thesis entitled "**Handwritten Character Recognition using Machine Learning Approach**" was carried out by **Mr. Shivangkumar R. Patel (**Enrollment No**. 130320702512)** at L.J. Institutes of Engineering and Technology (032) for partial fulfillment of Master of Engineering degree to be awarded by Gujarat Technological University. He has complied to the comments given by the Dissertation Phase-1 as well as Mid Semester Thesis Reviewer to my satisfaction.

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PAPER PUBLICATION CERTIFICATE

This is to certify that research work embodied in this thesis entitled "**Handwritten Character Recognition using Machine Learning Approach**" carried out by **Mr. Shivangkumar R. Patel (**Enrollment No. **130320702512**) at L.J. Institutes of Engineering and Technology (032) for partial fulfillment of Master of Engineering degree to be awarded by Gujarat Technological University, has published article entitled **"Handwritten Character Recognition using Machine Learning Approach – A Survey"** in the proceedings of the ***International Conference on Electrical, Electronics, Signals, Communication and Optimization (EESCO)*** held on 24th & 25th January 2015., by **ISBN : 978-1-4799-7676-8** and ***IEEE copyright notice: 978-1-4799-7678-2/15/$31.00 2015 IEEE.***

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THESIS APPROVAL CERTIFICATE

This is to certify that research work embodied in this thesis entitled **"Handwritten Character Recognition using Machine Learning Approach"** carried out by **Mr. Shivangkumar R. Patel** (Enrollment No. **130320702512**) at L.J. Institutes of Engineering and Technology (032) is approved for the degree of Master of Engineering with specialization of Computer Engineering by Gujarat Technological University.

Date:

Place:

Examiners Sign and Name:

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( ) ( )

[UNDERTAKING ABOUT ORIGINALITY OFWORK]

We hereby certify that we are the sole authors of this thesis and that neither any part of this thesis nor the whole of the thesis has been submitted for a degree to any other University or Institution.

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We have checked write up of the present thesis using anti-plagiarism database and it is in allowable limit. Even though later on in case of any complaint pertaining of plagiarism, we are sole responsible for the same and we understand that as per UGC norms, University can even revoke Master of Engineering degree conferred to the student submitting this thesis.

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ACKNOWLEDGEMENT

The Almighty God has given us a very important part of our body which makes a human being at par from other living organisms. It is because of this brain that we are able to undertake each and every activity in our life. So, I first thank the God.

I am truly thankful to my guide **Ms Jasmin Jha (**Assistant Professor, P.G.C.E. Department, L.J.I.E.T. Ahmedabad) for her invaluable guidance and great support and make my dissertation truly success.

I would also like to extend my gratitude to **Ms. Gayatri Pandi (Jain) (**HOD, PG Department, L.J.I.E.T. Ahmedabad) for her support.

I would also like to thankful to **Mr. Mahesh Goyani (**Assistant Professor, L.D.C.E. Ahmedabad) for his great support and help for startup study in image processing.

At last, I want to thanks to my *parents*, *both sisters*, *dear friends* and all *classmates* and *college professors* for their great support and make my confidence always up and up.

Shivangkumar R. Patel
(130320702512)

To

My Parents,

Loving Sisters,

& Friends,

For Their Love And Support.

Table of Content

List of Figures

List of Tables

HANDWRITTEN CHARACTER RECOGNITION USING MACHINE LEARNING APPROACH

Submitted by:

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Abstract

Research was in Handwritten Character recognition was started after 1980. Manny researchers proposed their various works and achieve good accuracy. But, still it is an area under research to achieve higher accuracy and reduce the time complexity. After artificial intelligence came, accuracy of pattern recognition increased with use of applying the machine learning algorithms on the pattern recognition. So, this machine learning algorithm apply on character recognition and achieve good recognition accuracy is the main reason behind it. This thesis presents the applying new strategy on offline handwritten English character recognition with machine learning approaches, And try to figure out, how much it is efficient then conventional way in terms of accuracy and time for recognition. Experiment was conducted with some assumptions and constraints. Result and analysis show that, proposed approach gives more accuracy in less time.

Keywords : Handwritten Character Recognition, Feature Extraction, Classification, Machine learning, Artificial Neural networks, SVM.

Chapter 1

Introduction

Handwritten character recognition is a application of pattern recognition. In 1981, Bezdek et. al.[28] gave the definition of the pattern recognition is, "A process of identifying structure in data by comparisons to known structure; The known structure is developed through method of classification". In general term, handwritten character recognition is the process to classify characters from the input handwritten texts, as per the predefined character classes. Applications for character recognition are character identification, digitization of handwritten record, application form reading and based on data entry, translation system - recognize the unknown language and translate it in a known language,[1] reading aids for the blind,[2,3] bank cheques processing,[2,3] signature verification, vehicle number plates,[2,3] automatic pin code reading to postal mail,[2,3] Box label reading in warehouse, etc.

In the India, almost every sector going to digitalization. In this situation English language is the more useful and more popular language. Character recognition cover many application area. Many recherches developed handwritten character recognition system for different Indian languages like Hindi, Gujarati, Malayalam, Urdu, English, Arabic, Chines,etc. But, now a days almost every sector going to digitalization. In this situation English is more useful in everyday life. So, English language is more suitable for handwritten character recognition system.

1.1 Motivation

First important thing is, in our daily life, actually we are doing character recognition all the time. Like when reading someone else notes, sign-board or novel or reading books, etc. Then we match it with our past experience and memory, and based on that we react or take an action or infer some new things. So, this is our natural character recognition.
Based on natural character recognition, other artificial recognition system are working.

Second important thing is, in human or nature learning always fast, more accurate and efficient when it is starting with small amount... Or we can say it, *Piece by Piece !*

Suppose, If we have 100 things to learn... Check below both cases, and you will

easily predict which one is batter...

Case 1 : And you are start learning with all of them at a time !

Case 2 : And you are start learning with first 10 things, your friend 1 start with second 10 things, your friend 2 start with next 10 things and so on...
(Actually you are lucky, because you have friends who are interested in learning !)

1.2 Thesis Outline

Rest of the thesis is organized as follow. Chapter 2, presents the theoretical background for the title. Chapter 3, presents the literature survey regarding handwritten character recognition system. It will gave the information regarding past and present with various machine learning techniques used by different researchers and then shows the comparison table of various recent research in handwritten character recognition. Chapter 4, presents the scope of thesis work. It elaborate, What is problems, goal ? Ans for problem solution, What is propose methodology. Chapter 5, present small brief information about tools and technology. Chapter 6, presents the work plan. Chapter 7, presents experiment's result regarding proposed methodology and already existed methods. Chapter 8, presents the conclusion and Future work of this research work.

Appendix A, contain scan copy of review card. Appendix B, contain plagiarism report. Appendix C, contain the meeting with expert detail. Appendix D, contain details of paper publication and published paper copy. Appendix E, contain Abbreviation. Last alphabetic ordered index.

Chapter 2

Theoretical Background

2.1 History - Character Recognition System

First time character recognition was done by Tyuring, who tried to develop an aid for the visually handicapped [4]. The first time character recognizer came in 1940s. Before that, mostly all works are related to machine-printed text or a small set of handwritten symbols or texts. [5]

After that, in 1980 to 1990, work growth of character recognition system development rapidly increased in IT with on-line and off-line approaches. [6, 7] After 1990, image processing and pattern recognition merged with each other with the use of artificial intelligence, and after that, very efficient and powerful computers and gadgets like scanners, cameras and other some special devices were developed. There is a large application area that is covered with handwritten character recognition. Even after these all research today, not a single system exists that completely fulfills the goal of handwritten character recognition. [8]

2.2 Handwritten Character Recognition System

All Characters classify in two category. handwritten or natural characters, this characters are ether handwritten or picture data that contains characters. Optical characters are print by machine. Based on types of characters, character recognition system classification shown in below figure.

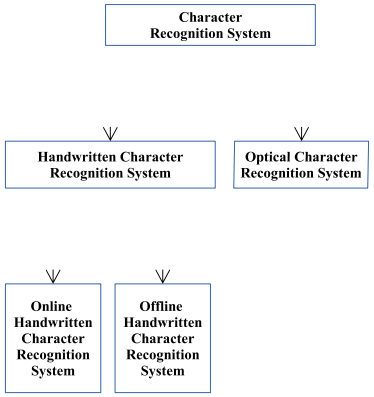


Figure 2.1: Classification of Character Recognition System

- **Off-line Handwritten Character Recognition System :**

  In this system, static inputs mean digitized text documents are used in application.[8]

- **On-line Handwritten Character Recognition System :**

  In this system, live handwriting is used for recognition, like human write on the digital device with the use of a special pen, and that data is used as live feed for online recognition system. Main difference between both systems is that online system contains one extra parameter ”time”, with data,[8] and it also contains the strokes, speed, pen-up and down information.

Recognition system contain mainly two phases, Feature extraction and Classification. In Figure: 2.2 show the detail taxonomy of the handwritten character recognition system.

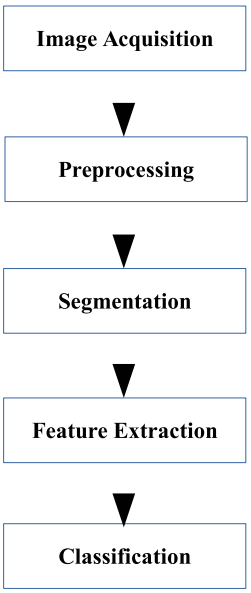


Figure 2.2: Taxonomy of Handwritten Character Recognition System

Each phase is very impotent for the handwritten character recognition system. Image acquisition for the collection row data images, after that collected data images prepaid for segmentation in preprocessing phase. Then line, word and character segmenta-

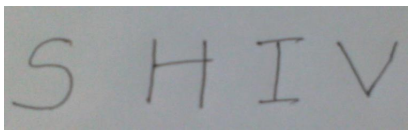
tion performed and separate the single characters. Feature extraction phase, extraction and selection operations are performed and then last is the classification phase classify the input characters in specific class. All phases are explain in detail in below.

2.2.1 Image Acquisition

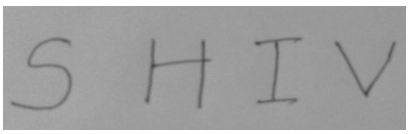
Data Acquisition is the process of acquiring handwritten input data for the system for the character recognition. Based on data acquisition, on-line and off-line systems were developed.

2.2.2 Preprocessing

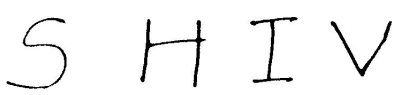
Preprocessing is performed on acquired input data. It enhances the quality of the input data and makes them more suitable for the next phase of the recognition system. Gray scale conversion, binary conversion, noise removal, etc are the various techniques that are perform in this phase. In the below figure, gray scale and binary conversion shown.



(a) RGB Image - 230x755x3 uint8



(b) Gray Scale Image - 230x755 uint8



(c) Binary Image - 230x755 logical

Figure 2.3: Preprocessed Images

2.2.3 Segmentation

Segmentation, is the process of splitting the input text data image to line and then after individual character. It removes the unwanted part from the data image. There are two types of segmentation available, Internal, and External. External segmentation is segmenting paragraphs, lines and words. On the other side internal segmentation is

segmenting individual character from the input text data.[9,10] Below figures show the line segmentation and the, character segmentation.

Figure 2.4: Segmented Line

(a) (b) (c) (d) (e)

Figure 2.5: Segmented Character

2.2.4 Feature Extraction

Feature Extraction is the process of collecting different very useful information of an object or a group of objects, so based on that collected information, we can classify new unknown object with matching with it. Feature is the robust representation of the row data.

Various feature extraction methods are available. Zone based, statistical, structural, chain code histogram, sliding window, gradient feature, hybrid, etc[1,3,11] are the most useful feature extraction techniques.

Figure: 2.6, show the various techniques for the feature extraction. *Global feature* called global transformation. A continuous signal always cary more information than needs to be represented for the purpose of classification. This may be true for discrete approximations of continuous signals as well. One approach to represent a signal is by a linear combination of a sequence of simpler goodly-defined functions. The linear combination of coefficients provides a compact encoding known as transformation or/and series expansion. Statistical feature and Geometrical feature are the local feature.

Statistical feature deal with statistical distribution of points and takes care of style variations to some extent. Although this type of features does not allow the reconstruction of the original image, it is used for reducing the dimension of the feature set providing high speed and low complexity. *Geometrical Feature* encode some knowledge about the structure of the object or may provide some knowledge as to what sort of components make up that object.[12]

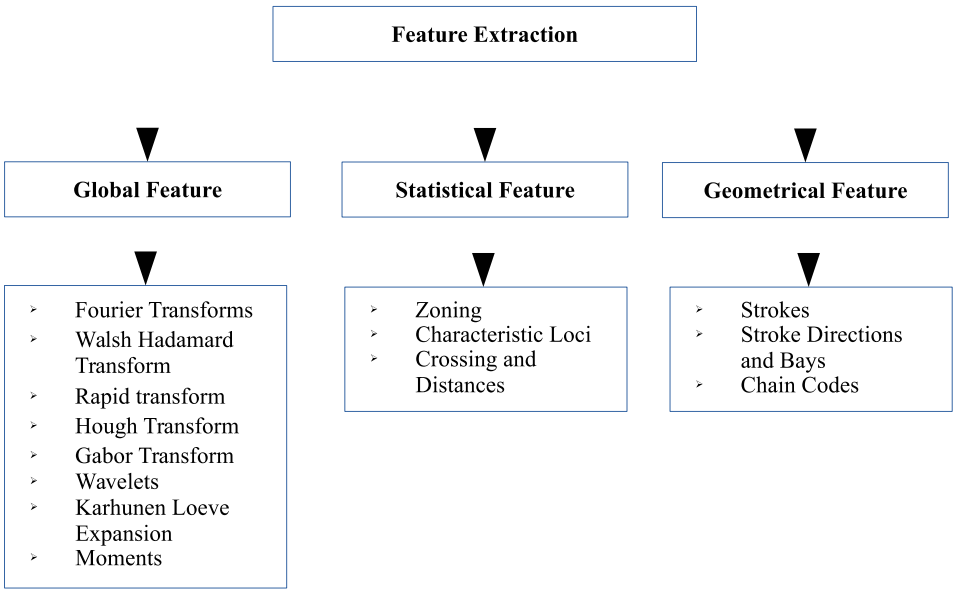


Figure 2.6: Feature Extraction Techniques[12]

Some of the most useful feature extraction techniques Chain code, Sobel, and HOG(Histogram of Oriented Gradients) edge features and Zoning features are explain below.

1. **Chain Code Features**[29]

   Region of the Images can be represented as the border or the pixels of the region. Chain codes represent a boundary of a connected region. It separately encode each connected component in the image with respect to counterclockwise direction.

   Two types of chain code :

   - 4 - Connectedness

- 8 - Connectedness

In the Figure:2.7 show the direction numbers for chain code.

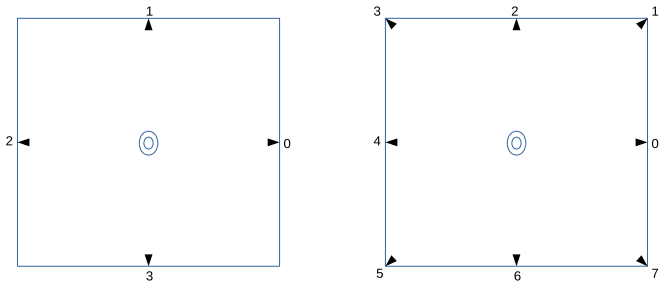


Figure 2.7: Direction Numbers for 4-directional chain code and 8-directional chain code [29]

In the Figure:2.8 show the how to encode chain code.

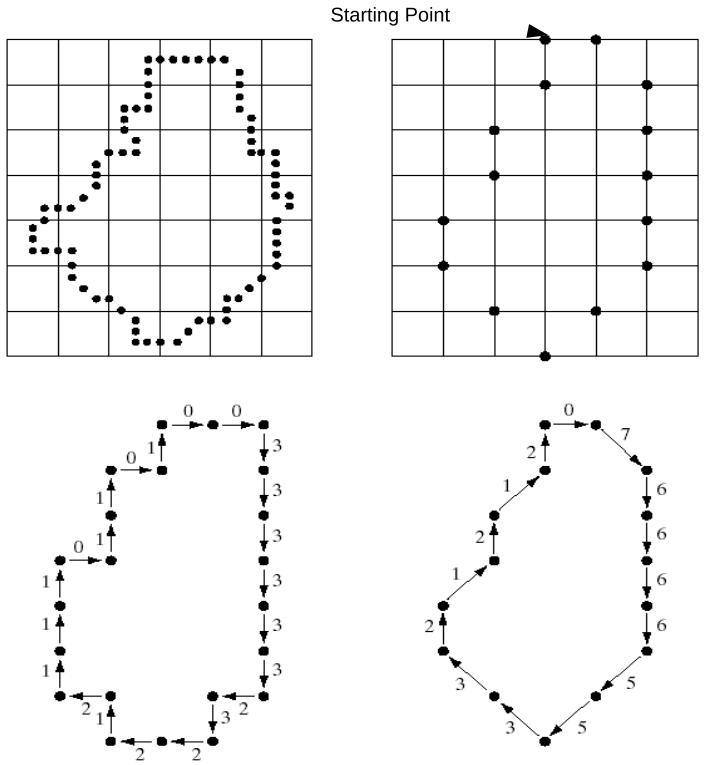


Figure 2.8: Chain Code [29]

For representation of chain code have two problems...

- It dependent on the starting point
- It dependent on the orientation

For these problems, we need to ”Normalize Chain code” and ”Differential Chain code”.

In the figure:2.9 show the normalize chain code. and fig

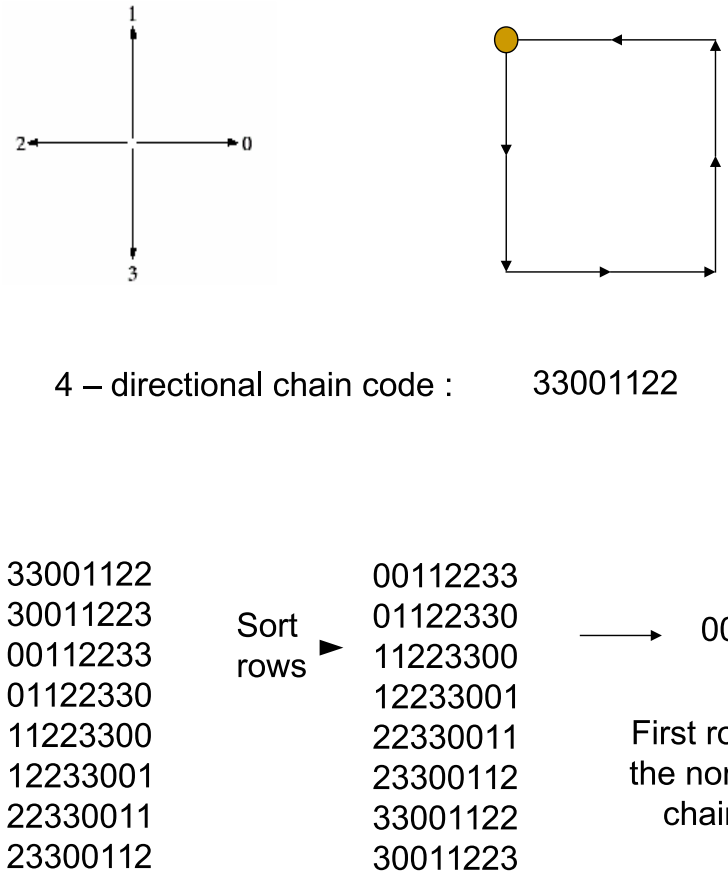


Figure 2.9: Normalize Chain Code [29]

2. **Edge / Gradient Features**

   Sobel [13] :

   To extract Gradient feature, 3x3 and 5x5 Sobel operators (illustrated in Figure 1) are used to obtain the horizontal and vertical gradient at each image Figure:2.10

for 3x3 and Figure:2.11 for 5x5 Sobel operators pixel respectively.

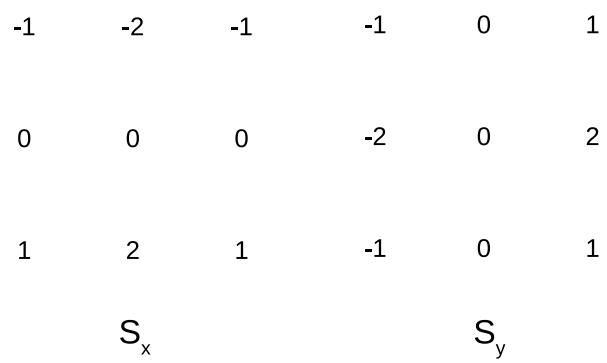


Figure 2.10: 3x3 Sobel[13]

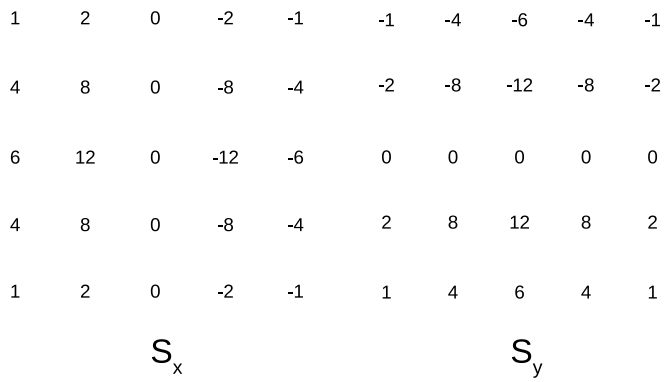


Figure 2.11: 5x5 Sobel[13]

Supposed f(x, y) is the grayscale level of point (x, y), the horizontal and vertical grayscale gradient are derived as:

$$g_x = f(x-1, y+1) + 2.f(x, y+1) + f(x+1, y+1) \\ -f(x-1, y-1) - 2.f(x, y-1) - f(x+1, y-1)$$

$$g_y = f(x+1, y-1) + 2.f(x+1, y) + f(x+1, y+1) \\ -f(x-1, y-1) - 2.f(x-1, y) - f(x-1, y+1)$$

Then we define L directions with an equal interval $(2\pi/L)$, and decompose the

gradient vector into its two (g x , g y) nearest directions in a parallelogram manner, as illustrated in Figure:2.12.

