

# **A Novel Method for Handwritten Digit Recognition System**

## **A PROJECT REPORT**

Submitted by

**19Z341 - RISHIKA V**

**19Z355 - SWETHA M**

**19I208 - CS THARUN RAJ**

**19I218 - GOKUL RAJAN N**

**TEAM ID : PNT2022TMID12666**

In partial fulfillment for the  
award of the certification of  
Dissertation submitted in partial fulfillment of the requirements for the degree of



**NOV 2022**

**DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING**

**AND**

**DEPARTMENT OF INFORMATION TECHNOLOGY**

**PSG COLLEGE OF TECHNOLOGY**

**(Autonomous Institution)**

**COIMBATORE – 641 004**

## 1. INTRODUCTION

### 1.1 Project Overview

Due to the fact that everyone in the world has a distinctive writing style, handwriting identification is one of the most interesting areas of research now being conducted. It is the ability of a computer to recognise and comprehend manually entered numbers or letters automatically. Everything is becoming digitalized to minimize human effort as a result of advancements in science and technology. As a result, many real-time applications require the ability to recognise handwritten digits. For this recognition process, the MNIST data collection, which contains 70000 handwritten digits, is frequently employed. We train these photos using artificial neural networks and create a deep learning model. The user can upload an image of a handwritten digit using a web application that has been constructed. The model analyses this picture and returns the result.

### 1.2 Purpose

Digit recognition system is the working of a machine to train itself or recognizing the digits from different sources like emails, bank cheque, papers, images, etc. and in different real-world scenarios for online handwriting recognition on computer tablets or system, recognize number plates of , numeric entries in forms filled up by hand and so on.

Handwritten digit recognition is the process to **provide the ability to machines to recognize human handwritten digits**. It is not an easy task for the machine because handwritten digits are not perfect, vary from person-to-person, and can be made with many different flavors.

## 2. LITERATURE SURVEY

### 1. A Novel Method for Persian Handwritten Digit Recognition using Support Vector Machines

Persian handwritten digits categorization has been confronting challenges because of various handwriting styles, between class likenesses, and intra-class contrasts. In this paper, an original technique for identifying Persian handwritten digits is introduced. In the proposed strategy, a blend of Histogram of Arranged Inclinations (Hoard), 4-side profiles of the digit picture, and a few flat and vertical examples was utilized and the element of the component vector was decreased utilizing Head Part Investigation (PCA). The proposed technique applied to the HODA data set, and Support Vector Machine (SVM) was utilized in the classification step.

HODA is one of the biggest and challenging datasets of Persian handwritten digits. This dataset includes 60000 training data samples and 20000 test ones. The proposed method can be divided into three major parts, namely pre-processing, feature extraction and classification. the dimension proportion of various pictures is different intrinsically. For example, pictures of '1' or '9' are outlined upward, while '0' and '5' pictures are the square shapes. For overcoming this issue, a picture figuring out algorithm is directed. The proportion of the length to the width of the image is determined and approximately zero lines or sections are cushioned to it evenly, on the off chance that that the proportion is less than 0.95 or more prominent than 1.05. In the subsequent stage, the size of all images are changed, to produce exceptional block size and feature length during applying the feature extractor algorithm. The final pre-handling part is noise reduction and Binarization of the pictures. Several features are extricated from each picture and connected together to construct feature vectors. They are Hoard, 4-side profiles of the digit picture and some level and vertical examples. Histogram of situated slopes (Hoard) is a strong feature extracting strategy which is often utilized in character and digit recognition algorithms in various dialects.

Results uncovered that the recognition precision of such a strategy has close to 100% exactness with a sufficient rate due to existing unsatisfactory examples in the data set. In this manner, the proposed technique could further develop the results thought about to other existing strategies.

## **2. A novel method for Handwritten Digit Recognition with Neural Networks**

Handwritten character recognition is a system generally utilized in the world to perceive postal districts or postal code for mail arranging. There are various strategies that can be utilized to perceive handwritten characters. In this paper two procedures explored are Pattern Recognition and Artificial Neural Network (ANN). Both procedures are characterized and various strategies for every method are additionally talked about. Bayesian Decision theory, Nearest Neighbor rule, and Straight Arrangement or Segregation are sorts of techniques for Pattern Recognition. Shape recognition, Chinese Character and Handwritten Digit recognition utilizes Neural Network to remember them. Neural Network is utilized to train and distinguish written digits.

An image is fed into the network to train. Back-propagation neural network is utilized for training the network. In spite of the fact that it is just a single image, it contains 100 examples of the equivalent number. For each 10 ages, the data is saved into the network. In the wake of training, the network was tried and the accuracy rate came to almost 100%. This is an extremely high accuracy rate. The network was not steady on the grounds that the training results changed regularly. On the off chance that we take numerals — 2" as an example, today we would need to train multiple times to reach almost 100% accuracy, yet tomorrow perhaps we need to train multiple times in order to arrive at close to 100% accuracy.

Utilizing the Neural Network system, back-propagation learning, to perceiving handwritten digits was extremely effective. An image, which contained 100 samples of each number, was trained and tested. The accuracy rate of perceiving the number was close to 100%. This accuracy rate is extremely high. From the training and testing results, it was inferred that the system had more inconvenience distinguishing numerals — 5". This perhaps brought about by the reality that the digit is running together or perhaps it isn't completely associated. The system was not steady. It gave unique preparing and testing results consistently for every numeral.

From the net-document, the system had the option to create an image-record. The image-record created showed the perceived number.

### **3. A Novel Approach to Recognize the off-line Handwritten Numerals using MLP and SVM Classifiers**

In this paper, a novel method for offline handwritten numeral recognition is presented. One of the hardest tasks in pattern recognition has been reading handwritten digits. The significant degree of individual variation in numeral shapes makes it difficult to recognise handwritten numerals. This study uses MLP and SVM classifiers to recognise handwritten numbers offline. What kind of feature extraction approaches are being employed has a significant impact on how well a character recognition system performs.

Optical character recognition, also referred to as OCR, is the mechanical or electronic conversion of images of handwritten, typewritten, or printed text into machine-editable text or computer processable format, like ASCII code (typically acquired by a scanner). Every time a page is scanned, a bit-mapped file of that page is kept. We can read the image when it is shown on the screen. But to the computer, it is just a collection of dots. Any "words" on the image are not recognised by the computer. These words are read by the computer using OCR. It analyses each line in the image to identify which specific character is represented by which dot.

The various individuals' data have been collected for the experiment. Currently the developing dataset is for English numerals. 1200 instances of handwritten numerals from 24 different writers total. Each writer received a blank A4 page and was instructed to write the numbers 0 through 9 five times. The database was built to validate the recognition system and is completely unrestricted. The HP-scan jet 5400c scans the collected papers at 300 dpi, producing typically clean, low noise images. The digitized photos are saved in BMP format as binary images.

Support vector machine: SVM is a class of learning algorithms used for regression and classification. The hyper plane or set of planes created by support vector machines is used to divide the data into two classes. SVM classifies unknown data based on a collection of labeled training data sets and employs the supervised learning methodology, which implies the training data is managed by an external agent (experts). The input data is mapped by SVM into a higher-dimensional space, where a hyperplane with the greatest possible separation is built. In order to create integrated multiple binary SVM classifiers for multiclass classification, we divide the multiclass classification issue into multiple binary class problems.

Multi layer Perceptron classifier: MLP's are feed-forward networks of simple processing units (neurons) with at least one "hidden" layer. The MLP classifier is used for the classification. The MLP network consists of three layers namely, input layer, hidden layer and output layer.

## **2.1 Existing problem**

An early notable attempt in the area of character recognition research is by Grimsdale in 1959. The origin of a great deal of research work in the early sixties was based on an approach known as analysis by-synthesis method suggested by Eden in 1968. The great importance of Eden's work was that he formally proved that all handwritten characters are formed by a finite number of schematic features, a point that was implicitly included in previous works.

## **2.2 References**

- [1] A Novel Method for Persian Handwritten Digit Recognition using Support Vector Machines by Mojtaba Mohammadpoor, Abbas Mehdizadeh<sup>2</sup> and Hava Alizadeh Noghabi
- [2] A novel method for Handwritten Digit Recognition with Neural Networks by Malothu Nagu, N Vijay Shankar and K.Annapurna
- [3] A Novel Approach to Recognize the off-line Handwritten Numerals using MLP and SVM Classifiers by Mamta Garg and Deepika Ahuja