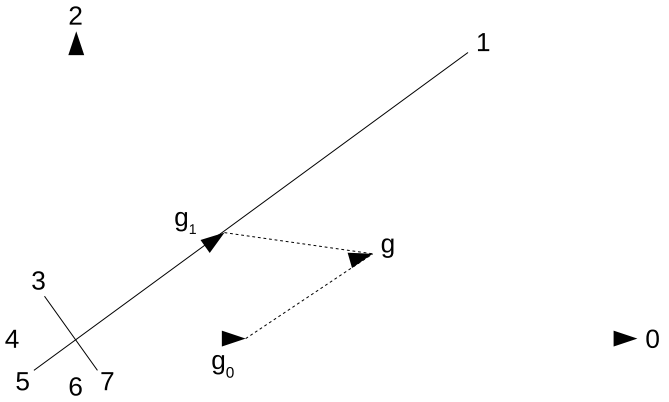


Figure 2.12: Decomposing of the gradient vector[13]

This decomposition method is first proposed by Liu et. al.[13] In this way we obtain an L-dimensional gradient code at each image pixel.

HOG :

HOG features computed on a dense grid of uniformly spaced cells and uses overlapping local contrast normalization for improved accuracy.

The essential thought behind the Histogram of Oriented Gradient descriptors is that local object appearance and shape within an image can be described by the distribution of intensity gradients or edge directions. The implementation of these descriptors can be achieved by dividing the image into small connected regions, called cells, and for each cell compiling a histogram of gradient directions or edge orientations for the pixels within the cell. The combination of these histograms then represents the descriptor. For improved accuracy, the local histograms can be contrast-normalized by calculating a measure of the intensity across a larger region of the image, called a block, and then using this value to normalize all cells within the block. This normalization results in better invariance to changes in illumination or shadowing.

Similarly, we can use other edge features like Canny, Kirsch, Plessey, etc as per requirement.

3. **Zoning**

   Most popular and simple feature extraction method. The commercial OCR system developed by CALERA used Zoning mechanism on binary characters.
   An (n*m) grid is superimposed on the character image and then for each zone average value is computed giving a feature vector of length (n*m), if required further we can compute the average on this zone again in row wise and column wise respectively or find the features of each zone and make a feature vector.

   List of zoning features like,

   - starters
   - Intersections
   - Minor starters
   - #horizontal lines.
   - #vertical lines.
   - #Right diagonal lines.
   - #Left diagonal lines.
   - Normalized Length of all horizontal, vertical, right diagonal, left diagonal lines.
   - Normalized Area of the Skeleton.

   All this features are explained in detail by Dinesh Dileep et.al.[14] with complete matlab code.

2.2.5 Classification/Recognition

Classification or recognition process is for the decision making, this new character fit in which class or looks likes. In this phase characters are classify or identify.

Various classifier are available, likes DBN(Dynamic Bayesian Network), MQDF – Modified Quadratic Discriminant Function, DLQDF – Discriminative Learning Quadratic Discriminant Function, Euclidean distance matrix, HMM(Hidden Markov model), MLP

(Multilayer Perceptron), SVM(Support Vector Machine),ANN(Artificial Neural Network),etc. Various classification techniques are shown in Figure:2.13.

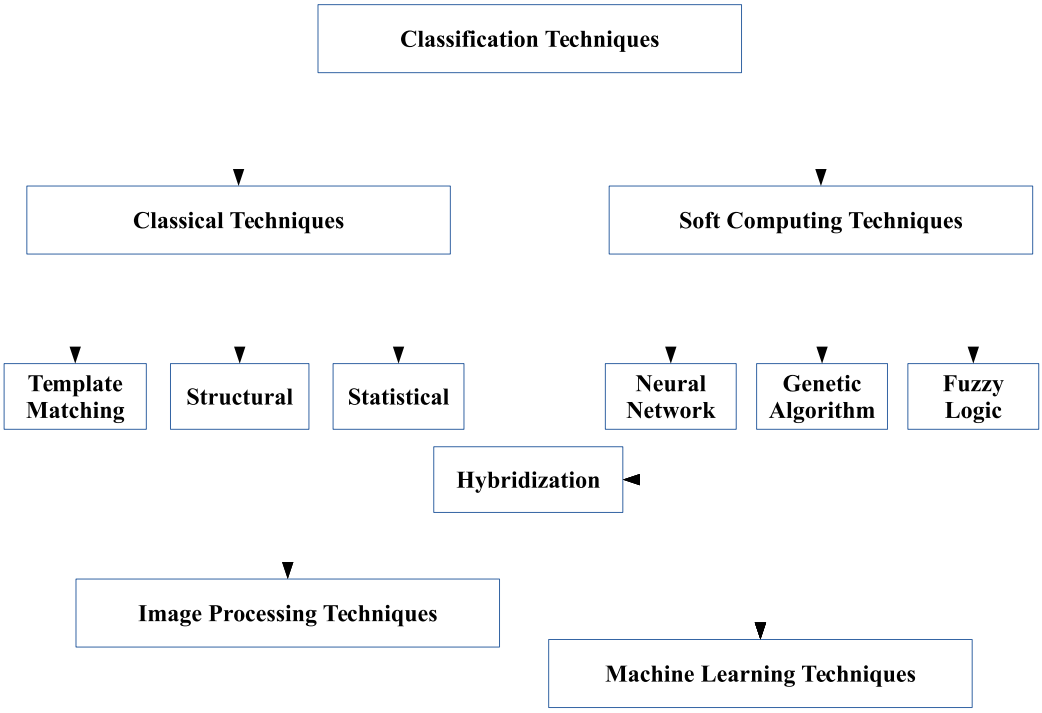


Figure 2.13: Classification Techniques [15]

Classification techniques mainly divided in classical and soft computing techniques. Classical techniques further divided in template matching, structural and statistical techniques. Template matching and structural techniques mainly based on image processing. On other side, soft computing further divided in neural network, genetic algorithm, fuzzy logic and hybridization of all soft computing techniques. Statistical and all soft computing techniques are belongs to machine learning.

Machine learning techniques are very effective then classical techniques. Various machine learning techniques like, HMM(Hidden markov model), [16, 17] MLP(Multilayer Perceptron), [18] SVM(Support Vector Machine), [2] ANN(Artificial Neural Network) [19, 20] are widely using in recognition system.

2.3 Machine Learning

Machine learning is a grew out of work in artificial intelligence. It's a new capability of the computer,and with it computer can learn like human.

In 1959, **Arthur Samuel** gave the definition of the machine learning.

> " Machine learning: Field of study that gives computers the ability to learn without being explicitly programmed. "

Then after, In 1998 **Tom Mitchell** well-posed learning problem :

> "A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E."

2.3.1 Machine Learning Algorithms

Machine learning algorithms categorized as show in the Figure:2.14.

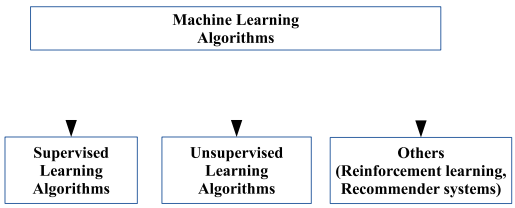


Figure 2.14: Machine Learning Algorithms

These all machine learning algorithms are applying on the soft computing techniques and make it more powerful. Most popular soft computing technique is neural network. Various types neural network are available based on machine learning algorithms. Hebbian and Winner-take-all are the unsupervised learning and Perceptron and Delta(BP) are the supervised learning.

Supervised Learning

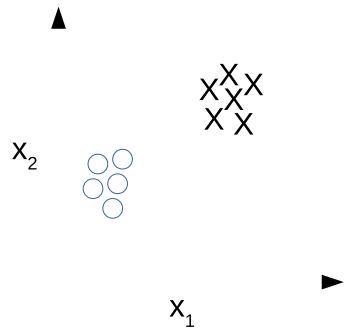


Figure 2.15: Supervised Learning

Figure:2.15 show two types data are available. This data linearly classify with use of single line. And easily labeled it. It's a supervised learning. In supervised learning, supervisor is present and monitor the learning and adjust the error. Supervised learning can correct the error.

Unsupervised Learning

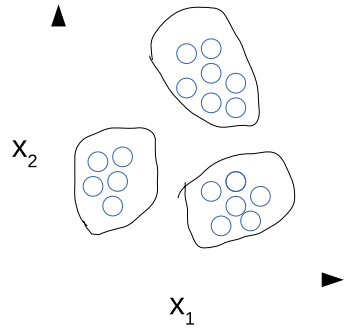


Figure 2.16: Supervised Learning

Figure:2.16 show three types of data are available. This data linearly or nonlinearly not classify. So labeling not working here. So, other way is make the cluster of similar kind of data. In figure, show the three clusters is created. It's a unsupervised learning. In unsupervised learning, supervisor is not present. Unsupervised learning can not correct the errors.

Reinforcement Learning

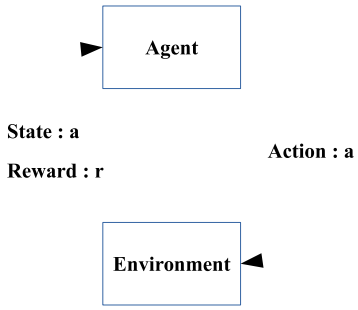


Figure 2.17: Reinforcement Learning

Figure:2.17 show the basic idea about Reinforcement Learning.

- Receive feedback in the form of **rewards**
- Agent's utility is defined by the reward function
- Learn for **maximize expected rewards**
- All learning is based on observed sample of outcomes!

2.3.2 Machine Learning Techniques [30]

Based on machine learning algorithms, various machine learning techniques are developed. All techniques are not suitable for every purpose, Hence purpose means classification,Regression or Market Basket Analysis. Choice of proper machine learning technique is depend on types of data - inputs, like text data, numeric, or big-data etc.

- **Lazy Learning** : Classification using Nearest Neighbors
- **Probabilistic Learning** : Classification using Naive Bayes
- **Divide and Conquer** : Classification using Decision Tree and Rules
- **Forecasting Numeric Data** : Regression Methods
- **Black Box Methods** : Neural Network and SVM
- **Finding Pattern** : Market Basket Analysis using Association Rules

Handwritten character recognition is the classification problem. We already know, how many characters are available. That mean, we know the total number of classes and we need to classify unrecognized character in that known classes.

Black Box methods work like a magic. But their internal mechanism can be difficult to understand, because of complex mathematics and results are difficult to interpret. Black Box containing two methods,

- Artificial Neural Network (ANN) and
- Support Vector Machine (SVM)

ANN, use the concept of Human brains and SVM, use the multidimensional surfaces to define the relationship between features and outcomes.

2.3.3 Artificial Neural Network (ANN) [30,31]

ANN concept based on human brain's activity. Human brain contain *Biological Neurons*, and everything is processed by it in brain. Figure:2.18 show the biological neuron. Neuron can divide in three major regions : *the cell body*, which is also called *soma*, the *axon*, and the *dendrites*.

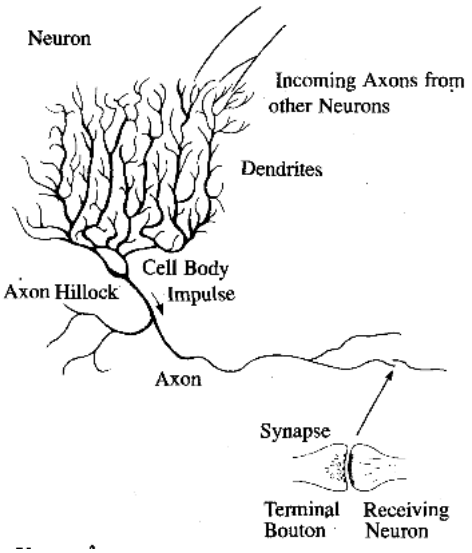


Figure 2.18: biological Neuron [31]

Dendrites form a dendritic tree, which is a very fine bush of thin fibers around the neuron's body. Dendrites receive information from neurons through axons-long fibers

that serve as transmission lines. An axon is a long cylindrical connection that carries impulses from the neuron. The end part of an axon splits into a fine arborization. Each branch of it terminates in a small endbulb almost touching the dendrites of neighboring neurons. The axon-dendrite contact organ is called a synapse. The synapse is where the neuron introduces its signal to the neighboring neuron. The signals reaching a synapse and received by dendrites are electrical impulses. The interneuronal transmission is sometimes electrical but is usually effected by the release of chemical transmitters at the synapse. Thus, terminal boutons generate the chemical that affects the receiving neuron. The receiving neuron either generates an impulse to its axon, or produces no response.

Based on this biological neuron, artificial neuron model was developed. The first formal definition of a synthetic neuron model based on the highly simplified considerations of the biological model described in the preceding section was formulated by McCulloch and Pitts (1943). Figure:2.19 show the artificial neuron model presented by McCulloch and Pitts.

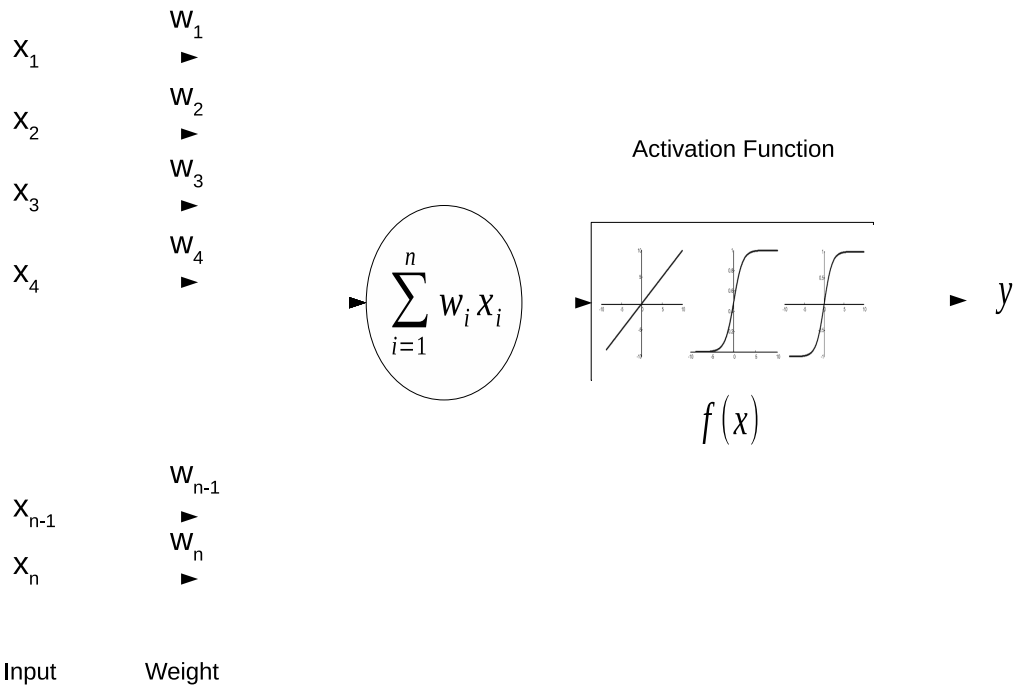


Figure 2.19: McCulloch and Pitt Artificial Neuron Model

In this model, x is the input, w is the weight $f(x)$ is the activation function, and y is the output of the neuron.

With combination of this kind of artificial neuron make a neural network architecture. In the figure:2.20 show the basic artificial neural network.

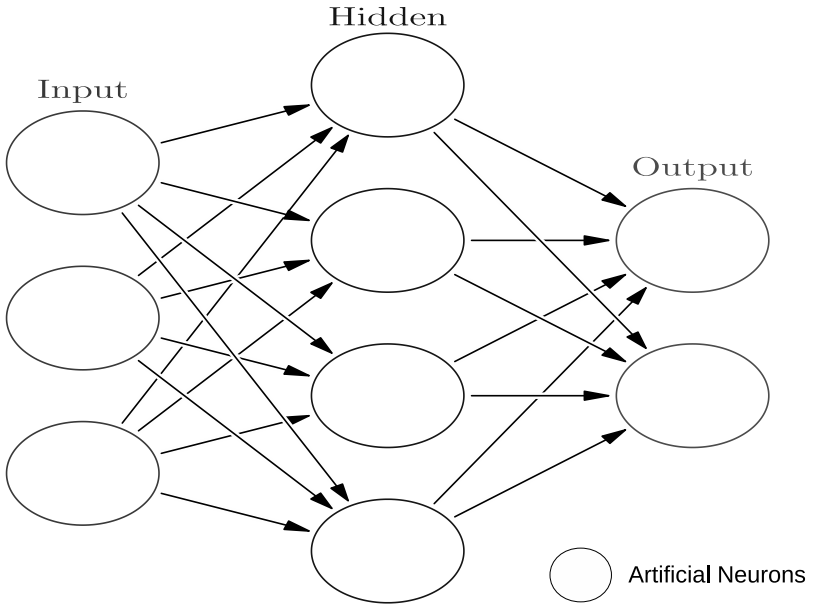


Figure 2.20: Architecture of Artificial Neural Network

In the Tabel: 2.1 show the comparison between biological neural network and artificial neural network.

Table 2.1: Biological NN v/s Artificial NN

No.	**Biological Neural Network**	**Artificial Neural Network**
1.	soma	unit
2.	axon, dendrites	dendrites
3.	synapse	weight
4.	potential	weighted sum
5.	threshold	bias, weight
6.	signal	activation function

Before the use of ANN, it's require learning/training. For the learning of ANN we can apply various learning rule/algorithm as per requirement and performance of application. In the Table: 2.2 show the various learning rules with it is supervised or

unsupervised.

Table 2.2: Learning Rules [31]

No.	Learning Algorithem	Learning
1.	Hebbian	unsupervised
2.	Perceptron	supervised
3.	Delta	supervised
4.	Widrow-Hoff	supervised
5.	Correlation	supervised
6.	Winner-take-all	unsupervised
7.	Outstar	supervised

Here, For the batter performance with good accuracy, we are using supervised learning algorithms with Delta learning rule. Higher accuracy needed and for that delta learning rules, that correct the errors.

Figure:2.21 show the Error Back-propagation delta learning rule block diagram.

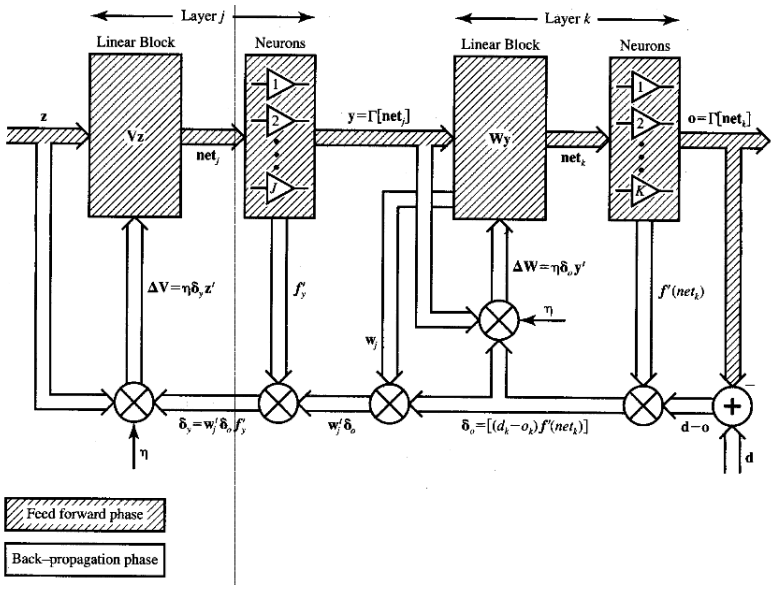


Figure 2.21: Error Back-propagation - Block Diagram [31]

In the figure: 2.3.3, two layers 'j' and 'k' are available. 'z' is a single pattern vector, and 'v' is the weight for 'j' layer. End of the layer 'j' computation output is 'y'. This output 'y' is the input for the layer 'k'. 'w' is weight for the layer 'k' and 'o' is the output for the layer 'k'. Then find the difference between desired output 'd' and layer

'k' output 'o'. Based on that find the error(δ) in each layer and update the value of the weight(Δ). When $(d-o)$ nearly 0 comes, on that time training accuracy of this network is nearly 100%. This type Error Back-propagation algorithm working.

2.3.4 Support Vector Machine [30] [32]

SVM looks like a surface that divide the various points of data and represent them in multidimensional space according to their feature value. The goal of a SVM is to creat a flat boundary, called hyperplane(Decision Surface), Which leads to fairly homogeneous partitions of data on either side. SVM are used for almost any types of learning task, Like classification and numeric prediction.

SVMs use a linear boundary called a hyperplane to partition data in to similar elements groups. Each elements called class values. In the Figure:2.22 show that, there is two kind of data are separated by hyperplane/decision surface.

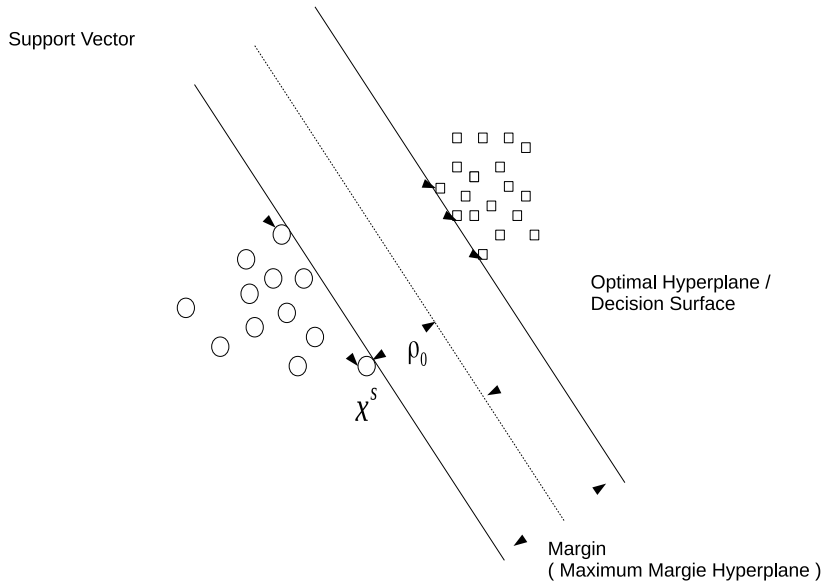


Figure 2.22: Support Vector Machine

Main purpose of the SVM is, "Construct a hyperplane or, to identify the decision surface and separate the same kind of data(+1 or -1) with maximum margin". Maximum Margin Hyperplane(MMH) separate the any one kind of data to other data. The Support

Vectors are the points from each class that are the closest to the MMH. Each class have at least one support vector. The support vectors provide the easy and compact way to store a classification model and it's doesn't matter, How big feature vector is...