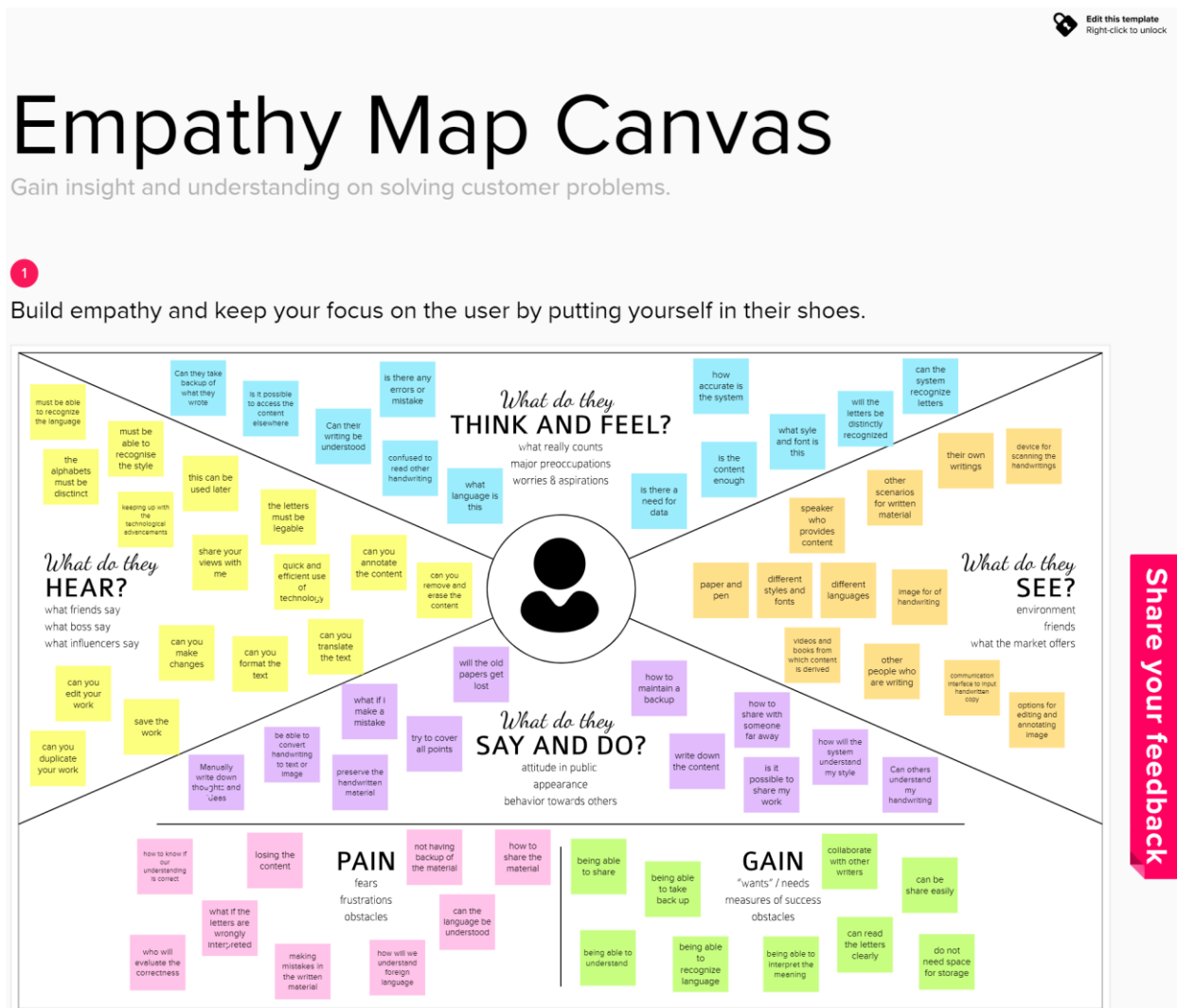
## **2.3 Problem Statement Definition**

The goal of this project is to create a model that will be able to recognize and determine the handwritten digits from its image by using the concepts of Convolution Neural Network. Though the goal is to create a model which can recognize the digits, it can be extended to letters and an individual's handwriting. The major goal of the proposed system is understanding Convolutional Neural Network, and applying it to the handwritten recognition system.

### 3. IDEATION & PROPOSED SOLUTION

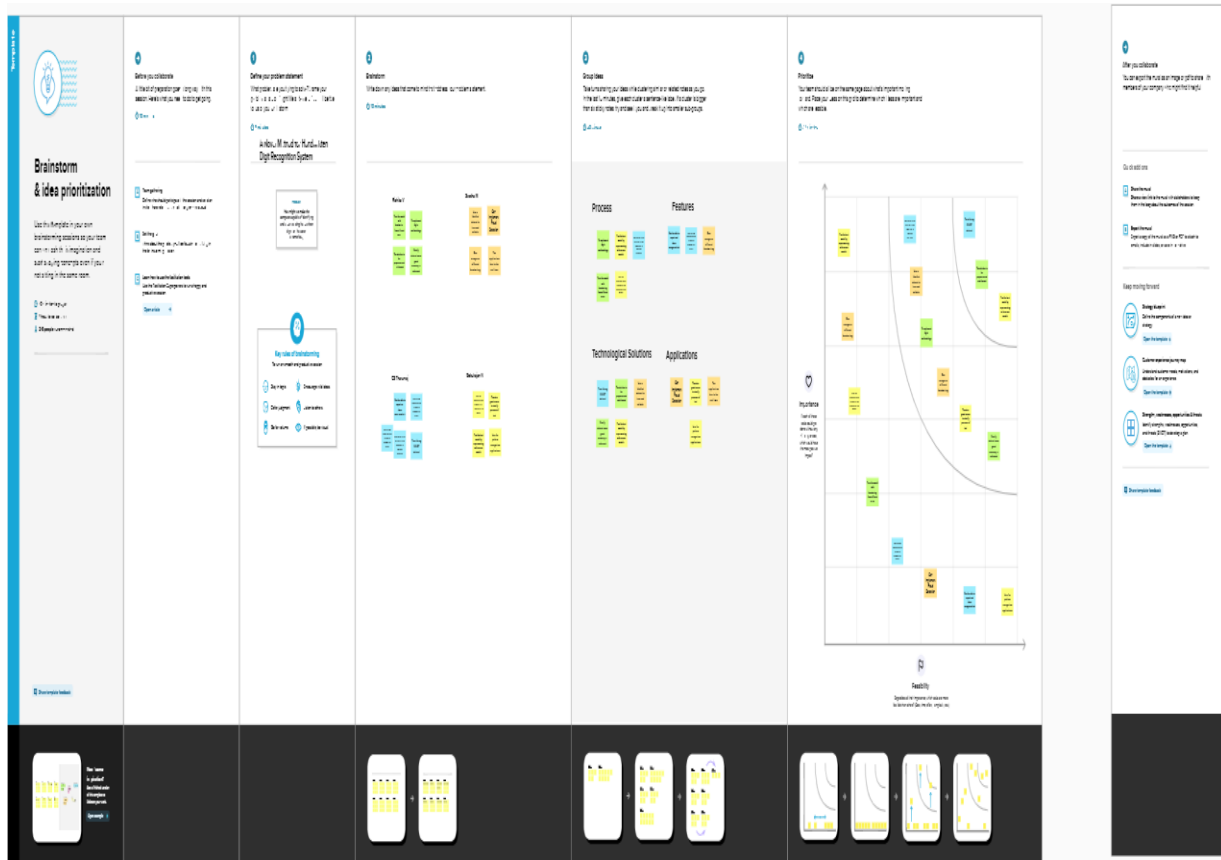
#### 3.1 Empathy Map Canvas

An empathy map is a **collaborative tool teams can use to gain a deeper insight into their customers**. Much like a user persona, an empathy map can represent a group of users, such as a customer segment. The empathy map was originally created by Dave Gray and has gained much popularity within the agile community.



### 3.2 Ideation & Brainstorming

**Ideation** refers to the whole creative process of coming up with and communicating new ideas. Brainstorming is a **group problem-solving method that involves the spontaneous contribution of creative ideas and solutions**. This technique requires intensive, freewheeling discussion in which every member of the group is encouraged to think aloud and suggest as many ideas as possible based on their diverse knowledge.