Construct Hyperplane for Linearly Separable Pattern :

- training sample : $\{(x_i, d_i)\}_{i=1}^{N}$,
  where, x_i is the input pattern, d_i is the target output or corresponding desired output pattern. And $d_i = +1$ or $d_i = -1$ are "linearly separable" patterns.

- equation for the decision surface hyperplane is...

$$w^T x + b = 0 \tag{2.1}$$

  Where, x is input vector, w is the adjustable weight vector, and b is the bias.

- rewrite equation 2.1,

$$\begin{aligned} w^T x_i + b >= 0 \quad \text{for} \quad d_i = +1 \\ w^T x_i + b < 0 \quad \text{for} \quad d_i = -1 \end{aligned} \tag{2.2}$$

- The hyperplane and the closest data point is called the *margin of separation* or *maximum margin hyperplane*, denoted by ρ. As per goal of a svm is to find the particular hyperplane for which the margin of separation,ρ, is maximum. Figure 2.3.4 show the geometric construction of an **optimal hyperplane** for a two dimensional input space.

- Suppose, w_o and b_o are the optimal value of the weight vector and bias vector, then the optimal hyperplane equation 2.1 rewrite as...

$$w_o^T x + b_o = 0 \tag{2.3}$$

- The discriminant function is...

$$g(x) = w_o^T x + b_o \tag{2.4}$$

Which gives the distance from x to the optimal hyperplane.(Duda and Hart, 1973). But, easy way to find distance is

$$x = x_p + r\frac{w_o}{\|w_o\|}$$

Where x_p is the normal projection of x onto the optimal hyperplane and r is the desired algebraic distance. r is positive if x is on positive side of hyperplane otherwise it's a negative. Combine equation 2.3 and 2.4, we get $g(x) = 0$. So, we can write it as...

$$g(x) = w_o^T x + b_o = r\|w_o|$$

or,

$$r = \frac{g(x)}{\|w_o\|} \tag{2.5}$$

The distance from origin to the optimal hyperplane is given by $\frac{b_o}{\|w_o}$. If $b_o > 0$, the origin is on positive side of the optimal hyperplane, if $b_o < 0$ then it's a negative side. And if $b_o = 0$ then we can say that, optimal hyperplane passes through the origin. This things are presented by Figure:2.23

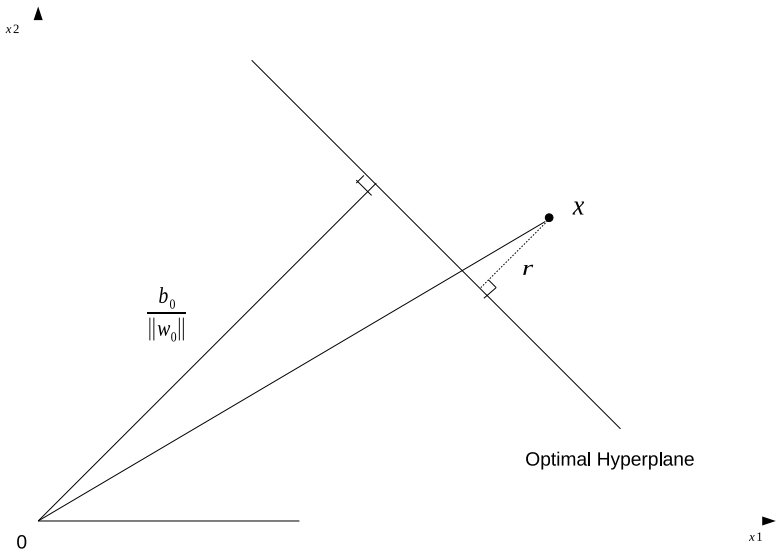


Figure 2.23: Distance from point(x) to hyperplane in 2D

- Main issue is to find the value of w_o and b_o for optimal hyperplane with training

set $t = \{(x_i, d_i)\}$, and satisfy the following constraint.

$$\begin{aligned} w_o^T x_i + b_o >= 0 \quad \text{for} \quad d_i = +1 \\ w_o^T x_i + b_o < 0 \quad \text{for} \quad d_i = -1 \end{aligned} \tag{2.6}$$

- Specific points (x_i, d_i) for that, equation 2.6 is satisfied with the equality sign are called support vectors. Now, support vector x^s to optimal hyperplane is

$$\begin{aligned} r &= \frac{g(x^s)}{\|w_o\|} \\ &= \begin{cases} \frac{1}{\|w_o\|} & \text{if} \quad d^s = +1 \\ -\frac{1}{\|w_o\|} & \text{if} \quad d^s = -1 \end{cases} \end{aligned} \tag{2.7}$$

- Now, for the optimum value of the margin of separation(ρ), between two classes...

$$\begin{aligned} \rho &= 2r \\ \rho &= \frac{2}{\|w_o\|} \end{aligned} \tag{2.8}$$

Find Optimal Hyperplane with Convex Optimization :

- training sample : $\{(x_i, d_i)\}_{i=1}^N$, and w,b are the optimum value of the weight and bias with satisfy the constraints

$$d_i(w^T x_i + b) >= 1 \quad \text{for} \quad i = 1, 2, ..., N \tag{2.9}$$

and w, is for the minimize the cost function

$$\Phi(w) = \frac{1}{2} w^T w \tag{2.10}$$

Here, $\frac{1}{2}$ is the scaling factor. This optimization problem called *the primal problem*. $\Phi(w)$ is a convex function of w.

This problem solve by using *Lagrangian Multipliers*(Bertsekas,1995). Lagrangian

function is,

$$j(w, b, \alpha) = \frac{1}{2} w^T w - \sum_{i=1}^{N} \alpha_i [d_i (w^T x_i + b) - 1] \tag{2.11}$$

Where, α_i are called *Lagrange Multipliers*. The solution of optimization problem is determined by the saddle point of the Lagrangian function $j(w, b, \alpha)$. A saddle point of a Lagrangian is a point where the roots are real, but of opposite signs. The saddle points are minimized with respect to w and b and maximized with respect to α. So, differentiating $j(w, b, \alpha)$ with respect to w and b and setting the results equal to zero, and get the two condition of optimality.

With respect to w :

$$w = \sum_{i=1}^{N} \alpha_i d_i x_i \tag{2.12}$$

With respect to b :

$$\sum_{i=1}^{N} \alpha_i d_i = 0 \tag{2.13}$$

- Now, for the *dual problem*, state that.... For training sample t, find the Lagrange multiplier $\{\alpha_i\}_{i=1}^{N}$ that maximize the objective function

$$Q(\alpha) = \sum_{i=1}^{N} \alpha_i - \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i \alpha_j d_i d_j x_i^T x_j^T \tag{2.14}$$

So, constraints are...
(1) $\sum_{i=1}^{N} \alpha_i d_i = 0$
(2) $\alpha_i >= 0$ for $i = 1, 2, ..., N$

- Suppose, Optimal Lagrange multipliers is $\alpha_{o,i}$ then, the optimal weight vector is w_o...

$$w_o = \sum_{i=1}^{N_s} \alpha_{o,i} d_i x_i \tag{2.15}$$

Where, N_s is the number of support vectors for which the Lagrange multipliers $\aleph_{o,i}$ are all nonzero. Now, for the bias b_o...

$$\begin{aligned} b_o &= 1 - w_o^T x^s \quad \text{for} \quad d^s = 1 \\ b_o &= 1 - \sum_{i=1}^{N_s} \alpha_{o,i} d_i x_i^T x^s \end{aligned} \tag{2.16}$$

Optimul Hyperplane for Non-linearly Separable Patterns

- We can not use equation 2.9 for the non-linearly separable data, because data points violated this condition. It's a called *soft margin*.

  For the solution, new variable introduces and rewrite the hyperplane equation as...

$$d_i(w^T x_i + b) >= 1 - \xi_i \quad \text{for} \quad i = 1, 2, ..., N \tag{2.17}$$

  ξ_i is the slack variable. It measure the deviation of a data point from the ideal condition of pattern separability. (i) $0 < \xi_i <= 1$, Data points fall inside the region of separation, and correct side of the hyperplane.
  (ii) $\xi_i > 1$, Data are the wrong side of the hyperplane.

- Now, the final Lagrangian equation for the dual problem... For training sample t, find the Lagrange multiplier $\{\alpha_i\}_{i=1}^N$ that maximize the objective function

$$Q(\alpha) = \sum_{i=1}^{N} \alpha_i - \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i \alpha_j d_i d_j x_i^T x_j \tag{2.18}$$

  So, constraints are...
  (1) $\sum_{i=1}^N \alpha_i d_i = 0$
  (2) $0 <= \alpha_i <= 0$ for $i = 1, 2, ..., N$
  Where, C is a user-specified positive parameter.
  important noticeable thing is, slack variable and Lagrange multiplier not effect the dual problem. So, we can say that non linear and linearly separable patterns both case are same.

  Kernel

  - Another popular term is Kernel. Kernel is nothing but a function. A function that map the data in higher dimensional feature space, and separate the same kind of data and make a group of same kind of features. In other simply words, A function that find the support vectors. Generally, Kernel function

is denoted by the Greek latter phi $\phi(x)$

$$K(\vec{x}_i, \vec{x}_j) = \phi(\vec{x}_i).\phi(\vec{x}_j)$$

Using this form, various kernel was developed.

- Some of the very popular and widely acceptable kernel is listed below...
  (1) Linear Kernel / Zero Kernel
  (2) Polynomial Kernel (3) Sigmoid Kernel (4) Gaussian Kernel
- There is no specific rules for use this kernels. It's a depends on learning as well as amount of data and the relationships among the features.

For Multiclass Classification :

- Multiclass classification, means for the data separation we have more then two types of class data are available and for the classification, we need to separate each data in appropriate correct class. example, English character classification. We have different 26 character classes.
- For the solution many methods were developed.
  (1) One - vs - All
  (2) All - vs - All
  (3) Single Machine
  (4) Error Correcting Code
- One -vs- All is a one kind of binary classification. Make N different binary classifiers, for the i^th classifier, let the positive examples be all the points in class i, and let the negative examples in the other class. It's a most famous n easy implementation method for multiclass classification.

Chapter 3

Literature Survey

3.1 Literature Survey

After many literature survey, it's a easy to say that handwritten character recognition system mainly dependent on features extraction technique and good efficient classifier. Here, in this section show the literature survey regarding it.

3.1.1 Feature Extraction :

Feature extraction is the very important, HCR system's good accuracy and speed of the classifier also depends on it. So always choose less features but it's a enough good for more accurately classification.

Feature extraction techniques mainly based on image processing techniques. D.K. Patel, T. Sam et al. used discrete wavelet transformation with appropriate level of multiresolution.[19] Then Reza Ebrahimzadeh et al. used Histogram of Oriented Gradients(HOG) features for stabilize the illumination variation with MNIST handwritten digits dataset.[21] Dewi Nasien et al. used chain code feature and with it they got good accuracy.[22]

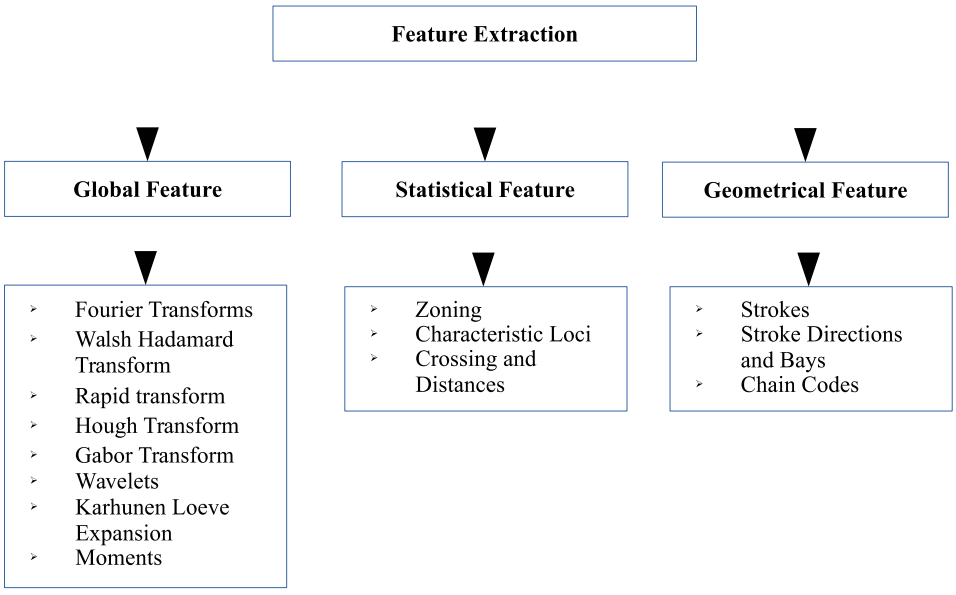


Figure 3.1: Classification of Feature[12]

Then after, Kumar et al. show the classification of feature and explain it with detail.[12] Kumar et al. classify the types of feature in three category. 1)Statistical Features

2)Global Transformation and Series Expansion Features 3)Geometrical and Topological Features. further detailed classification shown in Figure:3.1.

3.1.2 Classification Techniques :

For the classification, most efficient classifiers are related or came from machine learning techniques like, SVM, ANN etc. ANN have many different types and learning algorithms. Many researchers try to combine two or more classification technique and make it hybrid like neuron-fuzzy. It's a combination of neural network with fuzzy logic.

D. K. Patel, T. Sam et al. shown a handwritten character recognition using artificial neural network and euclidean distance matrix. ANN compute and adjust the weight for each character and make a weight matrix for each tested characters with respect to new input characters. And highest value for both input parameters show the character is recognize.

Character 'D', 'R', 'K' and some other characters are not recognized correctly. Unrecognized characters are further classified by use of Euclidean distance metrics.

Table 3.1: The Result Showing the Average Recognition Accuracy [19]

Test Data Set (A-Z)	Level of Multiresolution	Methods	Average Recognition Accuracy (%)
30 x20 Pixel Images	1	Learning rule	88.46
		Euclidean Distance	92.31
		Euclidean Distance with recognition score	99.23

Table: 3.1 shows ANN provides a good recognition accuracy of 88.46%. For misclassifcation, the Euclidean distance metric improves the recognition accuracy to 92.31% and then its product with recognition score further improves the recognition accuracy to 99.23%. [19]

Reza Ebrahimzadeh et al. proposed the handwritten digits recognition using SVM and praposed model shown in Figure:3.2.

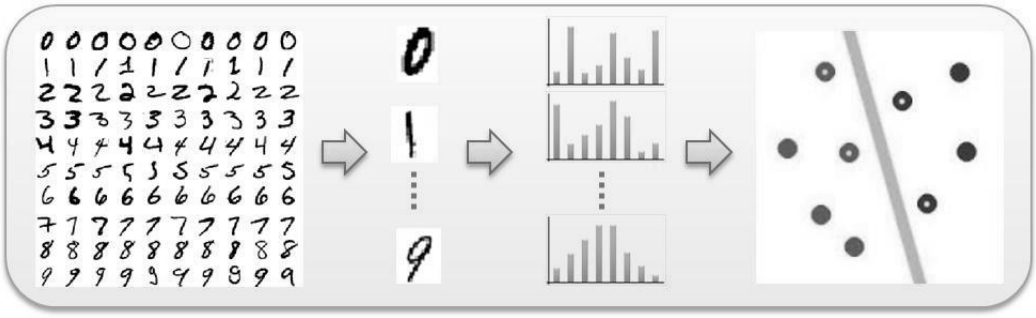


Figure 3.2: First separate digits and then extract features and finally, features are classified by multiclass SVM classification [21]

Similarly, Dewi Nasien et al. proposed model for handwritten lowercase and uppercase characters with chain code feature extraction method. [22] For SVM, author used radial basis kernel and results are shown below Table:3.2

Table 3.2: Result of Dewi Nasien et al. Proposed System [22]

Data Set	**Samples**	**Accuracy(%)**
Lowercase	189,411	86.0077
Uppercase	217,812	88.4671
Lowercase+Uppercase	407,223	73.4464

On other side, Reza et al. shown the comparison between different kernels results. Used kernels are linear, polynomial, RBF, Sigmoid. And results shown in Table: 3.3.

Table 3.3: Comparison between different kernels of SVM [21]

Kernel	**Linear**	**Polynomial**	**RBF**	**Sigmoid**
Accuracy(%)	97.25	85.91	95.75	94.97

Amal Ramzi et al. used back propagation neural network(BPNN) for the classification. Actual system for online Arabic handwritten character recognition. Author used online and offline both feature and dataset is own created because of ADAB and OHASD dataset not available public use. Back propagation neural network topology show in Table 3.4.

Experiment result show that accuracy of trained network is upto 99% but testing data accuracy is 64% only.

Table 3.4: ANN - BPNN topology [8]

Parameters	Value
Transfer function	Sigmoid function for all the layers 'tansig'
Maximum training iterations	5000
No. of Hidden Layers	3 Layers - [8 16 32]
No. of Outputs	15 character classes
Initial weight	Randomly
allowed maximum error for learning	0.01
Training function	Back Propagation 'trainlm'

3.2 Comparison Table

Table 3.5: Various Literature Comparison

Paper	Feature Extraction	Language	Dataset	Classifier	Results & Comments
[18]	Grapheme segmentation & Sliding Window	English	Rimes Database	MLP	Very Fast But Low accuracy
[19]	DWT with Multiresolution techniq	Characters	Own Character Dataset	NN with Euclidien distance matrix	good accuracy - upto 99.23%, But taking more time

[16]	Gradient feature	chinese Alph-Numeric	10,000 single character image and 4709 legal amount trxt line images extracted from real life Chinese bank checks	HMM	Avrg 97.13%
[17]	Chain Code histogram Features, Distribution of forground density accross zones	Farsi	Own database – 198 word classes	HMM	89.00%
[20]	4x8 and 8x4 matrix for each character – Segmantation of row and columan	Bangla	Not specify	NN	very simple and 94.30%
[3]	not specify	Alpha numerical + symbols	Not specify	RNN	good recognition
[2]	Simple & Efficient Zone based Hybrid Feature Extraction Algorithm	Kanada & Tamil – Numerals	Numerical Data – Own Created Datasets	Nearest Neighbor Classifire – NNC, Support Vector Machine - SVM	Kanada – (97.75% NNC +,98.2% SVM),Tamil – (93.9% NNC + 94.9% SVM)

[23]	DCT – Discrete cosine transformation	Arabic Numbers	ADBase database	DBN – Dynamic Bayesian Network	Average 85%, this result with currupted data, slow recognition
[24]	7 FE methods and then ranking the feature vector and make new 3 feature vector	Numeric	MNIST	ANFIS & IBA ANFIS	99.52% and speed for recogniton 24 digits/sec

Chapter 4

Scope of Thesis Work

4.1 Problem Statement

Handwriting, every person have own and somehow it is always differ to other person's handwriting, there is no uniqueness. So, it make character recognition more difficult.

Various researcher developed various methods with use of different approaches. Various approaches like Image Processing, Gaussian Distribution function, Template matching, Euclidean distance, Machine Learning, etc. But no one approaches is a perfect solution for the character recognition. We accept that, there is variety of applications are available for character recognition. So, it might be single approach or method almost can not be suited to each application.

Different languages are available. Every language contain various types characters, and every language character contain different properties, so again it's a hard to choose any one technique globally. These things make handwritten character recognition is a interesting research field.

Main two parameters are considered by researcher for the good handwritten recognition system. 1)Accuracy for character Recognition. 2) Time for character Recognition. Maintain both parameters is very hard and it's a one of the big challenge with different types of characters.

4.2 Goal

To develop the handwritten English characters recognition system that **reduce** the **Computation** and improve the **Accuracy** with the use of **SVM** and **ANN** machine learning technique.

- Computation reduction
- Improve recognition accuracy

4.3 Proposed Methodology

4.3.1 Assumptions and Constraints

1. Assume that, Zero noise present in available dataset. It's a already clean data.
2. Proposed system not supported handwritten cursive writing.
3. For the experiment, only capital English latter.
4. For the 26 character classes to subclass creation/reduction any kind of other techniques(image processing) can be used. Like, Euler number, horizontal or vertical symmetry, number of horizontal, vertical, cross, angular lines are available in characters, etc. Hence, in proposed system Euler number based class reduction proposed.
5. Developed system only deal with 0,1 and -1 Euler number based class. That mean, character must contain 0(one hole),1(no hole) and -1(two hole) Euler number.

4.3.2 Block Architecture

Figure:4.1 show the block diagram for proposed handwritten character recognition system. Proposed system have mainly two tasks...