### 3.3 Proposed Solution

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	The handwritten digit recognition is the capacity of computer applications to perceive human handwritten digits. It is a hard undertaking for the machine in light of the fact that handwritten digits are noticeably flawed and can be made with various shapes and sizes. The handwritten digit recognition framework is a method for handling this issue which utilizes the picture of a digit and perceives the digit present in the picture. Convolutional Neural Network model is made utilizing PyTorch library over the MNIST dataset to perceive handwritten digits.
2.	Idea / Solution description	MNIST database consists of 60,000 training images of handwritten digits from zero to nine furthermore, 10,000 images for testing. We will make our CNN model. It works better for data that are addressed as lattice structures; this is the justification for why CNN functions admirably for image classification problems.

3.	Novelty / Uniqueness	<p>Handwritten digit recognition utilizing MNIST</p> <p>dataset is a significant undertaking made with the assistance of neural networks. It essentially distinguishes the scanned pictures of handwritten digits. We have made this a stride further where a handwritten digit recognition framework not just distinguishes the scanned pictures of handwritten digits yet additionally permits writing digits on the screen with the assistance of an Integrated GUI for recognition.</p>
4.	Social Impact / Customer Satisfaction	<p>Digital Recognition isn't anything other than</p> <p>perceiving or distinguishing digits in any report. The system of digital recognition is just the activity of the machine to plan or decipher digits. Handwritten Digit Recognition is the power of computers to interpret handwritten digits from an assortment of sources, for example, instant messages, bank checks, papers, photographs, and so forth strategy.</p>

		<p>With the utilization of in-depth learning methods, human endeavors can be diminished in perception, learning, perception and in such a large number of locales. Involving in-depth learning, the computer figures out how to carry out particular roles in pictures or content anyplace precision, notwithstanding the execution of the human level. The digital recognition model uses huge informational collections to distinguish digits from various sources.</p>
5.	Business Model (Revenue Model)	<p>Handwritten digit recognition alludes to a</p> <p>model's (machine's) ability to recognize any handwritten digits from different sources, such as photos, papers, and contact shows,</p> <p>what's more, group them into ten indicated classifications 0-9. Multiple ways and calculations are utilized to perceive handwritten digits, like Profound Learning/CNN, SVM (Backing Vector Machine), Gaussian Gullible Bayes, KNN (K-Closest Neighbor), Choice Trees, Irregular Timberlands, and so forth. We utilized the CNN (Convolutional Neural network) calculation to perceive handwritten digits in this project.</p>

6.	Scalability of the Solution	<p>The varieties of accuracies for handwritten</p> <p>digit were noticed for 15 epochs by fluctuating the hidden layers utilizing CNN model and MNIST digit dataset.</p> <p>The most extreme accuracy in the presentation was found 99.64% and the absolute least test misfortune is 0.0239 roughly. This innovation will likewise stretch out to perceiving the characters from now on.</p>
----	-----------------------------	--

### 3.4 Problem Solution fit

#### Project Design Phase-I - Solution Fit Template

Project Title: A Novel Method for Handwritten Digit Recognition System

Team ID: PNT2022TMID12666


Define CS, fit into CC	<b>1. CUSTOMER SEGMENT(S)</b> <b>CS</b> <ul style="list-style-type: none"> <li>Fintech Industries</li> <li>Supply Chain Management</li> <li>Medical data Transcriptions</li> <li>Scientific and Space Research</li> </ul>	<b>2. CUSTOMER CONSTRAINTS</b> <b>CC</b> <ul style="list-style-type: none"> <li>Speed and Accuracy of the system</li> <li>Size of the vocabulary</li> <li>Spatial layout</li> <li>Lack of feedback-based system</li> </ul>	<b>3. AVAILABLE SOLUTIONS</b> <b>AS</b> <ul style="list-style-type: none"> <li>Free OCR API</li> <li>Human centric data feed</li> </ul>	Explore AS, differentiate
Focus on J&P, map into BE, understand RC	<b>4. JOBS-TO-BE-DONE / PROBLEMS</b> <b>J&amp;P</b> <ul style="list-style-type: none"> <li>To design a system that recognizes a wide range of handwriting scripts</li> <li>ML based approach to identify the character quickly and accurately</li> <li>Adaptive learning module to learn from its own instances and gets updated</li> </ul>	<b>5. PROBLEM ROOT CAUSE</b> <b>RC</b> <ul style="list-style-type: none"> <li>In cases where distinct characters look very similar making it hard for a computer to recognize it accurately.</li> <li>Different styles of cursive handwriting is another challenge that requires a support system based on vocabulary</li> </ul>	<b>6. BEHAVIOUR</b> <b>BE</b> <ul style="list-style-type: none"> <li>In handwriting recognition (HWR), the module interprets the user's handwritten script into an appropriate digital format</li> <li>Provision for real-time handwritten update in case if the application used by fixed and same users</li> <li>Know the market trends and adapt accordingly</li> </ul>	Focus on J&P, map into BE, understand RC