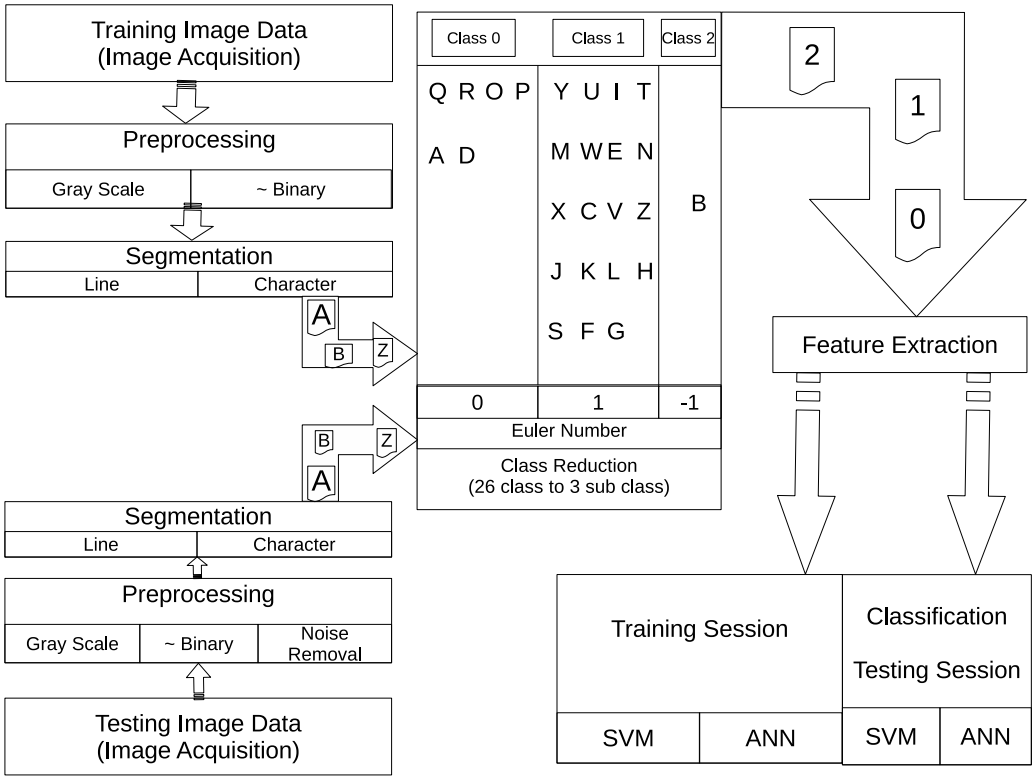


Figure 4.1: Proposed Handwritten English Character Recognition System

1. **Training**

   (a) Image Acquisition

   (b) Preprocessing

   (c) Segmentation

   (d) Euler number based class reduction - 26 character class to 3 class based on Euler numbers (phase 1).

   (e) Feature Extraction

   (f) Generate Classification / Training Model(based on SVM or ANN)

2. **Testing**

   (a) Image Acquisition

(b) Preprocessing

(c) Segmentation

(d) Euler number based class reduction - 26 character class to 3 class based on Euler numbers (phase 1).

(e) Feature Extraction

(f) Classify Character with the use of Classification / Training Model(based on SVM or ANN)

This type, proposed system's functionality working and classify the characters. In the next figure:4.2 show the, How proposed model can reduce the computation...

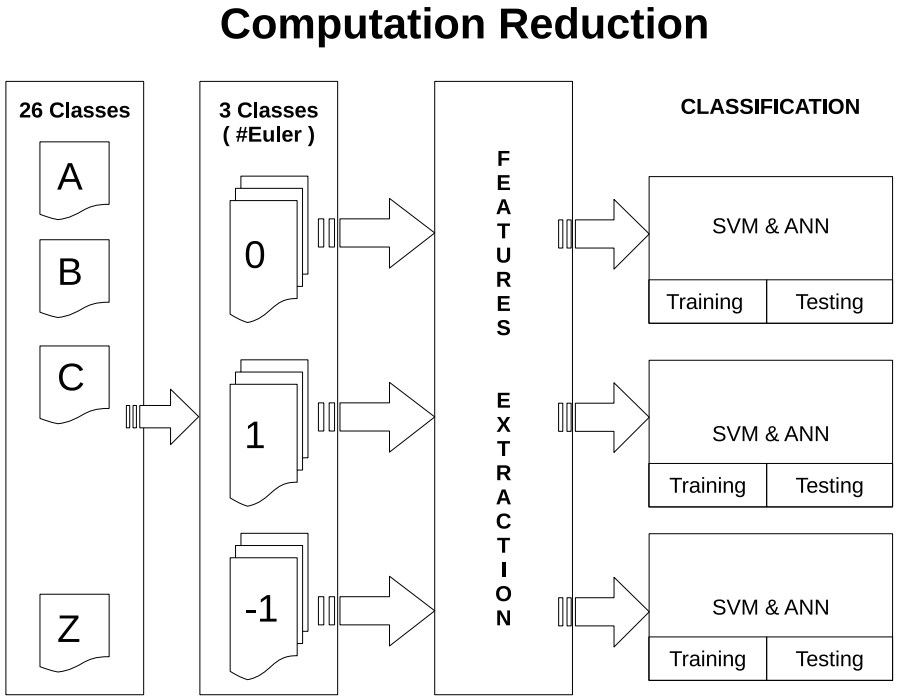


Figure 4.2: Class reduction based on Euler number

We have 26 English characters. Each character present individual class. So, for the character classification process we have 26 class. This all 26 character classes further going in first training and then testing. In this training process, system need to compute or create a training model/net for all 26 classes and train the system. Then in testing, each character compare with all 26 class model/net and try to fit in any one class. This type conventional character classification system working.

We can see that, for classification each character try to fit in all 26 class and it wast the time. For that reason, If we can reduce the 26 class in to sub class then, each character do not need to try fit in all 26 class. This type there is more chances to classify in correct class and system need to low computation. Now, for the class reduction we can apply different kind of things. Likes, Euler number base class reduction, Horizontally symmetry based reduction, Vertically symmetry based reduction, Number of Horizontal and Vertical lines, etc. Hence, In the proposed system we are using Euler based 26 class reduction in to 3 subclass.

Euler Number

Before going further, we need to explore abut Euler number. Euler Number is defined as number of connected components in the image minus the number of holes. This will divide the characters into 3 groups:[25]

- Euler number equal one and this contains: s, S, f, F, G, h, H, j, J, k, K, l, L, z, Z, x, X, c, C, v, V, n, N, m, M, w, W, E, r, t, T, y, Y, u, U, i, I.
- Euler number equal zero and this contains: q, Q, R, o, O, p, P, a, A, d, D, g, b.
- Euler number equal minus one and this contains: B.

Euler Number Computation[26,27]

$EulerNumber = 1/4(X - V + 2Z)$ for 4 connectivity

$EulerNumber = 1/4(X - V - 2Z)$ for 8 connectivity

i.e. $Eulernumber = 1/4(convexities - concavities + 2 * diagonal)$ where,

X = the number of occurrences of the 2x2 pattern (i.e. the number of convexities)

$$\left|\begin{matrix}0 & 0\\ 0 & 1\end{matrix}\right| \left|\begin{matrix}0 & 0\\ 1 & 0\end{matrix}\right| \left|\begin{matrix}1 & 0\\ 0 & 0\end{matrix}\right| \left|\begin{matrix}0 & 1\\ 0 & 0\end{matrix}\right|$$

V = the number of occurrences of the 2x2 pattern (i.e. the number concavities)

$$\left|\begin{matrix}1 & 1\\ 1 & 0\end{matrix}\right| \left|\begin{matrix}1 & 1\\ 0 & 1\end{matrix}\right| \left|\begin{matrix}0 & 1\\ 1 & 1\end{matrix}\right| \left|\begin{matrix}1 & 0\\ 1 & 1\end{matrix}\right|$$

Z = the number of occurrences of the 2x2 pattern (i.e. the number diagonals)

$$\left|\begin{matrix}1 & 0\\ 0 & 1\end{matrix}\right|\left|\begin{matrix}0 & 1\\ 1 & 0\end{matrix}\right|$$

Figure 4.3: Character 'A'

When the above binary object Figure:4.3 was given as an input to the Matlab to compute the Euler Number the result obtained is;

Number of object = 1

Number of holes = 1

Euler Number = 0

This is all about Euler number. Based on Euler number, 26 class divide in to 3 subclass and this terminology are using in the proposed system.

4.3.3 Flowchart

In next Figure:4.4 and Figure:4.5 show the flowchart for the proposed HCRsystem.

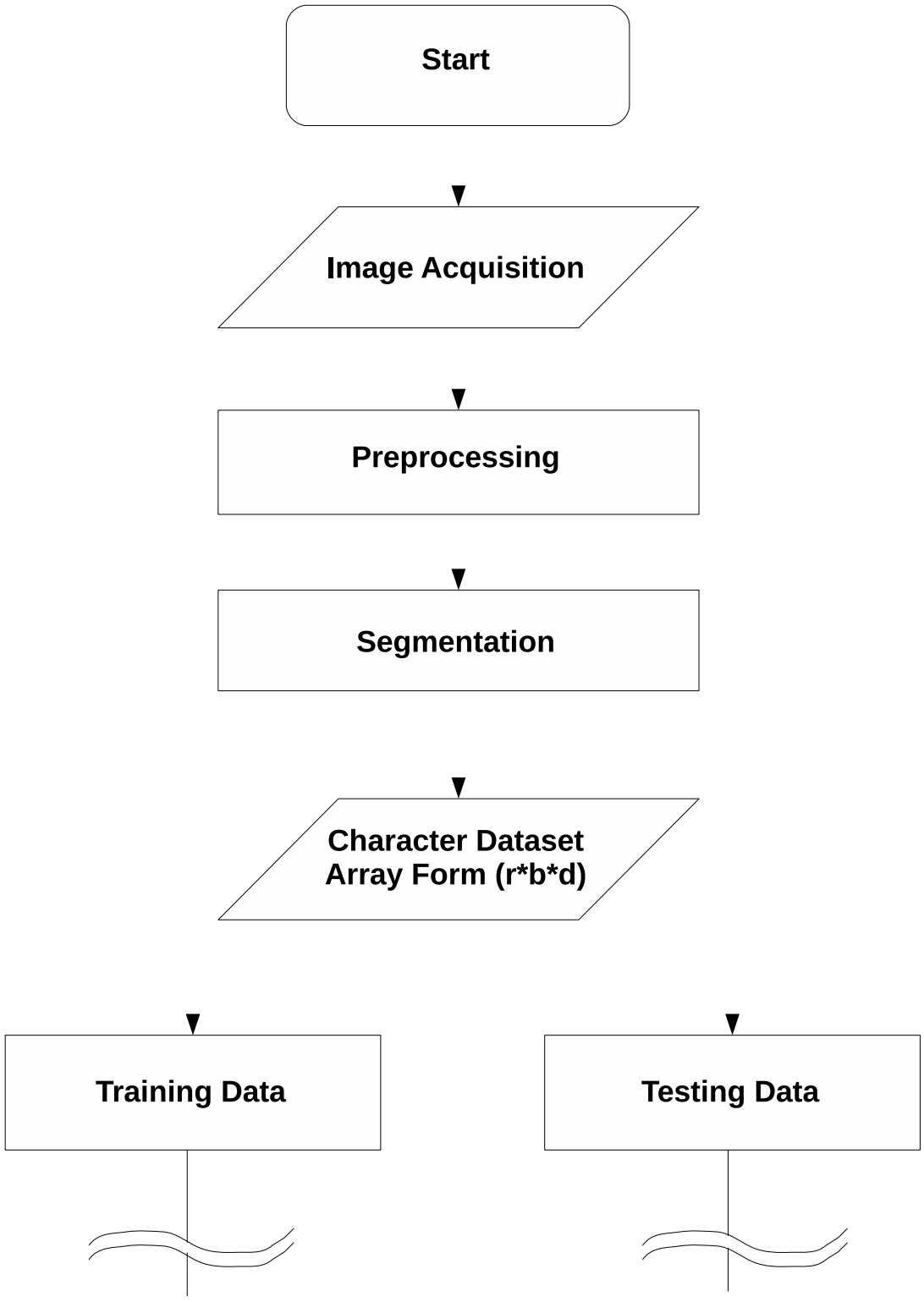


Figure 4.4: Flowchart - HCR System

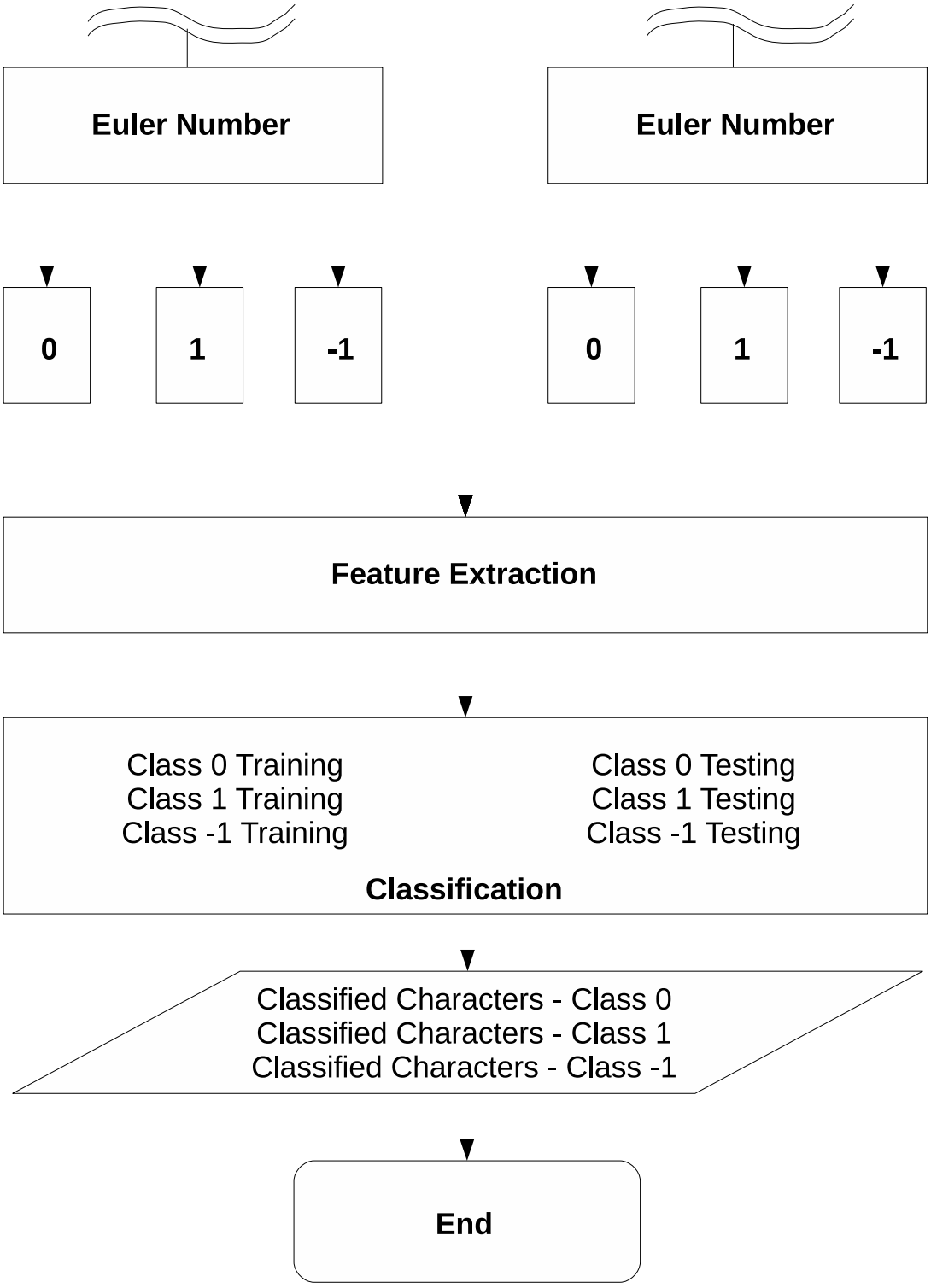


Figure 4.5: Flowchart - HCR System

Chapter 5

Tools and Technology

Tools and Technology is very impotent for the research work. More tools and good technology provide the boost for the experiments. Here, in this research work used tools and technology shown below...

Used Tools and Technology :

- **Tools :** Matlab (R2014a), Octave (3.8.2)
- **Technology :** Matlab

Matlab (Matrix Laboratory), A powerful tools and very popular for mostly all advanced technology. It's a computing tool. Matlab is not only tools but itself it's a programming language.Matlab is the language for technical computing. Matlab provide powerful computation and Simulation of the works. It's a collection of the various poweful tools. Matlab is a product of mathworks.com. Matlab is a proprietary product.

Octave is a high level interpreted language. Basically it's for the numerical computation and solving the linear and non-linear problems. It can be use with GUI or the CLI. Octave is a similar to Matlab technology. Matlab code can run on the Octave. It's a open-source tools and freely available.

Chapter 6

Work Plan

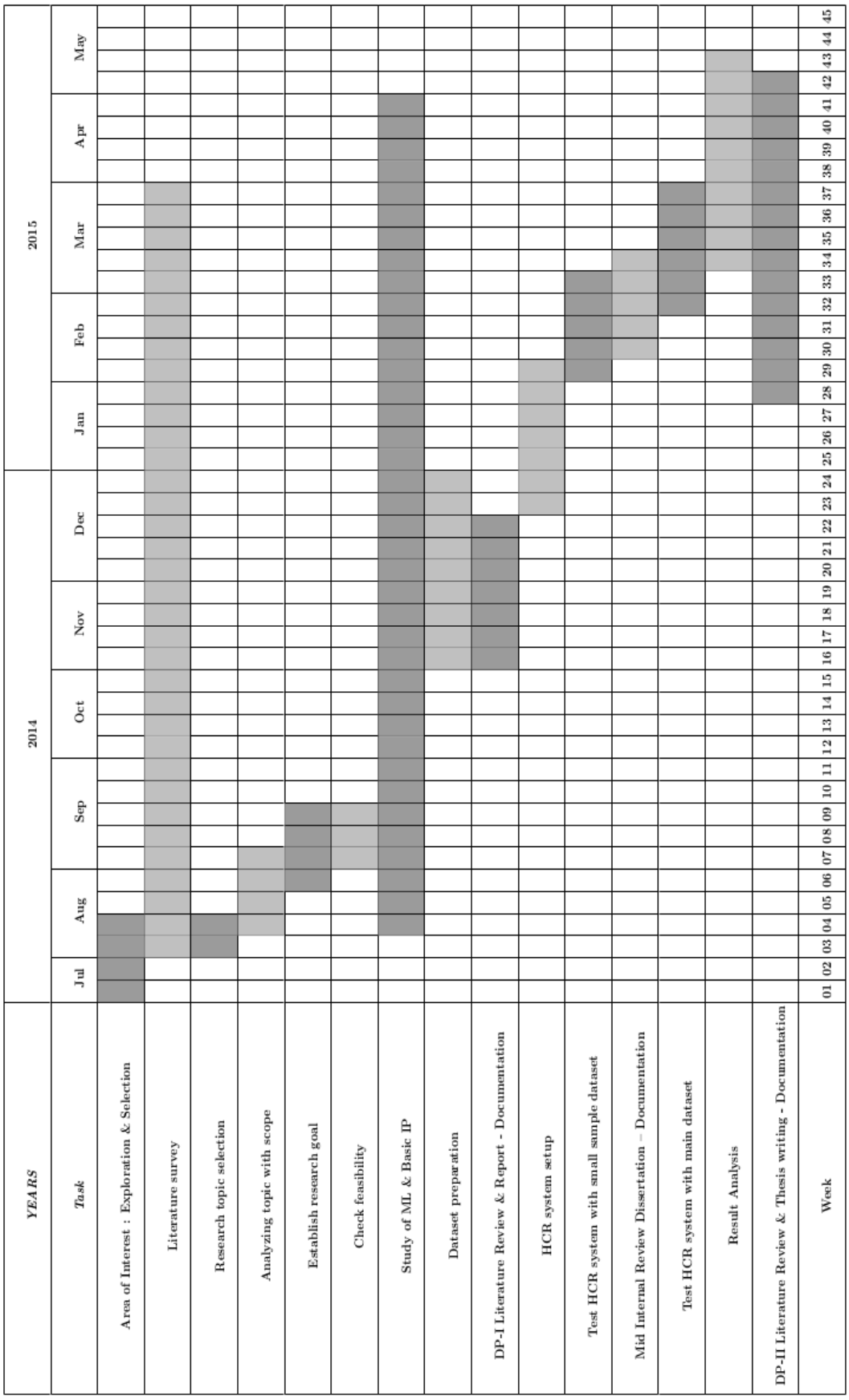


Figure 6.1: Work Plan for the Research Work (approx)

Chapter 7

Implementation & Experiments with Result Analysis

7.1 Implementation & Experiments

1. **Experimental Environment**

   - OS : Linux (Ubuntu 14.04.2 LTS)
   - Processor : Intel Core i3 1 Gen
   - RAM : 3 GB
   - Swap Memory : 6.9 GB
   - Matlab 2014a
   - libsvm - 3.20

2. **System Development Strategy**

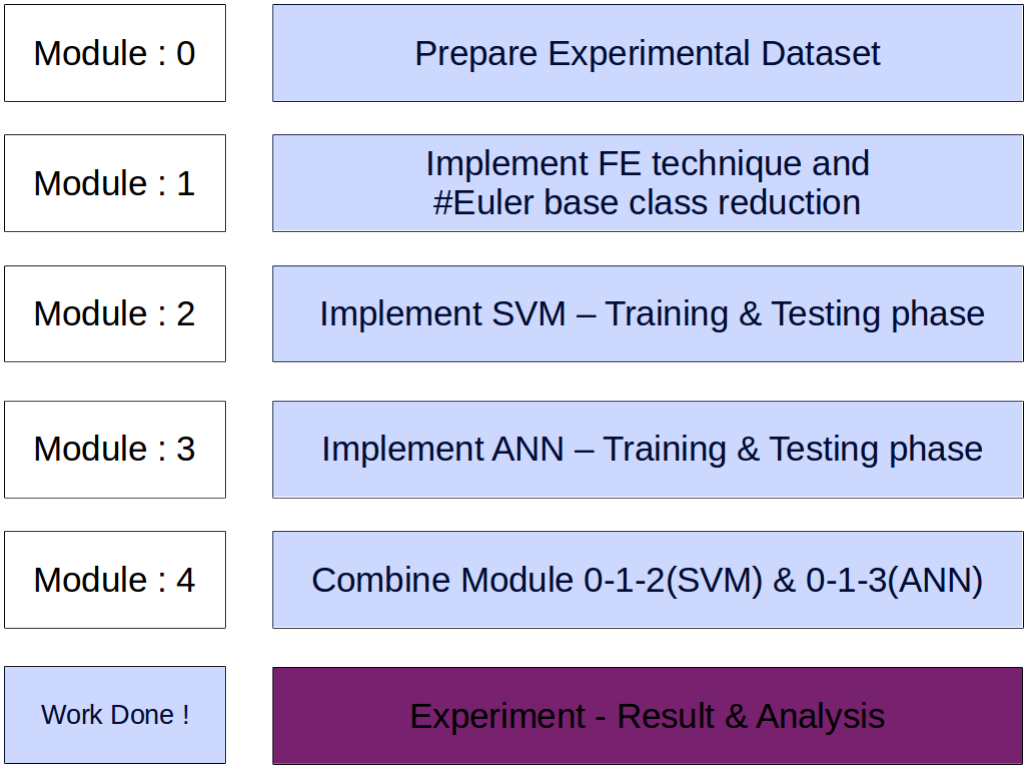


Figure 7.1: System Modules

Figure:7.1 show the list of modules for the complete proposed handwritten character recognition system development. Each module functionality shown in above figure.

3. **Dataset**

Dataset, A samples for the experiment. Dataset is a very important in experiment and research work, because of without dataset we can not experiment and prove the research hypothesis. There are two types datasets are available.

(a) Standard Datasets

(b) User Define/Created Datasets

Standard datasets are made by experts. They take care of all related and effected small things or environment and develop it in slandered environment. On other side, User created datasets are maybe not created in that much standard environment. Based on those things, we can not say that, user dataset is not trust able. Every user create dataset with different parameters, and maybe it will effect the experiment result. So, standard datasets are the first choice of researchers.

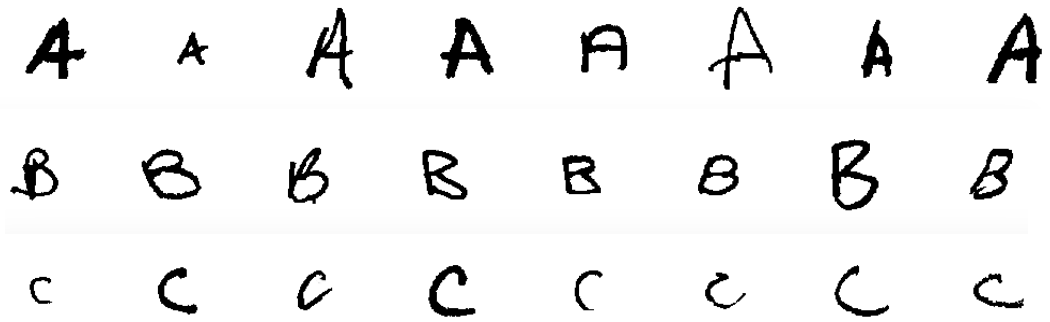


Figure 7.2: Sample Dataset

For the handwritten character recognition experiment, we are using nistsd19 dataset.

Table 7.1: NIST Dataset Detail (Total Characters 11439)

Character	Sample	Character	Sample	Character	Sample	Character	Sample	Character	Sample
A	427	**G**	379	**M**	445	**S**	444	**Y**	450
B	421	**H**	402	**N**	431	**T**	469	**Z**	467
C	518	**I**	814	**O**	458	**U**	457		
D	385	**J**	423	**P**	463	**V**	481		
E	362	**K**	374	**Q**	442	**W**	465		
F	68	**L**	495	**R**	428	**X**	471		

4. **Euler-number Base Class Reduction**

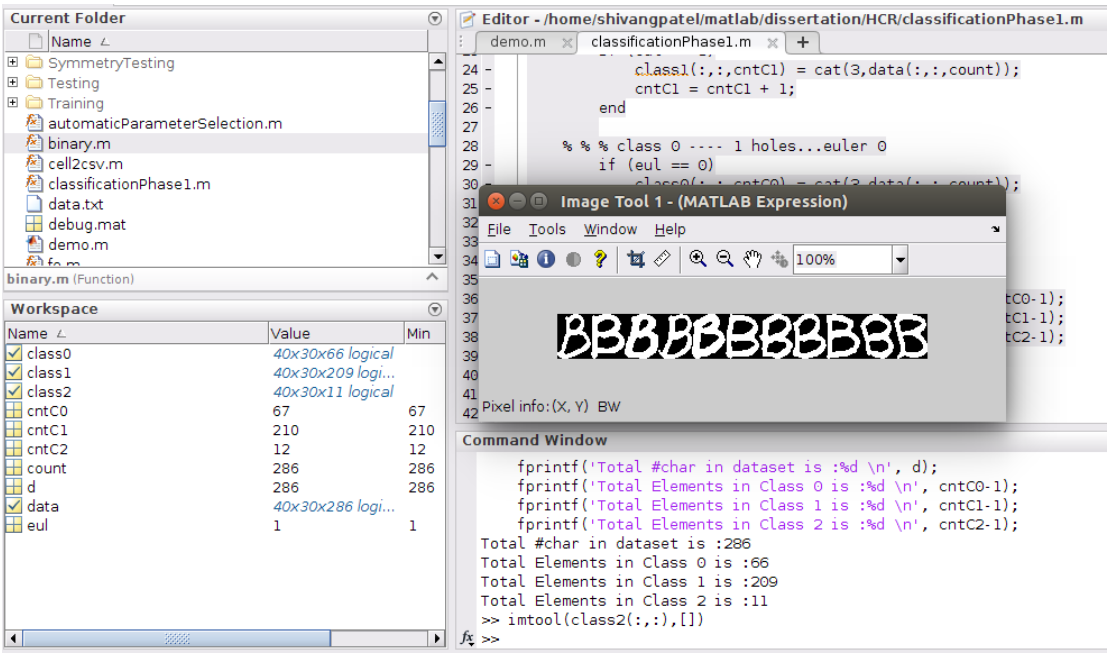


Figure 7.3: Class Reduction : 26Class to 3Class

Figure:7.3 show the result of Euler number base class reduction and then each class have how many data. In this process, as a output we got the all ”B” characters as a classified. Because, ”B” have ”two holes” and no other character have it. So, Class 2 is contains only ”B” character. Class 1 contain ”No hole” and Class 0 contain ”One Hole” characters.

5. **SVM Training and Testing**

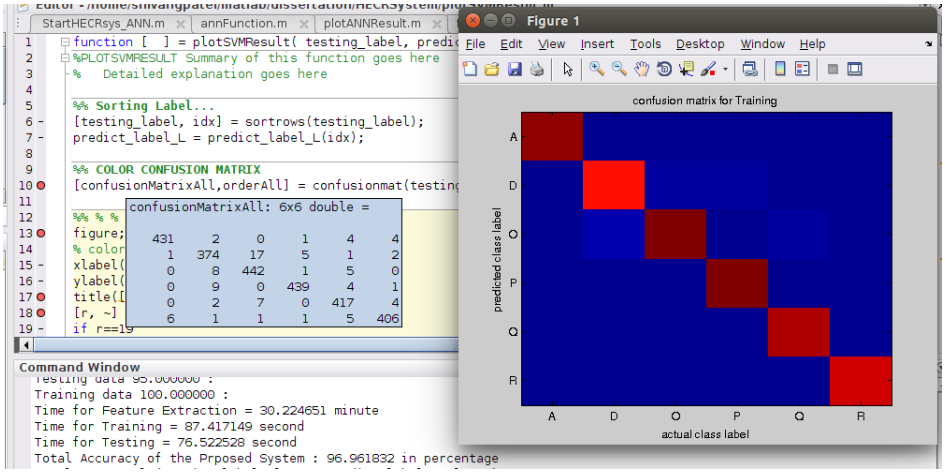


Figure 7.4: Confusion Matrices for SVM

Figure:7.4 show the how libSVM through we get the result? and in Which form? After completion of training and testing, system return the "**Confusion Matrices**", and Accuracy of the successful character recognition. In Figure:7.4, left side show the confusion matrices and right side it's a colored mapped representation. Diagonal of the confusion matrices show the correct classified characters.

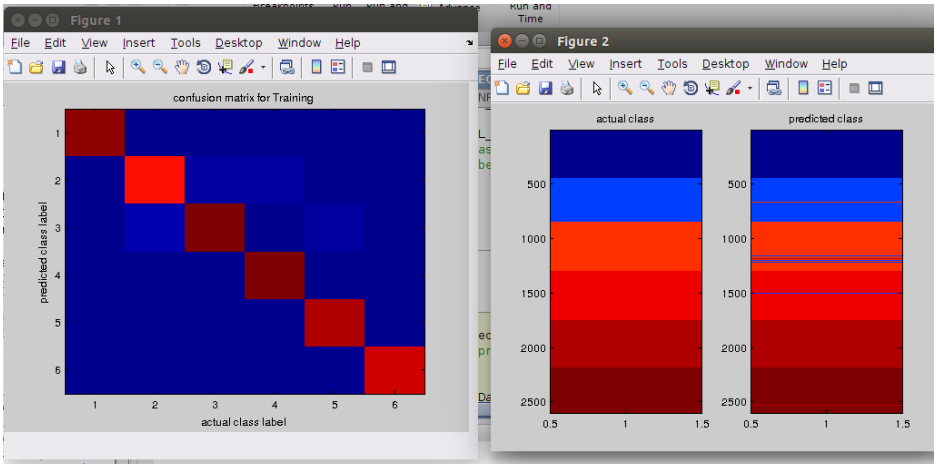


Figure 7.5: Result from Implemented SVM Classifier

In Figure:7.5, left side figure show the confusion matrices and right side figure show the comparison against actual class to predicted class.

6. **ANN Training and Testing**

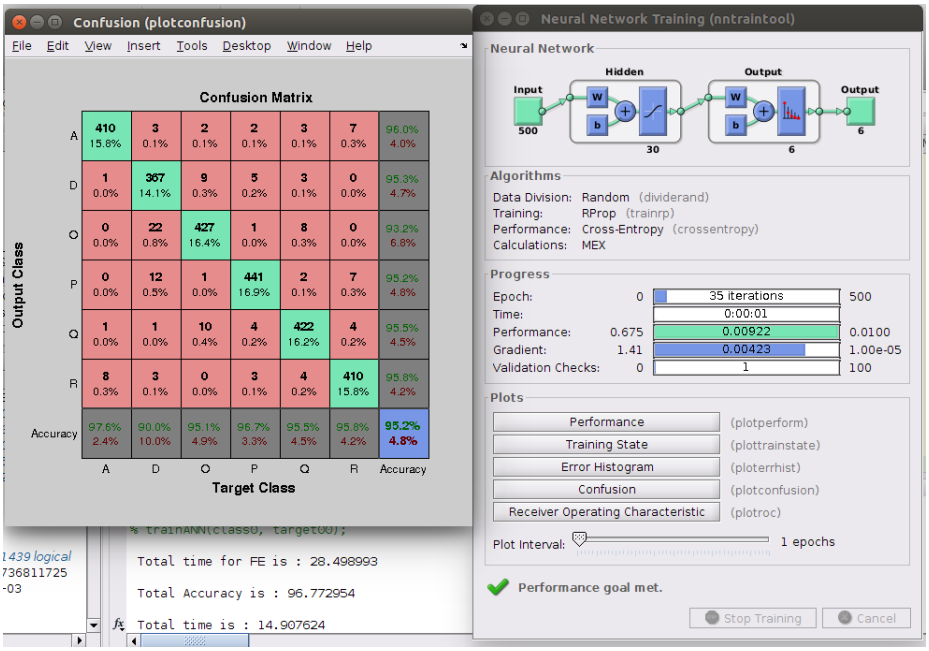


Figure 7.6: Confusion Matrices for ANN

Figure:7.6 show the how ANN through we get the result? and in Which form? After completion of training and testing, system return the "**Confusion Matrices**" same as SVM, and Accuracy of the successful character recognition. In Figure:7.6, left side show the confusion matrices and right side dialog box of neural network training for pattern net(Matlab tool for pattern recognition). Diagonal of the confusion matrices show the correct classified characters.

7. **Fixed Parameters for SVM**

   (a) Kernel : Zero kernel or linear

   (b) SVM library : libSVM

8. **Fixed Parameters for ANN**

   (a) Transfer function : logsig

   (b) Net : Pattern net - A feed-forward network for classification

   (c) TrainFcn : trainscg, trainrp (both are backpropagation algorithm)

   (d) Max error correction : 0.01

7.2 Results

1. **Experiment 1 : SVM Result for 26 class (Only Edge Features)**

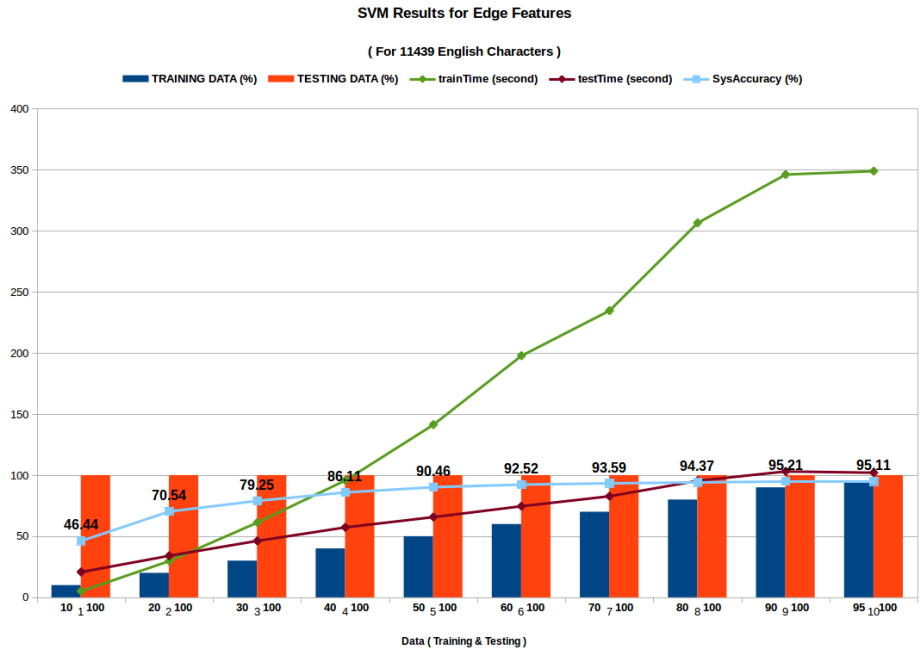


Figure 7.7: SVM - For 26 Class With Only Edge Features

Table 7.2: SVM - Only for Edge Features - Experiment 1

No.	TRAINING DATA (%)	TESTING DATA (%)	trainTime (second)	testTime (second)	SysAccuracy (%)
1	10	100	5.30689	20.997969	46.444059
2	20	100	29.967376	34.278364	70.537728
3	30	100	61.487549	46.478395	79.25412
4	40	100	95.972733	57.533346	86.114484
5	50	100	141.591662	65.990947	90.45967
6	60	100	198.000589	74.84449	92.515178
7	70	100	234.883019	83.027003	93.590633
8	80	100	306.671576	95.633272	94.371206
9	90	100	346.289623	103.312434	95.212489
10	95	100	349.056993	102.288704	95.108413

Figure:7.7 show the results from developed system with SVM classifier. Here, 26 class are available for character classification and only edge features are using. In the above Table : 7.2 show the collected results from experiment 1 data.

2. **Experiment 2 : SVM Result for 26 class (Chain code and Zoning Features)**

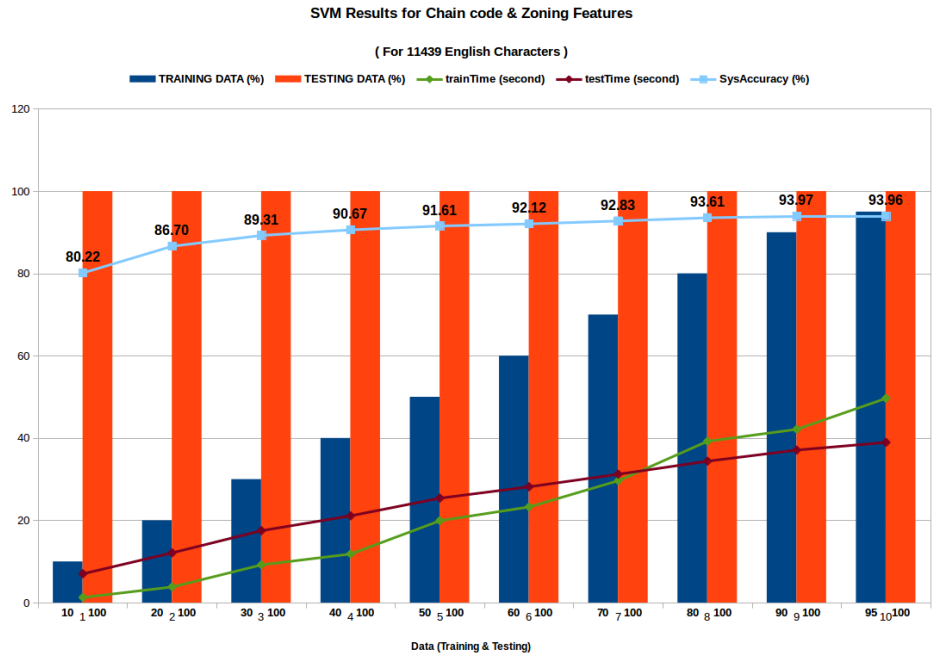


Figure 7.8: SVM - For 26 Class With Chain code & Zoning Features

Table 7.3: SVM - Only for Chain code and Zoning Features - Experiment 2

No.	TRAINING DATA (%)	TESTING DATA (%)	trainTime (second)	testTime (second)	SysAccuracy (%)
1	10	100	1.348383	7.088202	80.216826
2	20	100	3.893403	12.185133	86.695577
3	30	100	9.266168	17.562512	89.314831
4	40	100	11.898738	21.177538	90.667823
5	50	100	19.993496	25.460909	91.613183
6	60	100	23.335575	28.228706	92.124892
7	70	100	29.707515	31.294558	92.827407
8	80	100	39.291822	34.450297	93.607979
9	90	100	42.198814	37.160453	93.972246
10	95	100	49.718262	39.017907	93.963573

Figure:7.8 show the results from developed system with SVM classifier. Here, 26 class are available for character classification and chain code and zoning features are using. In the above Table : 7.3 show the collected results from experiment 2 data.

3. **Experiment 3 : SVM Result for 26 class (All Features)**

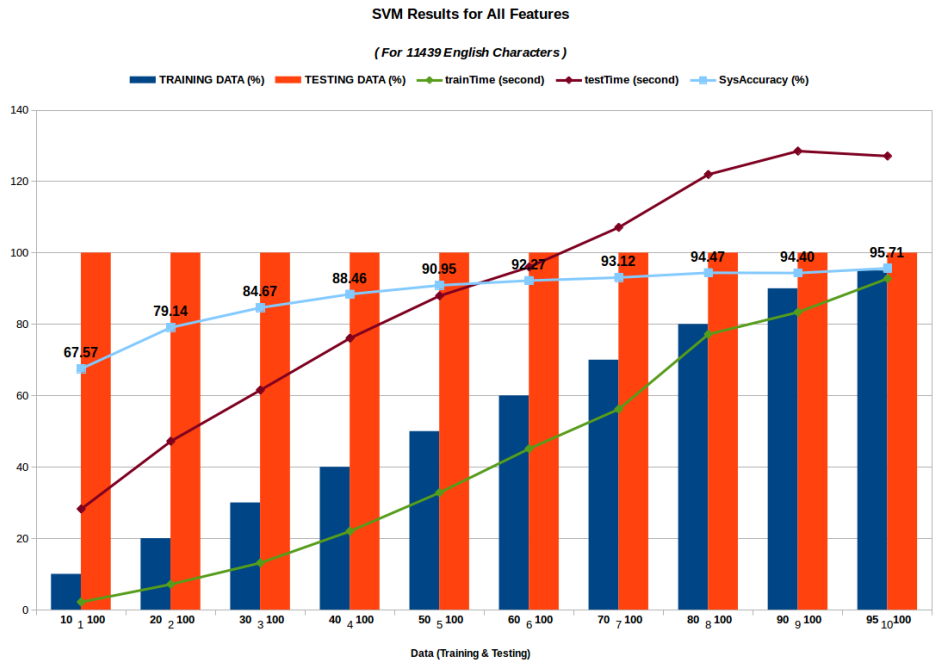


Figure 7.9: SVM - For 26 Class With All Features

Table 7.4: SVM - All Features - Experiment 3

No.	TRAINING DATA (%)	TESTING DATA (%)	trainTime (second)	testTime (second)	SysAccuracy (%)
1	10	100	2.222081	28.28411	67.571552
2	20	100	7.189919	47.267984	79.14137
3	30	100	13.19635	61.589677	84.674761
4	40	100	22.050805	76.120296	88.464874
5	50	100	32.861417	87.992235	90.954033
6	60	100	45.171021	96.063032	92.272333
7	70	100	56.253178	107.162212	93.12229
8	80	100	77.232557	121.996933	94.466609
9	90	100	83.414938	128.537	94.397225
10	95	100	92.828677	127.140918	95.706852

Figure:7.9 show the results from developed system with SVM classifier. Here, 26 class are available for character classification and all features are using. In the above Table: 7.4 show the collected results from experiment 3 data.