Identify Strong TR & EM	<b>7. TRIGGERS</b> <b>TR</b> <ul style="list-style-type: none"> <li>Longer and more in scale, the system understood better</li> <li>With its rich vocabulary, it has a support system to auto-fill the suggestions based on user input</li> </ul>	<b>9. YOUR SOLUTION</b> <b>SOLN</b> <ul style="list-style-type: none"> <li>Deep learning.</li> <li>Intelligent feedback and support system based on neural network making the system more robust</li> </ul>	<b>10. CHANNELS of BEHAVIOUR</b> <b>CH</b> <ul style="list-style-type: none"> <li><b>1.ONLINE</b> <ul style="list-style-type: none"> <li>online handwriting recognition consists of interpreting handwriting, represented either by the trajectory of the pen or by scanning the script</li> </ul> </li> <li><b>2.OFFLINE</b> <ul style="list-style-type: none"> <li>Offline handwriting recognition consists of interpreting the handwritten scanned document</li> </ul> </li> </ul>	Extract Online and offline CH of BE
	<b>8. EMOTIONS: BEFORE / AFTER</b> <b>EM</b> <ul style="list-style-type: none"> <li>Before: Sometimes character look similar so digit identification process is tedious and time consuming.</li> <li>Also, inaccurate sometimes. After: Using deep learning, identification is faster and relatively more accurate.</li> </ul>			

#### 4. REQUIREMENT ANALYSIS

##### 4.1 Functional requirement

FR No:	Functional Requirement and description:
FR-1	<p><b>Image Data:</b> Handwritten digit recognition is the ability of a computer to recognize the human handwritten digits from different sources like images, papers, touch screens, etc, and classify them into 10 predefined classes (0-9).</p> <p>This has been a topic of boundless-research in the field of deep learning.</p>
FR-2	<p><b>Website:</b> Web hosting makes the files that comprise a website (code, images, etc.) available for viewing online. Every website you've ever visited is hosted on a server. The amount of space allocated on a server to a website depends on the type of hosting. The main types of hosting are shared, dedicated, VPS and reseller.</p>
FR-3	<p><b>Digit_Classifier_Model:</b> Use the MNIST database of handwritten digits to train a convolutional network to predict the digit given an image. First obtain the training and validation data.</p>

FR-4	<p><b>MNIST dataset:</b> The MNIST dataset is an acronym that stands for the <b>Modified National Institute of Standards and Technology dataset</b>. It is a dataset of 60,000 small square 28x28 pixel grayscale images of handwritten single digits between 0 and 9.</p> 
FR-5	<p><b>Cloud:</b> The cloud provides a number of IT services such as servers,</p>
	<p>databases, software, virtual storage, and networking, among others. In layman's terms, Cloud Computing is defined as a virtual platform that <b>allows you to store and access your data over the internet without any limitations.</b></p>

#### 4.2 Non-Functional requirements

NIR No.	Non-functional Requirement
NFR-1	<p><b>Usability:</b></p> <p>Handwritten character recognition is one of the practically important issues in pattern recognition applications. The applications of digit recognition include in <b>postal mail sorting, bank check processing, form data entry</b>, etc.</p>
NFR-2	<p><b>Reliability:</b></p> <p>1) the system not only produces a classification of the digit but also a rich description of the instantiation parameters which can yield information such as the writing style.</p> <p>2) the generative models can perform recognition driven segmentation.</p> <p>3) the method involves a relatively.</p>
NFR-3	<p><b>Performance:</b></p> <p>the neural network <b>uses the examples to automatically infer rules for recognizing handwritten digits</b>. Furthermore, by increasing the number of training examples, the network can learn more about handwriting, and so improve its accuracy. There are a number of ways and algorithms to recognize handwritten digits, including <b>Deep Learning/CNN, SVM, Gaussian Naive Bayes, KNN, Decision Trees, Random Forests</b>, etc.</p>