4. **Experiment 4 : SVM Result for propose system (Only Edge Features)**

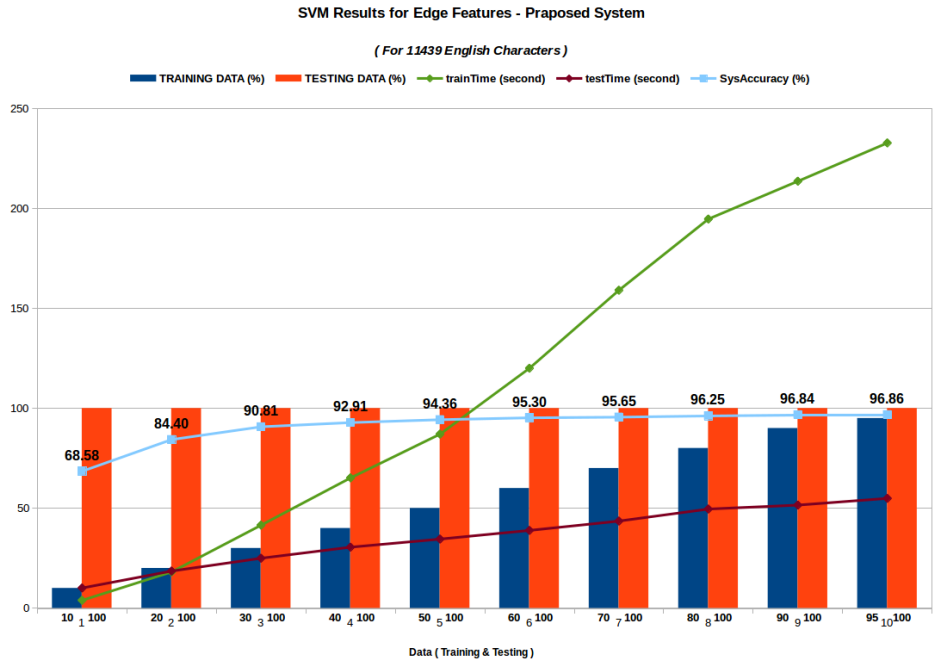


Figure 7.10: SVM - For 26 Class to 3 class With Only Edge Features

Table 7.5: SVM - Only for Edge Features - Experiment 4

No.	TRAINING DATA (%)	TESTING DATA (%)	trainTime (second)	testTime (second)	SysAccuracy (%)
1	10	100	4.020338	10.174536	68.58014
2	20	100	18.218471	18.65508	84.396347
3	30	100	41.606773	25.075341	90.81437
4	40	100	65.256259	30.604728	92.913362
5	50	100	87.156633	34.651207	94.3585
6	60	100	120.098965	38.986301	95.300146
7	70	100	159.122923	43.658651	95.651563
8	80	100	194.741814	49.686321	96.251993
9	90	100	213.645718	51.645285	96.837042
10	95	100	232.781243	55.006074	96.862801

Figure:7.10 show the results from developed system with SVM classifier for proposed system. Here, 3 class are available for character classification and only edge features are using. In the above Table: 7.5 show the collected results from experiment 4 data.

5. **Experiment 5 : SVM Result for proposed system (Chain code and Zoning Features)**

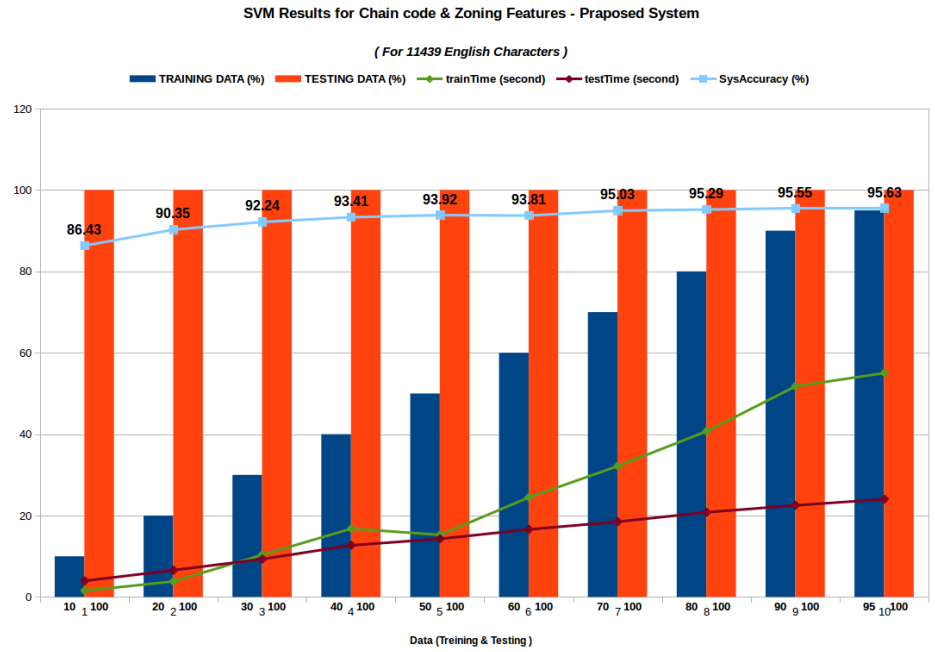


Figure 7.11: SVM - For 26 class to 3 class With Chain code & Zoning Features

Table 7.6: SVM - Only for Chain code and Zoning Features - Experiment 5

No.	TRAINING DATA (%)	TESTING DATA (%)	trainTime (second)	testTime (second)	SysAccuracy (%)
1	10	100	1.624514	4.057235	86.428414
2	20	100	3.918011	6.684049	90.353688
3	30	100	10.450785	9.400723	92.23617
4	40	100	16.885726	12.799779	93.408124
5	50	100	15.350607	14.384919	93.917674
6	60	100	24.58644	16.696512	93.81189
7	70	100	32.25122	18.592597	95.031771
8	80	100	40.815456	20.906576	95.28638
9	90	100	51.854859	22.606165	95.552075
10	95	100	55.114129	24.116647	95.627237

Figure:7.11 show the results from developed system with SVM classifier for proposed system. Here, 3 class are available for character classification and chain code and zoning features are using. In the above Table : 7.6 show the collected results from experiment 5 data.

6. **Experiment 6 : SVM Result for proposed system (All Features)**

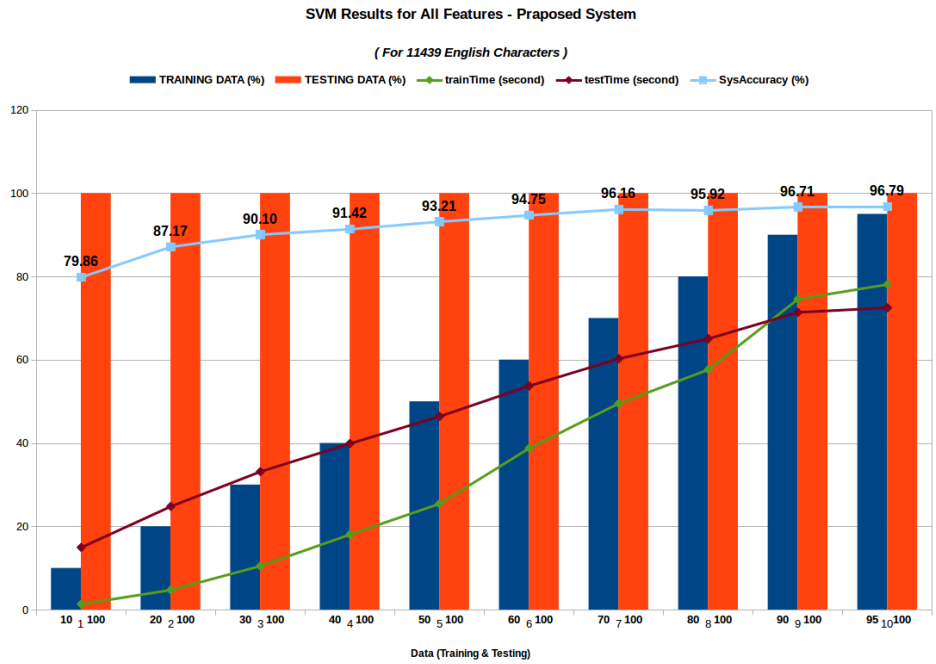


Figure 7.12: SVM - For 26 class to 3 class With All Features

Table 7.7: SVM - For All Features - Experiment 6

No.	TRAINING DATA (%)	TESTING DATA (%)	trainTime (second)	testTime (second)	SysAccuracy (%)
1	10	100	1.40548	15.002662	79.855653
2	20	100	4.782129	24.84079	87.169183
3	30	100	10.5414	33.200264	90.097694
4	40	100	18.098851	39.943397	91.420167
5	50	100	25.500084	46.457107	93.210678
6	60	100	38.82277	53.774869	94.746993
7	70	100	49.563173	60.315477	96.164751
8	80	100	57.70985	65.102056	95.916145
9	90	100	74.631305	71.466576	96.714348
10	95	100	78.14436	72.543926	96.79463

Figure:7.12 show the results from developed system with SVM classifier for proposed system. Here, 3 class are available for character classification and all features are using. In the above Table: 7.7 show the collected results from experiment 6 data.

7. Experiment 7 : ANN Result 26 character class system (Only Edge Features)

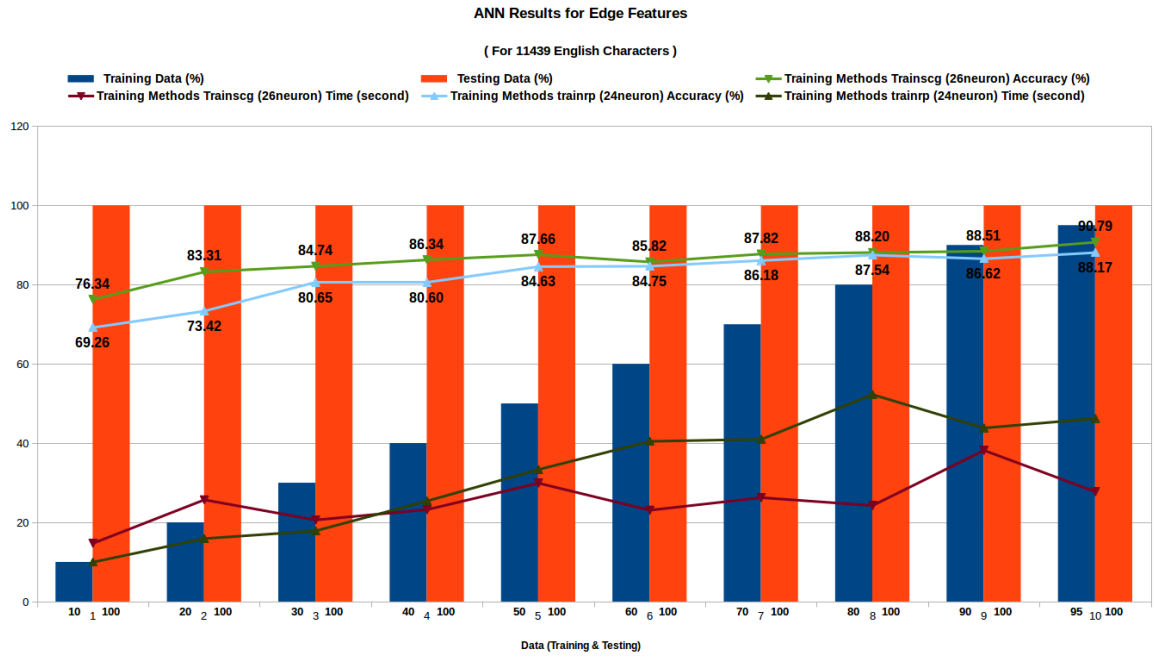


Figure 7.13: ANN - For 26 character class With Only Edge Features

Table 7.8: ANN - Only for Edge Features - Experiment 7

			Training Methods	*Training Methods*	*Training Methods*	*Training Methods*
			Trainscg (26neuron)	*Trainscg (26neuron)*	*trainrp (24neuron)*	*trainrp (24neuron)*
No	**Training Data (%)**	**Testing Data (%)**	**Accuracy (%)**	**Time (second)**	**Accuracy (%)**	**Time (second)**
1	10	100	76.335344	14.814242	69.263047	10.048463
2	20	100	83.311478	25.784232	73.415508	16.000323
3	30	100	84.736428	20.696496	80.653903	17.949518
4	40	100	86.336218	23.30863	80.601451	25.49439
5	50	100	87.656264	29.988066	84.631524	33.432156
6	60	100	85.820439	23.160763	84.74517	40.542417
7	70	100	87.822362	26.338033	86.178862	41.064376
8	80	100	88.198269	24.342859	87.542617	52.343831
9	90	100	88.512982	38.261838	86.624705	43.902514
10	95	100	90.79465	27.828239	88.172043	46.316749

Figure:7.13 show the results from developed system with ANN classifier for 26 character classes system - A conventional system approach. Here, 26 classes are available for character classification and only edge features are using. In the above Table : 7.8 show the collected results from experiment 7 data.

8. **Experiment 8 : ANN Result for 26 character class system (Chain code and Zoning Features)**

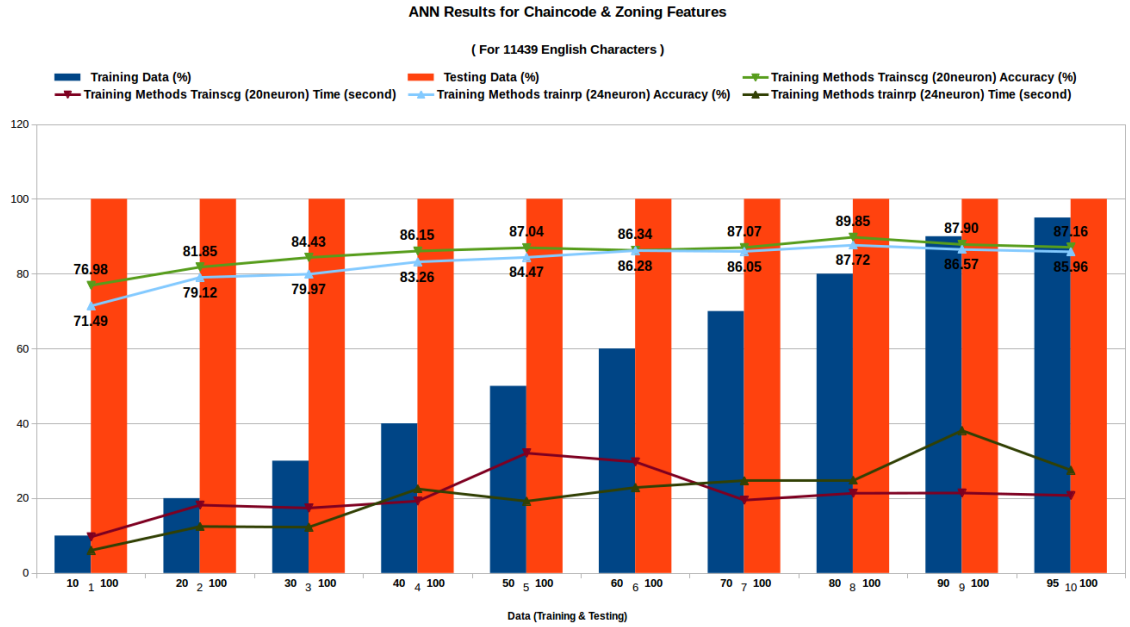


Figure 7.14: ANN - For 26 class classes With Chain code & Zoning Features

Table 7.9: ANN - Only for Chain code and Zoning Features - Experiment 8

			Training Methods	*Training Methods*	*Training Methods*	*Training Methods*
			Trainscg (20neuron)	*Trainscg (20neuron)*	*trainrp (24neuron)*	*trainrp (24neuron)*
No	**Training Data (%)**	**Testing Data (%)**	**Accuracy (%)**	**Time (second)**	**Accuracy (%)**	**Time (second)**
1	10	100	76.982254	9.760244	71.492263	6.155437
2	20	100	81.85156	18.240217	79.115307	12.526589
3	30	100	84.430457	17.455797	79.972026	12.337055
4	40	100	86.152636	19.317128	83.259026	22.561153
5	50	100	87.03558	32.131223	84.465425	19.286141
6	60	100	86.336218	29.782289	86.275024	22.948236
7	70	100	87.070548	19.564045	86.047731	24.750174
8	80	100	89.850511	21.408319	87.717458	24.867107
9	90	100	87.90104	21.473296	86.572253	38.172378
10	95	100	87.157968	20.818966	85.960311	27.574707

Figure:7.14 show the results from developed system with ANN classifier 26 character class system. Here, 26 class are available for character classification and chain code and zoning features are using. In the above Table : 7.9 show the collected results from experiment 8 data.

9. Experiment 9 : ANN Result for 26 character class system (All Features)

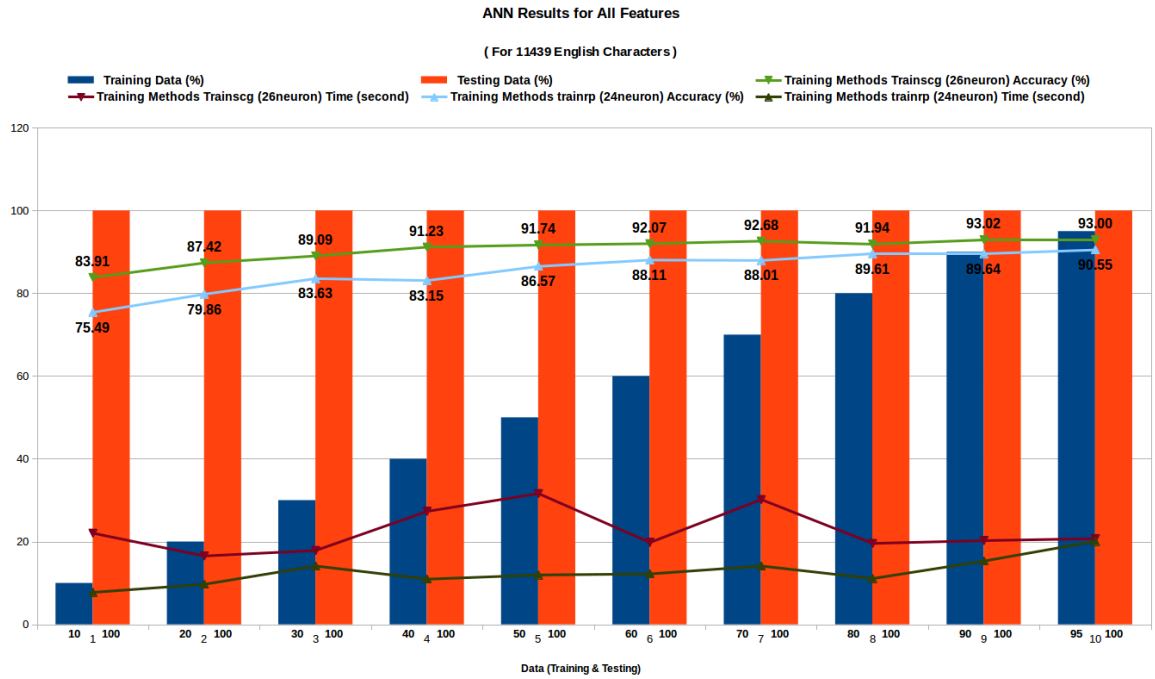


Figure 7.15: ANN - For 26 classes With All Features

Table 7.10: ANN - For All Features - Experiment 9

			Training Methods	*Training Methods*	*Training Methods*	*Training Methods*
			Trainscg (26neuron)	*Trainscg (26neuron)*	*trainrp (24neuron)*	*trainrp (24neuron)*
No	**Training Data (%)**	**Testing Data (%)**	**Accuracy (%)**	**Time (second)**	**Accuracy (%)**	**Time (second)**
1	10	100	83.905936	22.120587	75.487368	7.822911
2	20	100	87.420229	16.611631	79.858379	9.771475
3	30	100	89.089955	17.938762	83.634933	14.196153
4	40	100	91.231751	27.386296	83.154122	11.012599
5	50	100	91.738788	31.696554	86.572253	12.02279
6	60	100	92.070985	19.860442	88.110849	12.278405
7	70	100	92.682927	30.242183	88.014687	14.198293
8	80	100	91.939855	19.645292	89.605735	11.150013
9	90	100	93.023866	20.322958	89.640703	15.385084
10	95	100	92.99764	20.805109	90.549873	20.160924

Figure:7.15 show the results from developed system with ANN classifier for 26 character class system. Here, 26 class are available for character classification and all features are using. In the above Table : 7.10 show the collected results from experiment 9 data.

10. Experiment 10 : ANN Result for propose system (Only Edge Features)

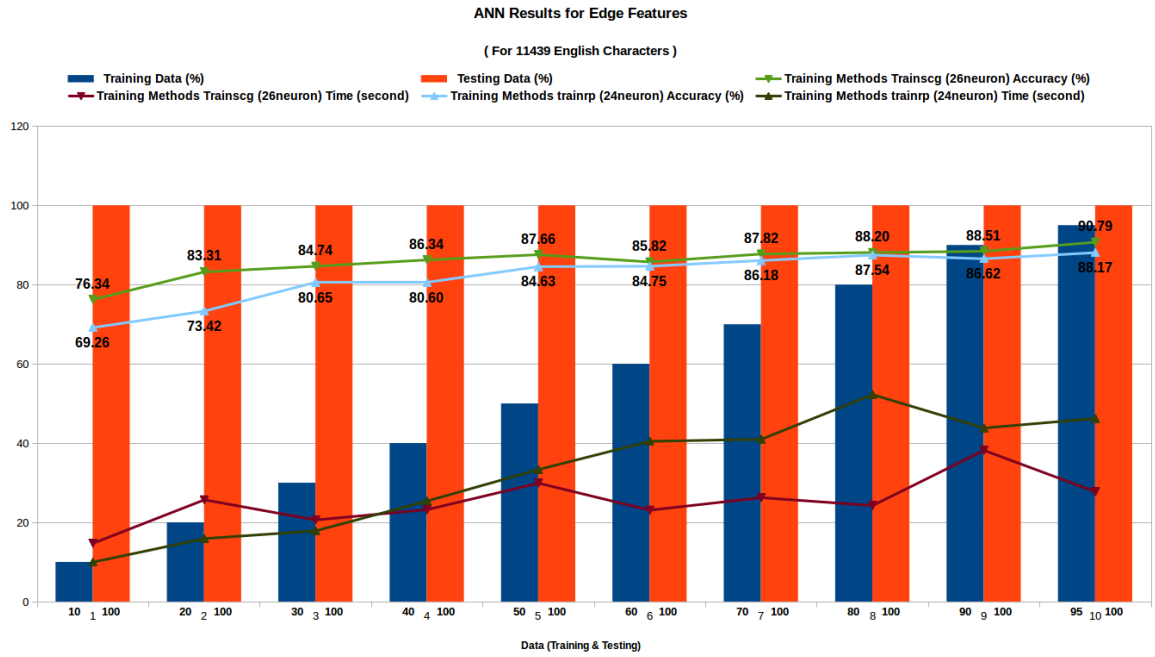


Figure 7.16: SVM - For 26 Class to 3 class With Only Edge Features

Table 7.11: SVM - Only for Edge Features - Experiment 10

			Training Methods	*Training Methods*	*Training Methods*	
			Trainscg (20neuron)	Trainscg (20neuron)	trainrp (30neuron)	trainrp (30neuron)
No	**Training Data (%)**	**Testing Data (%)**	**Accuracy (%)**	**Time (second)**	**Accuracy (%)**	**Time (second)**
1	10	100	92.598284	18.209811	88.090665	5.129953
2	20	100	94.211807	12.575979	90.907927	10.710164
3	30	100	95.389935	15.180622	92.675118	9.71414
4	40	100	95.056986	18.916907	93.494686	11.974155
5	50	100	95.620438	20.025008	94.058138	13.540361
6	60	100	96.132667	16.285928	94.647202	17.516416
7	70	100	96.311948	20.929586	95.466769	19.95727
8	80	100	96.363171	20.462519	94.544756	19.757992
9	90	100	96.414394	19.314164	93.110514	19.20975
10	95	100	96.311948	20.83619	94.544756	16.510789

Figure:7.16 show the results from developed system with ANN classifier for proposed system. Here, 3 class are available for character classification and only edge features are using. In the above table : 7.11 show the collected results from experiment 10 data.

11. **Experiment 11 : ANN Result for proposed system (Chain code and Zoning Features)**

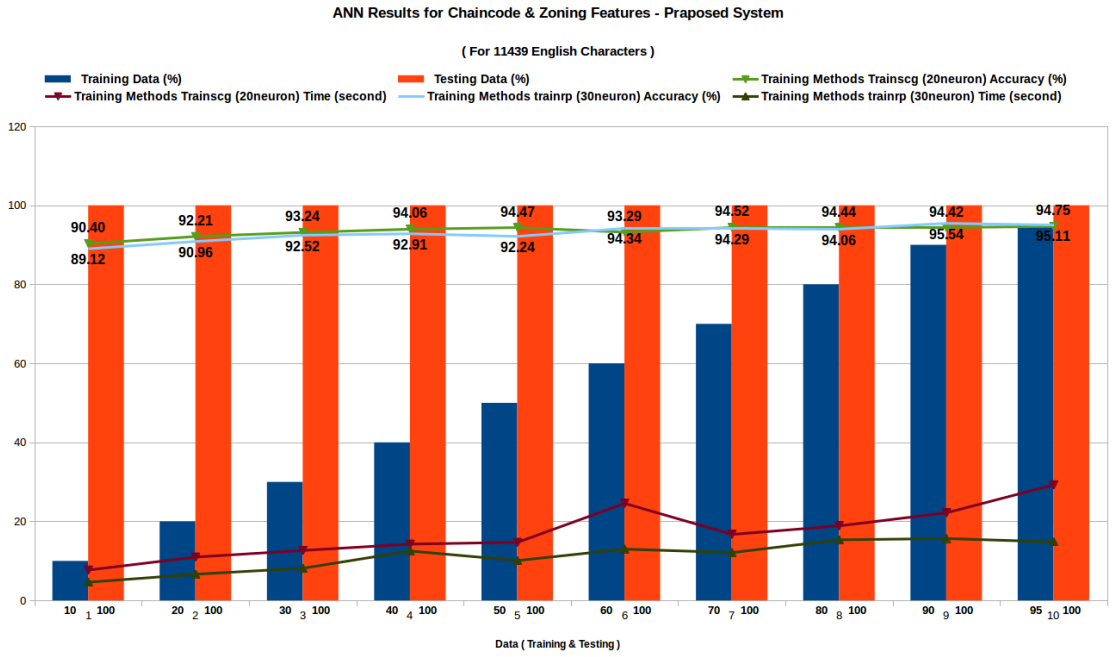


Figure 7.17: ANN - For 26 class to 3 class With Chain code & Zoning Features

Table 7.12: ANN - Only for Chain code and Zoning Features - Experiment 11

			Training Methods	*Training Methods*	*Training Methods*	*Training Methods*
			Trainscg (20neuron)	*Trainscg (20neuron)*	*trainrp (30neuron)*	*trainrp (30neuron)*
No	**Training Data (%)**	**Testing Data (%)**	**Accuracy (%)**	**Time (second)**	**Accuracy (%)**	**Time (second)**
1	10	100	90.395697	7.800869	89.115124	4.715024
2	20	100	92.214112	11.085179	90.95915	6.743321
3	30	100	93.238571	12.765177	92.52145	8.257541
4	40	100	94.058138	14.358144	92.905622	12.613602
5	50	100	94.467922	14.81256	92.239723	10.198975
6	60	100	93.289794	24.658512	94.339864	13.093389
7	70	100	94.519145	16.812396	94.288641	12.219812
8	80	100	94.44231	18.984682	94.058138	15.4508
9	90	100	94.416699	22.284383	95.543604	15.761511
10	95	100	94.749648	29.343048	95.108208	14.926158

Figure:7.17 show the results from developed system with ANN classifier for proposed system. Here, 3 class are available for character classification and chain code and zoning features are using. In the above Table : 7.12 show the collected results from experiment 11 data.

12. Experiment 12 : ANN Result for proposed system (All Features)

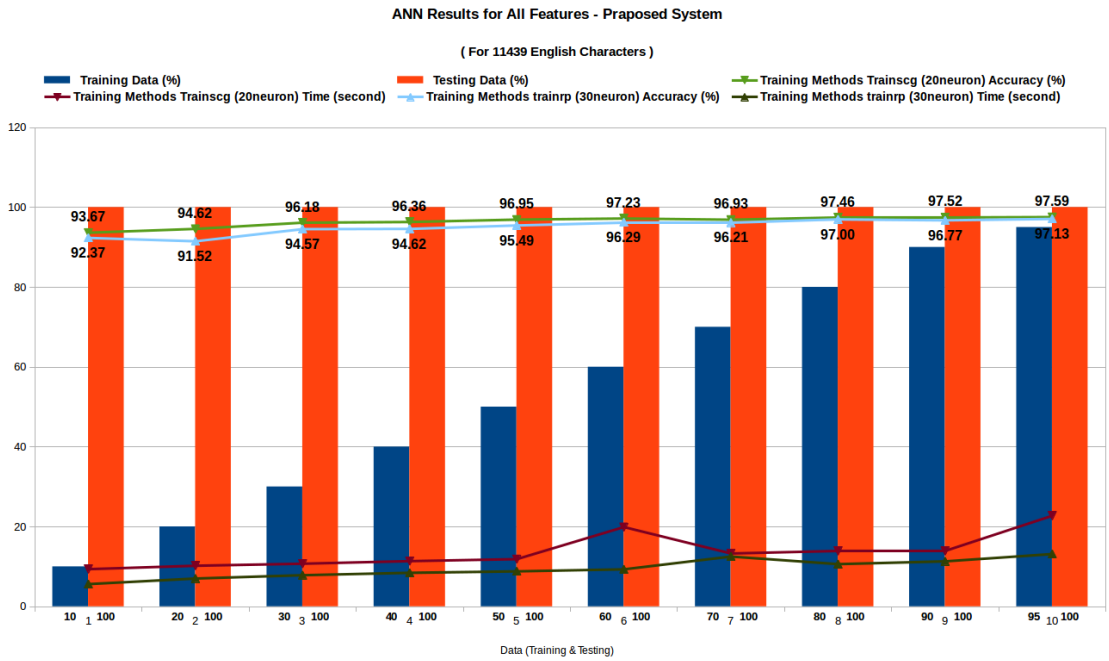


Figure 7.18: ANN - For 26 class to 3 class With All Features

Table 7.13: ANN - For All Features - Experiment 12

			Training Methods	*Training Methods*	*Training Methods*	*Training Methods*
			Trainscg (20neuron)	***Trainscg (20neuron)***	***trainrp (30neuron)***	***trainrp (30neuron)***
No	**Training Data (%)**	**Testing Data (%)**	**Accuracy (%)**	**Time (second)**	**Accuracy (%)**	**Time (second)**
1	10	100	93.673966	9.41073	92.367781	5.666271
2	20	100	94.62159	10.257125	91.522602	7.056725
3	30	100	96.18389	10.768571	94.570368	7.89074
4	40	100	96.363171	11.409581	94.62159	8.48964
5	50	100	96.952235	11.91438	95.492381	8.852825
6	60	100	97.233961	19.941714	96.286336	9.357872
7	70	100	96.926623	13.326493	96.209502	12.560835
8	80	100	97.464464	13.956719	97.003458	10.664223
9	90	100	97.515687	13.94806	96.772954	11.354139
10	95	100	97.592521	22.776465	97.131515	13.188602

Figure:7.18 show the results from developed system with ANN classifier for proposed system. Here, 3 class are available for character classification and all features are using. In the above Table : 7.13 show the collected results from experiment 12 data.

7.3 Analysis

1. **For SVM Results**

   (a) **Old Approach v/s New Proposed Approach - SVM - Accuracy Parameter**

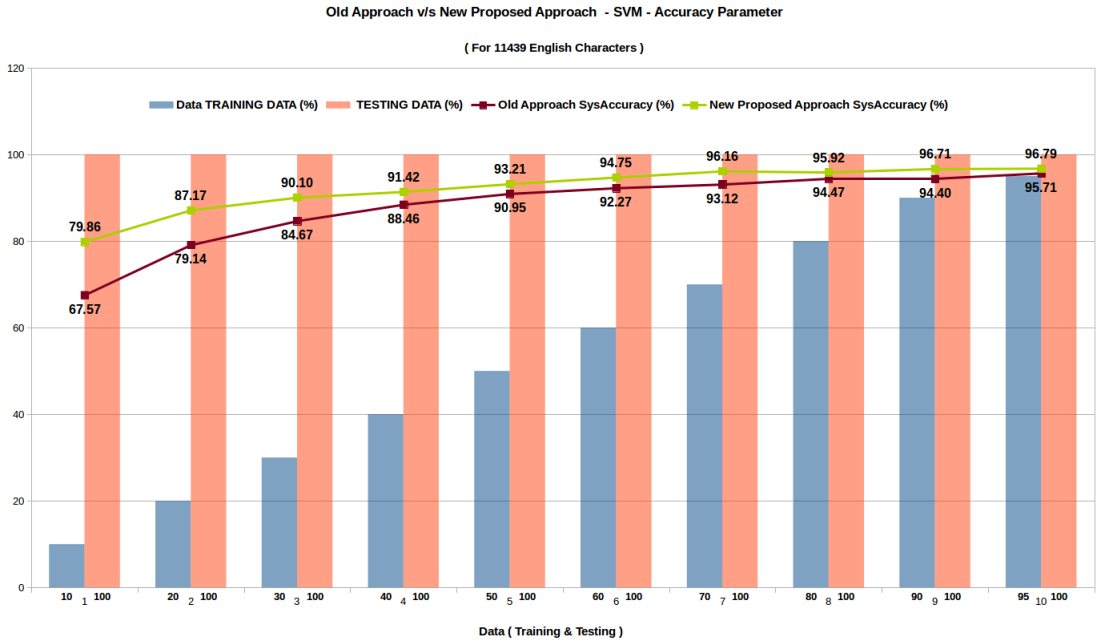


Figure 7.19: SVM - Accuracy Parameter

Table 7.14: SVM Data for Accuracy Parameter

No	Data		Old Approach	New Proposed Approach
	TRAINING DATA (%)	TESTING DATA (%)	SysAccuracy (%)	SysAccuracy (%)
1	10	100	67.571552	79.855653
2	20	100	79.14137	87.169183
3	30	100	84.674761	90.097694
4	40	100	88.464874	91.420167
5	50	100	90.954033	93.210678
6	60	100	92.272333	94.746993
7	70	100	93.12229	96.164751
8	80	100	94.466609	95.916145
9	90	100	94.397225	96.714348
10	95	100	95.706852	96.79463

Ploted graph shows that proposed approach is gives the batter accuracy.

(b) **Old Approach v/s New Proposed Approach - SVM - Time Parameter**

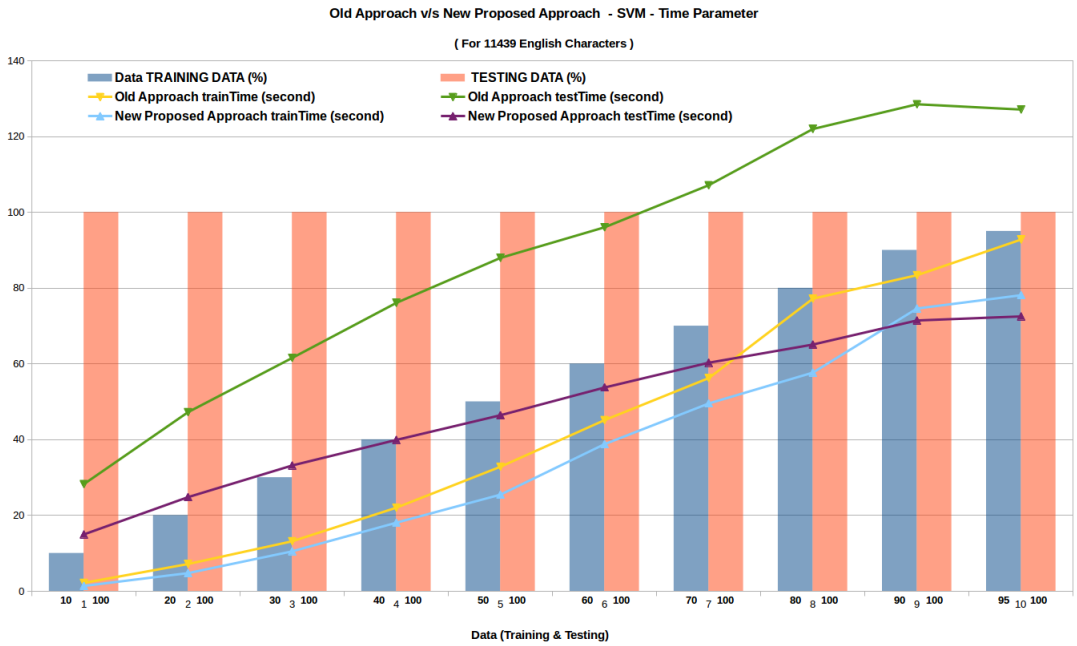


Figure 7.20: SVM - Time Parameter

Table 7.15: SVM Data for Time Parameter

No	Data		Old Approach	Old Approach	New Proposed Approach	New Proposed Approach
	TRAINING DATA (%)	TESTING DATA (%)	trainTime (second)	testTime (second)	trainTime (second)	testTime (second)
1	10	100	2.222081	28.28411	1.40548	15.002662
2	20	100	7.189919	47.267984	4.782129	24.84079
3	30	100	13.19635	61.589677	10.5414	33.200264
4	40	100	22.050805	76.120296	18.098851	39.943397
5	50	100	32.861417	87.992235	25.500084	46.457107
6	60	100	45.171021	96.063032	38.82277	53.774869
7	70	100	56.253178	107.162212	49.563173	60.315477
8	80	100	77.232557	121.996933	57.70985	65.102056
9	90	100	83.414938	128.537	74.631305	71.466576
10	95	100	92.828677	127.140918	78.14436	72.543926

Ploted graphs shows that proposed approach is take less time for training and testing.

2. **For ANN Results**

(a) **Old Approach v/s New Proposed Approach - ANN - Accuracy & Time Parameter - ”trainscg”**

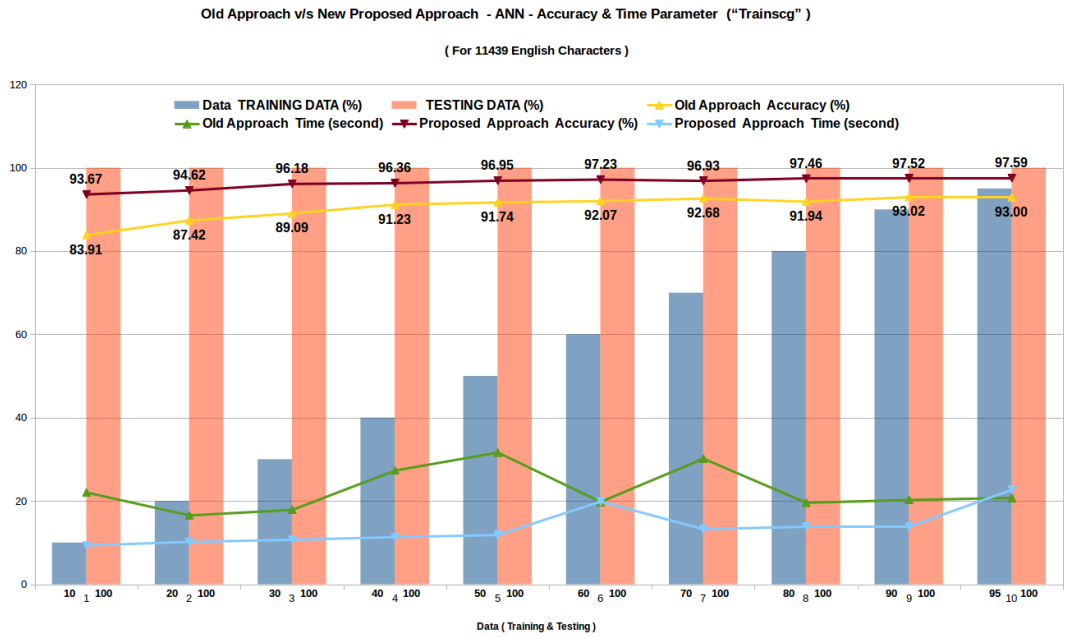


Figure 7.21: ANN ”trainscg” - Accuracy and Time Parameters

Table 7.16: ANN Data with ”trainscg” for Accuracy and Time

			Old Approach – Training Methods “Trainscg” 26neuron		Proposed,Approach – Training Methods “Trainscg” 20neuron	
No	**Data**		**Old Approach**	**Old Approach**	**Proposed Approach**	**Proposed Approach**
	TRAINING DATA (%)	**TESTING DATA (%)**	**Accuracy (%)**	**Time (second)**	**Accuracy (%)**	**Time (second)**
1	10	100	83.905936	22.120587	93.673966	9.41073
2	20	100	87.420229	16.611631	94.62159	10.257125
3	30	100	89.089955	17.938762	96.18389	10.768571
4	40	100	91.231751	27.386296	96.363171	11.409581
5	50	100	91.738788	31.696554	96.952235	11.91438
6	60	100	92.070985	19.860442	97.233961	19.941714
7	70	100	92.682927	30.242183	96.926623	13.326493
8	80	100	91.939855	19.645292	97.464464	13.956719
9	90	100	93.023866	20.322958	97.515687	13.94806
10	95	100	92.99764	20.805109	97.592521	22.776465

Ploted graph shows that proposed approach is gives the batter accuracy and take less time for computation.

(b) **Old Approach v/s New Proposed Approach - ANN - Accuracy & Time Parameter - ”trainrp”**

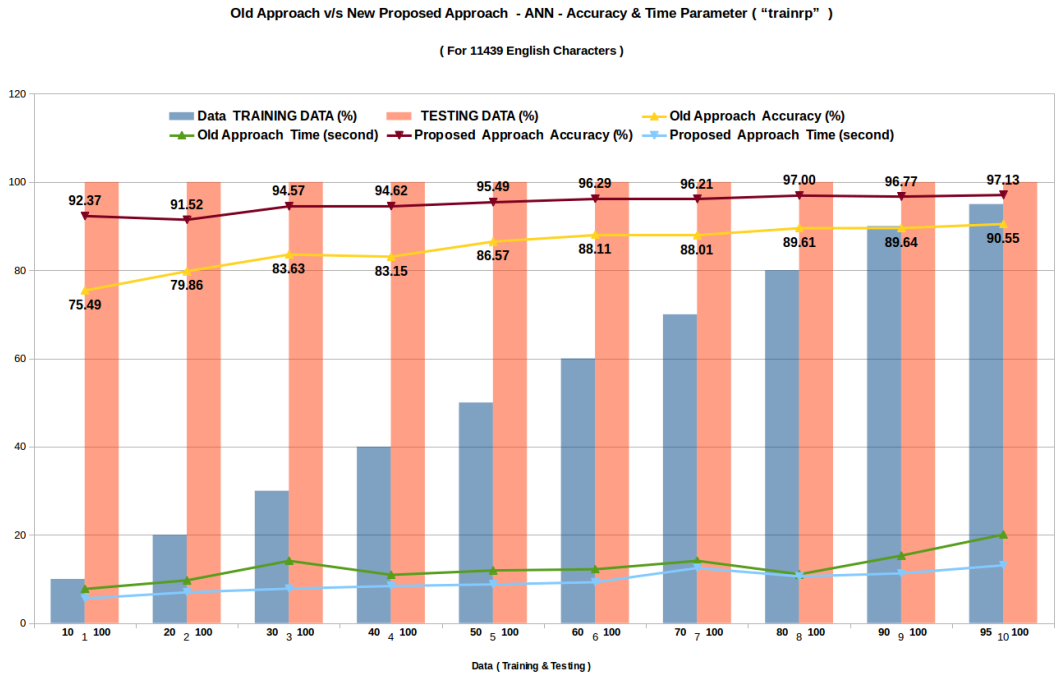


Figure 7.22: ANN ”trainrp” - Accuracy and Time Parameters

Table 7.17: ANN Data with ”trainrp” for Accuracy and Time

No.	Data		Old Approach – Training Methods “Trainrp” 24neuron		Proposed,Approach – Training Methods “Trainrp” 30neuron	
			Old Approach	Old Approach	Proposed Approach	Proposed Approach
	TRAINING DATA (%)	TESTING DATA (%)	Accuracy (%)	Time (second)	Accuracy (%)	Time (second)
1	10	100	75.487368	7.822911	92.367781	5.666271
2	20	100	79.858379	9.771475	91.522602	7.056725
3	30	100	83.634933	14.196153	94.570368	7.89074
4	40	100	83.154122	11.012599	94.62159	8.48964
5	50	100	86.572253	12.02279	95.492381	8.852825
6	60	100	88.110849	12.278405	96.286336	9.357872
7	70	100	88.014687	14.198293	96.209502	12.560835
8	80	100	89.605735	11.150013	97.003458	10.664223
9	90	100	89.640703	15.385084	96.772954	11.354139
10	95	100	90.549873	20.160924	97.131515	13.188602

Ploted graph shows that proposed approach is gives the batter accuracy and take less time for computation.