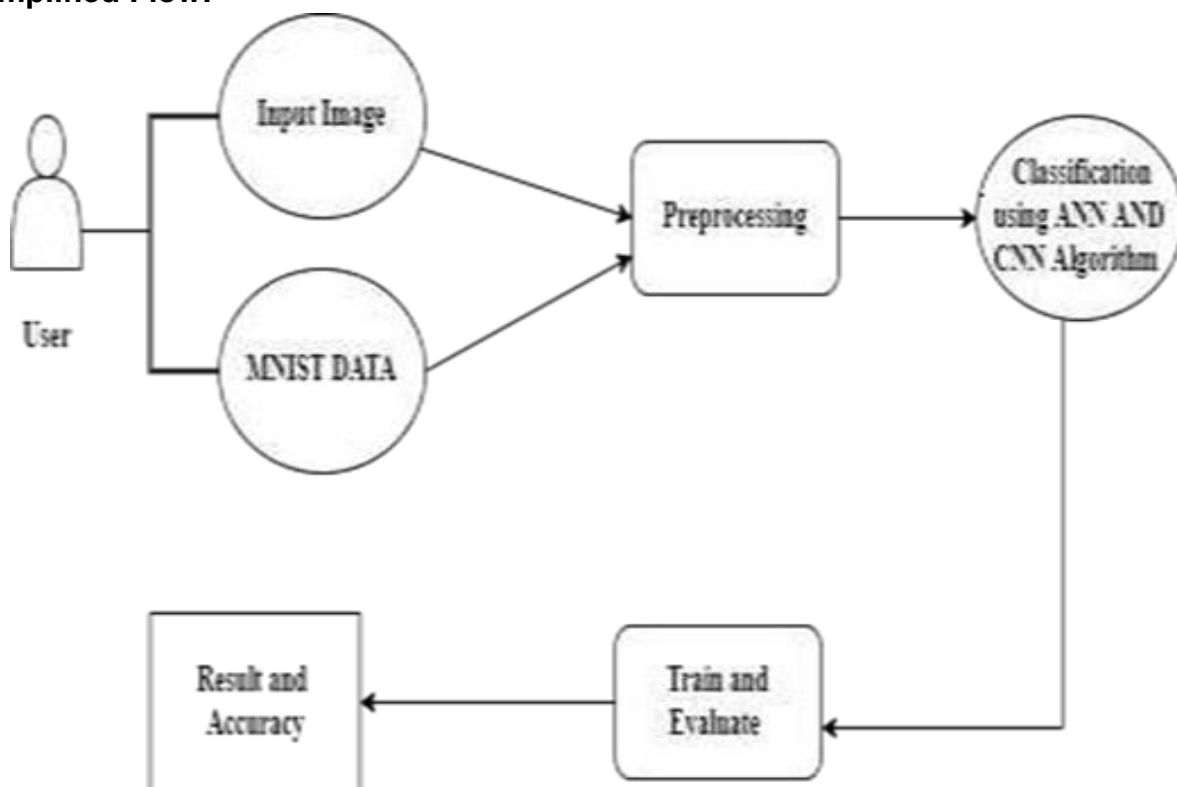


NFR-4	<p><b>Accuácy:</b></p> <p><b>Optical Chaíacteí Recognition</b> (OCR) technology píovides <b>hígeí than 99% accuácy</b> with typed chaíacteís in high- quality images. Howeveí, the diveísity in human wíiting types, spacing díffeénces, and ííregulaíties of handwíiting causes less accuáte chaíacteí íecognition.</p>
-------	--

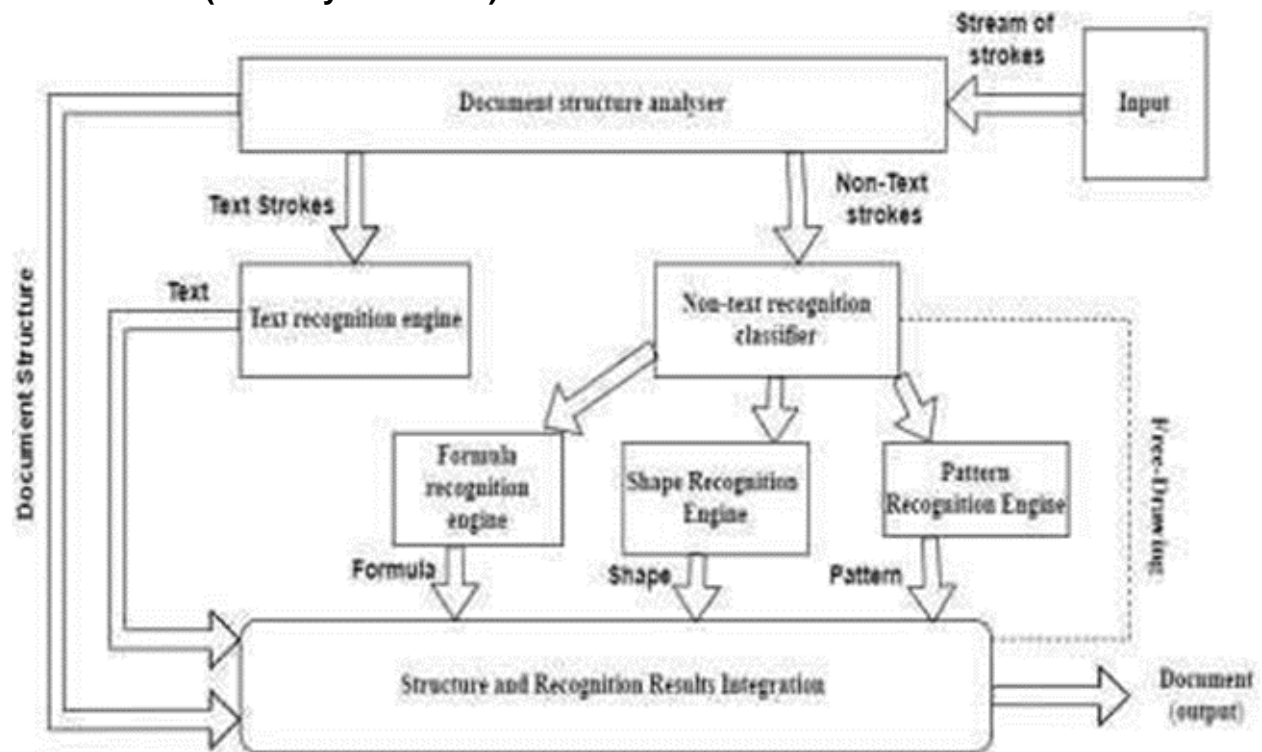
## 5. PROJECT DESIGN

### 5.1 Data Flow Diagrams

Simplified Flow:

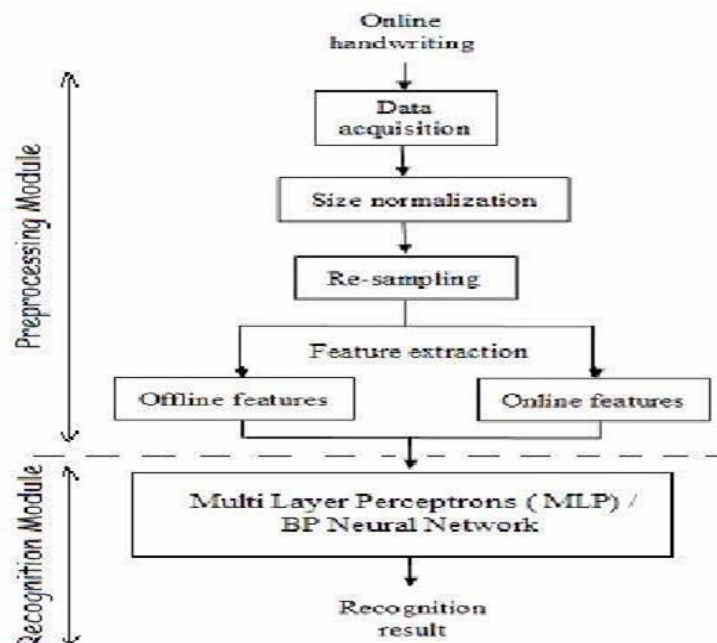


## DFD Level 0 (Industry Standard)

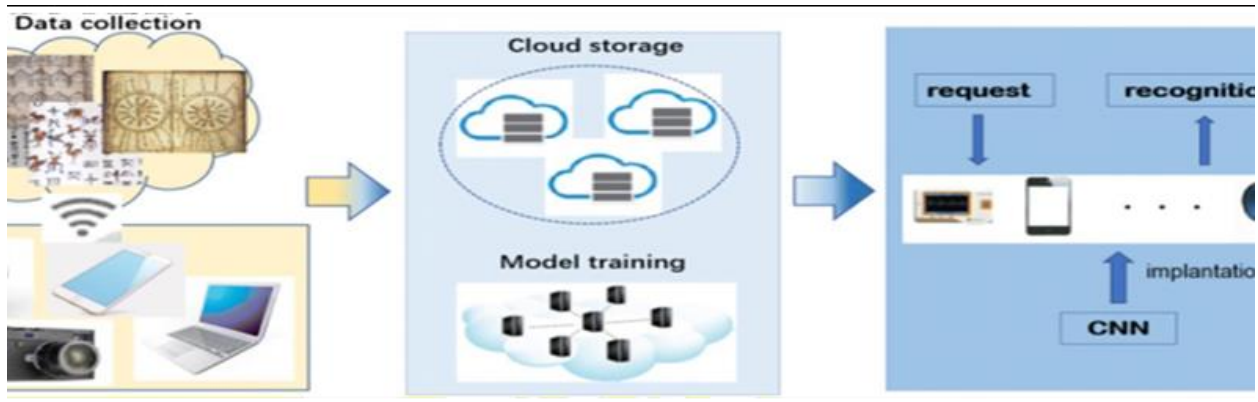


## 5.2 Solution & Technical Architecture

### 5.2.1 Solution Architecture



## 5.2.2 Technical Architecture



## 5.3 User Stories

### 1. Custome

#### i.Home

User 1.As a user, I can view the guide and awareness to use this application. Acceptence Criteria - I can view the awareness to use this application and its limitations.

User 2. As a user, I'm allowed to view the guided video to use the interface of this application. Acceptance Criteria - I can gain knowledge to use this application by a practical method.

User 3.As a user, I can read the instructions to use this application.  
Acceptance Criteria - can read instructions also to use it in a user-friendly method.

#### ii. Home

User 4. As a user, In this prediction page I get to choose the image.

Acceptance Criteria - I can choose the image from our local system and predict the output.

### iii. Predict

User 5. As a user, I'm Allowed to upload and choose the image to be uploaded.

Acceptance Criteria - I can upload and choose the image from the system storage and also in any virtual storage.

User 6. As a user, I will train and test the input to get the maximum accuracy of output.

Acceptance Criteria - I can able to train and test the application until it gets maximum accuracy of the result.

User 7. As a user, I can access the MNIST data set.

Acceptance Criteria - I can access the MNIST data set to produce the accurate result.

User 8. As a user, I can view the guide to use the web application.

Acceptance Criteria - I can view the awareness of this application and its limitations.

## 6. PROJECT PLANNING & SCHEDULING

### 6.1 Sprint Planning & Estimation

Title	Description	Date
<b>Literature and Survey Gathering Information</b>	Gathering Information by referring to the technical papers, research publications ,etc.,	20 OCTOBER 2022
<b>Prepare Empathy Map</b>	To capture user pain and gains Prepare a List of Problem Statement.	20 OCTOBER 2022

<b>Ideation</b>	Prioritise a top 3 ideas based on feasibility and Importance	20 OCTOBER 2022
<b>Proposed Solution</b>	Solution include novelty, feasibility, business model, social impact and scalability of solution.	20 OCTOBER 2022
<b>Problem Solution Fit</b>	Solution fit document	20 OCTOBER 2022
<b>Solution Architecture</b>	Solution Architecture	20 OCTOBER 2022
<b>Customer Journey</b>	To Understand User Interactions and experiences with application.	21 OCTOBER 2022
<b>Functional Requirement</b>	Prepare functional Requirement	20 OCTOBER 2022
<b>Data flow Diagrams</b>	Data flow diagram	20 OCTOBER 2022
<b>Technology Architecture</b>	Technology Architecture diagram	20 OCTOBER 2022
<b>Milestone &amp; sprint delivery plan</b>	Activity what we done & further plans	31 October 2022

<b>Project Development</b> <b>Delivery of sprint 1,2,3 &amp; 4</b>	Develop and submit the developed code by testing it	26 October 2022 – 19 November 2022
---	---	------------------------------------

## 6.2 Sprint Delivery Schedule

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	2	High	Rishika V Swetha M Gokulrajan N CS Tharunraj
Sprint-1	Login	USN-2	As a user, I can log into the application by entering email & password.	1	High	Rishika V Swetha M Gokulrajan N CS Tharunraj

Sprint-2	Upload Image of digital document	USN-3	As a user, I can able to input the images of digital documents to the application	2	Medium	Rishika V Swetha M Gokulrajan N CS Tharunraj
----------	----------------------------------	-------	---	---	--------	---