Chapter 8

Conclusions

Handwritten Character Recognition very useful in our daily life, and it covers large area of useful applications. Various researchers proposed their work in this area and few researchers achieve more then 90% accuracy. Very few researchers focus and manage the time complexity.. Applying machine learning techniques in handwritten character recognition system for increase the recognition accuracy and selection of good features reduce the time complexity of the HCRSystem. For robust classifiers ML algorithms likes SVM or ANN , while for reduction of computation we reduce 26 character classes in to 3 class based on Euler number of each character in proposed HCR system. For the good machine learning, more training data require.

End of the experiment, all result show that proposed system quite good then conventional system approach. It take less time and give the overall good accuracy. We also conclude that Edge features take more time for training and testing. On other side, Chain code and Zoning features take less time for training and testing then Edge features.

Future Work : In future work, remove the as possible constraints and experiment again this novel approach.

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Appendix A - Review Comments Card

Gujarat Technological University

Master of Engineering

Dissertation Review Card

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College Code & Name:- 032, L.J. Institute of Engineering & Technology.

Theme of Title:- Pattern Recognition & Machine learning

Title of Thesis:- Handwritten Character Recognition using Machine Learning Approach

(I) Name of Supervisor:-
Ms. Jasmine Jha

(II)Name of Co – Supervisor(if any):-

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jj

Exam Date:-28/11/2014.

Comments For Literature Review (730002)
Semester:-03

Comments Given By Internal Review Panel (Pl write specific comments in bullets).	Modification done based on Comments
1). Report is not prepared. needs to be submitted to guide. 2). Includes figures to justify your work in presentation. 3). Presentation skill need to be improve.	- Report is submitted - Workflow has been added in his proposed work - He will work on his presentation skill.
Internal Review Panel *Name:-* Dhirubhai J. Pancholi *Name:-* Jignesh Vanza *Sign:-* *Sign:-* *Inst. Name & Code:-*032, LJIET *Inst. Name & Code:-* 032 *Contact No.:-* 9429301454 *Contact No.:-*9033380348	*Guide* *Name:-* Jasmine Jha *Sign:-*

Enrollment No. of Student: - 130320702512 **Hall No.:-** 6

Comments of Dissertation Phase-1 (730003) (Semester 3)

Exam Date: 23 / 12 /2014

Title:-
Handwritten Character Recognition using Machine learng Approach

1. Appropriateness of title with proposal. (Yes/ No) Yes
2. Justify rational of proposed research. (Yes/ No) Yes.
3. Clarity of objectives. (Yes/ No) Moderate

4. Enlist models, process, methodology, DOE (design of experiment) and parameters (whatever applicable) proposed by student in material and method of project for the Dissertation.
Handwritten Recognition using ANN/SVM. two stage classification

5. Enlist suggestions given to the students for any modification regarding models, process, methodology, DOE (design of experiment) and parameters (whatever applicable), if any.
Work on standard dataset.

130320702512 Hall No :-6

6. General suggestions (if any)

Comments Given By External Examiners: (Pl write Specific comments in bullets).	Modification done based on Comments
1) Work on Standard database 2) Presententation skills very poor and need improvements. 3) Background knowledge not enough.	- He is using NIST dataset as per previous comment. - Has studied more literature for the same area. - Working on Presentation skills

7. Approved [ ] / Approved with suggested recommended changes [✓] / Not Approved [ ]
(Please tick any one)

- **Suggestions**

_____

_____

_____

External Examiners

	College Name & Code	Name of Examiner,	Mobile No.	Signature
1)	GCET - 011	M S Patel	9428488563	Maulika
2)	D.D.U.	M.M.Goswami	9426341155	
3)	OM Engg coll.	Dr. M.M.Nimbarte	9825241150	

Enrollment No. of Student:- 130320702512 Hall No.:- 4

Comments of Mid Semester Thesis Progress Review (740001) Semester:-04

Exam Date: -30 / 3 /2015

Comments Given By External Examiners (Pl write Specific comments in bullets).	Modification done in based on Comments
⊙ Student not able to Explain how training is done. ⊙ (~~Specifically~~ Needs to write constraints assumed while solving Hwf. character Recognision. problem. ⊙ Needs to ~~g~~understand & Elaborate timing/ classification accuracy being improved. ?! -> does it really require ?!	- Training set details have been put in slides. - Constraints have been specified. - Accuracy & Time complexity have been improved.

External Examiners

Name:- Dr. H.M. Nimbark *Name:-* Dr. Manish Joshi

Sign:- *Sign:-*

Inst. Name & Code:- CE Engg (101) *Inst. Name & Code:-*

Contact No.:- 9825281150. *Contact No.:-*

Guide Jasmin Jha

Name:-

Sign:-

Enrollment No. of Student: - Hall No.:-

Comments of Final Dissertation Phase-II (740002) Semester:-04

Exam Date: - / /201

Comments Given By External Examiners (Pl write specific comments in bullets)

Thesis Accepted ☐ Rejected ☐

External Examiners		*Internal Examiner (Guide)*
Name:-	*Name:-*	*Name:-*
Sign:- *Inst. Name & Code:-*	*Sign:-* *Inst. Name & Code:-*	*Sign:-*
Contact No.:-	*Contact No.:-*	

Appendix B - Plagiarism Report

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Submission title:	Handwritten Character Recognition..
File name:	written_Character_Recognition_Us..
File size:	3.13M
Page count:	86
Word count:	13,311
Character count:	69,839
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Appendix C - Meeting with Expert

1. Meeting with Expert

   (a) Dr. Amit P. Ganatra

   Professor and HOD in computer Engineering

   Department (since 2001 to till date)

   At. CSPIT, CHARUSAT

   Email ID : *amitganatra.ce@charusat.ac.in*

   Purpose : Main intense of the visit was how to start dissertation and how to go further with Machine Learning. And also discuss about, what things are importance for dissertation and how to find knowledge regarding dissertation topic.

   Time : Aug 2014

Appendix D - Paper Publication

Paper Publication :

Title	Handwritten Character Recognition using Ma-chine Learning Approach - A Survey
Journal/Conference	International Conference on Elec-trical, Electronics, Signals, Communication and Optimization (EESCO) - 2015
ISBN	978-1-4799-7676-8 (2015 IEEE)

EESCO-2015

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VIGNAN'S INSTITUTE OF INFORMATION TECHNOLOGY-VISAKHAPATNAM

(Affiliated to JNTUK, Kakinada)

International Conference on Electrical, Electronics, Signals, Communication and Optimization

EESCO-2015

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Handwritten Character Recognition using Machine Learning Approach - A Survey

in the proceedings of the International Conference on Electrical, Electronics, Signals, Communication and Optimization (EESCO) held on 24th & 25th January 2015., by ISBN:978-1-4799-7676-8 and IEEE copyright notice:978-1-4799-7678-2/15/$31.00 2015 IEEE.

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Handwritten Character Recognition using Machine Learning Approach - A Survey

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***Abstract*—Handwritten character recognition is a very popular due to its wide range of application. Processing application forms, digitizing ancient articles, postal address processing, bank cheque processing and many others are the growing fields in area of handwritten character processing. Handwritten character is attracting researchers since last 3 decades. Many approaches have been proposed for effective recognition. In this paper, we have shown the detail survey on handwritten character recognition using neural network as a machine learning approache.**

Keywords—handwritten character recognition; feature extraction; classification; machine learning; ann; svm

I. INTRODUCTION

First, Handwritten Character Recognition (HCR) is a classical application of pattern recognition. In 1981, Bezdek et. al. [1] gave the definition of pattern recognition, a process of identifying structure in data by comparisons to known structure; the known structure is developed through method of classification. In general terms, handwritten character recognition is the process to classify characters from the input handwritten texts, as per the predefined character classes. Applications of HCR span across the wide domain like, Identification of characters, Digitization of handwritten record, Application form reading and based on data entry, Translation system – recognizes the unknown language and translate it in a known language, Reading aids for the blind [2], [3], Bank cheque processing, Signature verification, Vehicle number plates [2], [3], Automatic pin code reading to postal mail [2], [3] etc.

In our daily life, we are doing character recognition all the time. While reading notes, sign-board or novel, our brain continuously does the HCR. We match it with our past experience and memory, and based on that we react or take an action or infer some new things. So, this is our natural character recognition.

First time character recognition was done by Tyuring, who tried to develop an aid for the visually handicapped [4]. The first time character recognizer came in 1940s. Before that, mostly all works were related to machine-printed text or a small set of handwritten symbols or texts [5].

Fig.1, show the types of character recognition system.

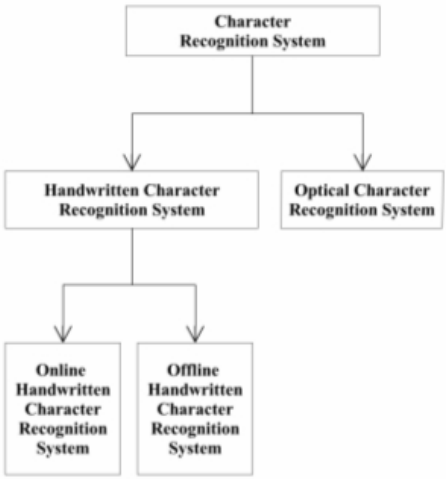

Fig. 1. Types of Character Recognition Systems

In 1980 to 1990, HCR rapidly got attention in research with online and offline approaches [6], [7]. After 1990, image processing and pattern recognition merged with each other with the use of Artificial Intelligence, and after that, very efficient and powerful computers and gadgets like scanners, cameras and other some special devices were developed. There is a large applications area that is covered with handwritten character recognition. Even after all these research, till this date not a single system exists that completely fulfills the goal of handwritten character recognition [8].

Offline handwritten character recognition system acquire static inputs. That means digitized text documents or scanned image copy of handwritten text [8]. Online handwritten character recognition system acquire live handwriting for recognition. Here a person writes on the digital device with the use of a special pen, and that data is used as live feed for system. Main difference between both systems is that online system contains one extra parameter that is time with data [8]. And it also contains the strokes, speed, pen-up and pen-down information as parameters [8]. State of the art, framework of

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handwritten character recognition system shown in the Fig.2. Basically all handwritten character recognition system contain image acquisition, preprocessing, segmentation, feature extraction and classification phases.

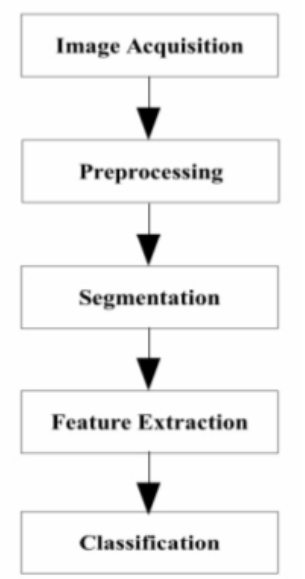


Fig. 2. Framework of Handwritten Character Recognition System

Rest of the paper is organized as follow. Section II, is literature review of various off-line handwritten characters recognition systems by various researchers. Section III, shows the comparison table of various systems. Last, Section IV concludes the survey.

II. LITERATURE SURVEY

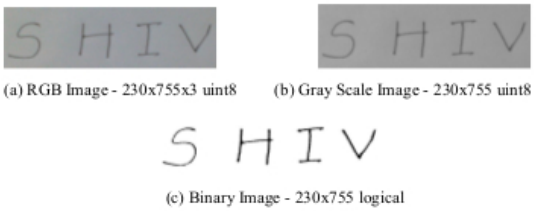
This Literature, review explore the every phase of handwritten character recognition system.

A. Image Acquisition

Image acquisition is the process of acquiring handwritten input data for character recognition system. Based on image or data acquisition, online and offline systems were developed. Bluche et al. used Rimes Dataset, which is in English [11]. For the numeric data, MNIST is a very popular dataset and used in [9]. Some other datasets are, Chars74K (English characters - natural images) [19], CEDAR (paid) [20], Semeion handwritten digit dataset [21], Pen-Based recognition of Handwritten digits dataset [21], etc. When there is no standard dataset available researchers use their own dataset for the recognition system [10].

B. Preprocessing

The Preprocessing is performed on acquired input data. It enhances the quality of input data and makes it more suitable for the next phase of recognition system. Gray scale conversion, binary conversion, noise removal, etc. are various techniques that are performed in this phase. Fig.3, show the basic preprocessing operations on the image.



(a) RGB Image - 230x755x3 uint8 (b) Gray Scale Image - 230x755 uint8

(c) Binary Image - 230x755 logical

Fig. 3. Preprocessed Images

Bluche et al. used gray scale conversion, binary conversion and then a noise removal technique is performed on the input data [11], [9]. While considering the results in [10] after the Gray scale and binary conversion, researcher used edges detection for segmentation. Otsu's algorithm widely used for gray scale image to binary image conversion.

C. Segmentation

Segmentation, is the process of splitting input text data image to line and then after individual character. It removes the unwanted part from the data image. There are two types of segmentation available, External and Internal. External segmentation is segmenting the paragraphs, lines and words. On the other side internal segmentation is segmenting of individual character from input text data [12], [13].

Various algorithms are available for segmentation. Histogram profiles and connected component analysis are some of the methods for line segmentation which are used in [14], [15]. Fig.4 and Fig.5 show the line and character looks like after histogram based segmentation.

Fig. 4. Segmented Line based on Histogram

(a) (b) (c) (d) (e)

Fig. 5. Segmented Characters based on Histogram

Spatial space detection for the words and Histogram method for the characters and other symbols which are used in [16], [17]. In [2], for character segmentation authors are using bounding box technique. After successful segmentation, resize operation is performed on all segmented image for uniform size.

D. Feature Extraction

Feature Extraction is the process of collecting different and very useful information of an object or a group of objects, so

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based on that collected information, we can classify new unknown objects by matching it. Feature is the robust representation of the raw data.

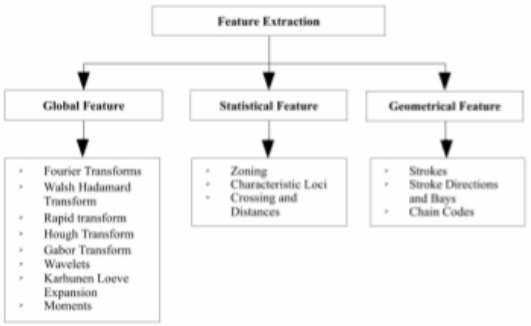

Fig. 6. Feature Extraction Techniques [22]

Fig.6, show various feature extraction methods. Zone based, statistical, structural, chain code histogram, sliding window, gradient feature, hybrid, etc. [3], [10], [14] are some of the most useful feature extraction techniques. In 1961, Freeman introduced chain code method called Freeman Chain Code. There are mainly two directions of chain code, 4-neighborhood and 8-neighborhood.

Xuewen Wang and Kai Ding et al. compare the Gabor feature and Chain code(the contour direction) feature, and results showed that Gabor feature is much better than chain code feature [18], [19]. Kai Ding and Cheng-Lin Liu et al. showed that Gradient feature and Gabor feature have some common properties : both are applicable on binary and gray scale images and is also immune to image noise [19], [20]. In addition, performance is almost similar but Gabor is more suitable for large scale texture data. Imani et al. used in [21], chain code histogram feature and distribution of foreground density across zones.

E. Classification

Classification or Recognition process is for decision making, like this new character fit in which class or looks like. It means, in the phase of classification characters are identified and assign labeling. Performance of the classification depends on good feature extraction and selection. Various classification techniques are available and they all are ultimately based on image processing and artificial intelligence.

In the Fig.7 show the various classification techniques [22]. Template matching, Statistical technique, Structural technique are the classical techniques which are mainly based on image processing. Neural networks, fuzzy logic and genetic techniques are based on soft computing. Jayashree et al. in [23], proposed hybrid method of soft computing. She used neuro-fuzzy with adaptive network, neuro-fuzzy is the hybridization of fuzzy logic and neural network.

After artificial intelligence involved with machine learning, almost all research areas are covered by it, and with the machine learning, very good results are achieved. In the field of handwritten character recognition, machine learning used various methods like artificial neural networks, support vector machine, naive bayes, nearest neighbor algorithms, decision trees, neuro-fuzzy, etc.

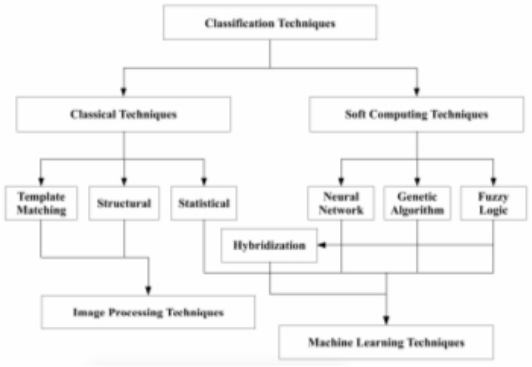

Fig. 7. Classification Techniques

Bluche et al. in [9], used HMM with the convolution neural networks, and made an explicit feature extraction system. Developed system was tested with Rimes dataset and found that character recognition rate was fast, but accuracy is low. Imani and Bingyu Chi et al. used Hidden Markovian Modeling, and results show that efficiency of the HMM classification are more dependent on feature extraction methods [21], [24].

Rahman et al. in [25], proposed system for Bangla characters. He used Backpropagation neural network, and achieved 94.3% recognition accuracy. Amal Ramzi et al. in [8], used Backpropagation neural networks as a classifier. Ramzis proposed system for Arabic handwritten characters with combining online and offline features. The proposed system got 99.5% training accuracy but in testing, the maximum recognition rate achieved was 78.8%.

Rajashekararadhya et al. compared the NNC (Nearest Neighbor Classifier) with SVM (Support Vector Machine). Results showed that SVM is one step ahead of NNC [2]. Nasien et al. used SVM with FCC in [26]. Nasien used English handwritten NIST dataset. Accuracy of recognition is 86% for lowercase characters, 88.46% for uppercase characters, and 73.45% for (lowercase + uppercase) characters [26].

Nisha Sharma et al. in [27], proposed recognition system for hand printed English character, numerals and special symbols. Proposed system used multilayer perceptron neural network with Backpropagation and SVM classifier. System used hand printed English characters - uppercase, lowercase, numerals, and special symbols as a datasets. Recognition rate is 98% for numerals, 96.5% for special characters, 95.35% for uppercase and 92% for lowercase characters. Nisha Sharma et al. gave the reason behind choosing neural network and SVM is: "Neural network have been preferred to be used due to their high noise tolerance and SVM, for its high flexibility, scalability and speed".

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In the next section, the various research works comparison in handwritten character recognition is shown.

III. COMPARISON TABLE

Comparison between various researchers proposed model show in the Table 1.

IV. DISCUSSION AND CONCLUSION

Handwritten Character Recognition is very useful in our daily lives, because it covers large area of useful applications. Various researchers proposed their work in this area and achieved good accuracy rate. Very few researchers focused and managed the time complexity. After many research works, we found that there is not even a single technique or system that can completely fulfill the requirements of Handwritten Character Recognition. So, off-line handwritten character recognition is still an open area of research for identifying various complexities and to resolve them.

Acknowledgment

I want to thanks to my parents, both lovely sisters, dear friends, classmates and, some old and present college professors for their great support for make my confidence always up and up.

TABLE 1: COMPARISON TABLE

Paper	Feature Extraction	Language	Dataset	Classifier	Results and Comments
1.[2]	Simple & Efficient Zone based Hybrid Feature Extraction Algorithm	Kanada and Tamil Numerals	Numerical Data Own Created Datasets	NNC and SVM	Kanada (97.75% NNC + 98.2% SVM), Tamil (93.9% NNC + 94.9% SVM)
2.[3]	not specify	Alphanumerical + symbols	Not specify	RNN	good recognition
3.[9]	Grapheme segmentation and Sliding Window	English	Rimes Database	MLP	Very Fast But Low accuracy
4.[11]	DWT with Multi resolution technique	English Characters	Own Character Dataset	NN with Euclidian Distance matrix	good accuracy – up to 99.23%, But taking more time
5.[21]	Chain Code histogram Features, Distribution of foreground density across zones	Farsi	Own database 198 word classes	HMM	89.00%
6.[24]	Gradient feature	Chinese Alpha-Numeric	10,000 single character image and 4709 legal amount text line images extracted from real life Chinese bank checks	HMM	Average 97.13%
7.[25]	4x8 and 8x4 matrix for each character Segmentation of row and column	Bangla	Not specify	NN	very simple and 94.30%
8.[27]	Multi zoning, Geometrical feature distance and angle, topological feature end point transition, Directional feature chain code histogram	English characters and symbols	Own dataset	BPNN and SVM	BPNN: 98% for English numeral, 96.5% for special characters, 95.35% for uppercase English characters and 92% for lowercase English characters SVM: 92.167% for (uppercase and lowercase)characters
9.[28]	DCT Discrete cosine transformation	Arabic Numbers	ADBase database	DBN - Dynamic Bayesian Network	Average 85%, this result with corrupted data, slow recognition
10.[10]	7 FE methods and then ranking the feature vector and make new 3 feature vector	Numeric	MNIST	ANFIS & IBA ANFIS	99.52% and speed for recognition 24 digits/sec

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Appendix E - Abbreviation

#	number of
AI	Artificial Inteligence
ANN	Artificial Neural Network
BPNN	Back-Propagation - Neural Networks
DBN	Dynamic Bayesian Network
DLQDF	Discriminative Learning Quadratic Discriminant Function
HCRS	Handwritten Character Recognition System
HMM	Hidden Markov Models
HOG	Histogram of Oriented Gradients
ip	Image Processing
ML	Machine Learning
MLP	Multilayer Perceptron
SVM	Support Vector Machine

Alphabetical Index