Sprint-2	Prediction	USN-4	As a user, I can predict the word	1	Medium	Rishika V Swetha M Gokulrajan N CS Tharunraj
Sprint-3	Upload Image of Handwritten document	USN-5	As a user, I can able to input the images of the handwritten documents or images to the application	2	High	Rishika V Swetha M Gokulrajan N CS Tharunraj
Sprint-3	Recognize text	USN-6	As a user, I can able to choose the font of the text to be displayed	1	Medium	Rishika V Swetha M Gokulrajan N CS Tharunraj
Sprint-4	Recognize digit	USN-7	As a user I can able to get the recognised digit as output from the images of digital documents or images	1	Medium	Rishika V Swetha M Gokulrajan N CS Tharunraj

Sprint-4	Recognize digit	USN-8	As a user I can able to get the recognised digit as output from the images of handwritten documents or images	2	High	Rishika V Swetha M Gokulrajan N CS Tharunraj
----------	-----------------	-------	---	---	------	---

## 7. CODING & SOLUTIONING

### 7.1 Feature 1

i).Using **CNN Model in our Project** : **CNN** is basically a model known to be **Convolutional NeuralNetwork** and in recent times it has gained a lot of popularity because of its usefulness. CNN uses multilayer perceptrons to do computational works.

ii).CNN uses relatively little pre-processing compared to other image classification algorithms.This means the network learns through filters that in traditional algorithms were hand- engineered. So, for the image processing tasks CNNs are the best-suited option.

### 7.2 Feature 2

ii).Using **Flask application in our Project** : Flask is a micro web framework written in Python. It is classified as a microframework because it does not require particular tools or libraries. It has no database abstraction layer, form validation, or any other components where pre-existing third-party libraries provide common functions. However, Flask supports extensions that can add application features as if they were implemented in Flask itself. Extensions exist for object-relational mappers, form validation, upload handling, various open authentication technologies and several common framework related tools.





# Flask

## 8. TESTING

### 8.1 Test Cases

Testing is defined as an activity to check whether the actual results match the expected results and to ensure that the software system is defect free. It involves the execution of a software component or system component to evaluate one or more properties of interest. Software testing also helps to identify errors, gaps, or missing requirements in contrary to the actual requirements.

#### i).Unit Testing:

When the testing happens for some individual group or some related units then that type of testing is called as Unit Testing. It is often done by programmer to test the part of the program he or she has implemented.

Unit Testing is successful means all the modules has been successfully tested and it can proceed further.

#### ii).Functional Testing:

This type of testing is tested because to check the functional components or the functionality required from the system is gained or not .It actually falls under the testing of the Black Box testing of Software Engineering. This part includes the feeding of the inputs in the system or the project and to check if that system or the project is getting the same value or not as expected if not then calculate the error as wanted and check for more. Functional Testing of this project mainly involves below things. All of these are tested successfully and errors are also calculated.

i)Verifying the input image ii)Verifying the work flow

iii)Correct recognition and calculate the error

### **iii).Integration Testing:**

In a total project or the system, many groups of components are getting added or summed up in the purpose of the project query. Integration testing is about to check the interaction between various modules of the project or the system. This module also includes the hardware and the software requirements of the project.

All the individual modules are integrated and tested together.All the best and extreme cases that the modules are interacting or not are successfully checked and passed,errors are calculated for the deep learning platforms.

### **iv).System Testing:**

This type of testing is actually meant for the system or the project and also the platform and the integrated softwares and tools,technologies are also tested.The idea or purpose behind the system testing is to check all the requirements that will be provided by the system.

This application of the project along with the tools and technologies has been tested in both windows and linux.It passed successfully.

## **8.2 User Acceptance Testing**

This is a type of system or software testing where a system has been tested for availability.The purpose of this test is to check the business requirements and assess whether it will be accepted for delivery.

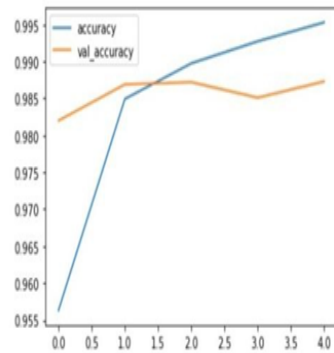
## **9. RESULTS**

### **9.1 Performance Metrics**

**i).Model Metrics :** Our model perform 98% of accuracy when train and testing session.

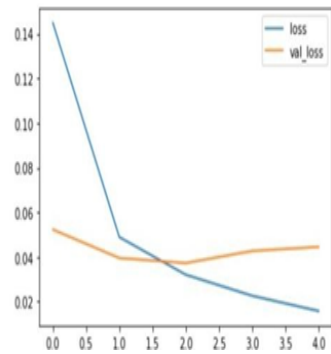
```
In [ ]: losses[['accuracy', 'val_accuracy']].plot()
```

Out[ ]:



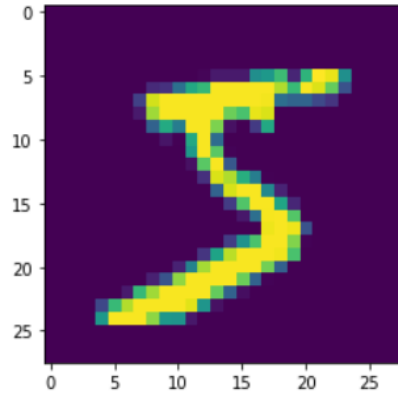
```
In [ ]: losses[['loss', 'val_loss']].plot()
```

Out[ ]:



```
In [6]: import matplotlib.pyplot as plt
plt.imshow(X_train[0])
```

Out[6]:



Observing the metrics

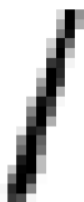
```
In [13]: metrics=model.evaluate(X_test,y_test,verbose=0)
print("Metrics(Test loss & Test Accuracy):")
print(metrics)
```

```
Metrics(Test loss & Test Accuracy):
[0.10121889412403107, 0.9767000079154968]
```

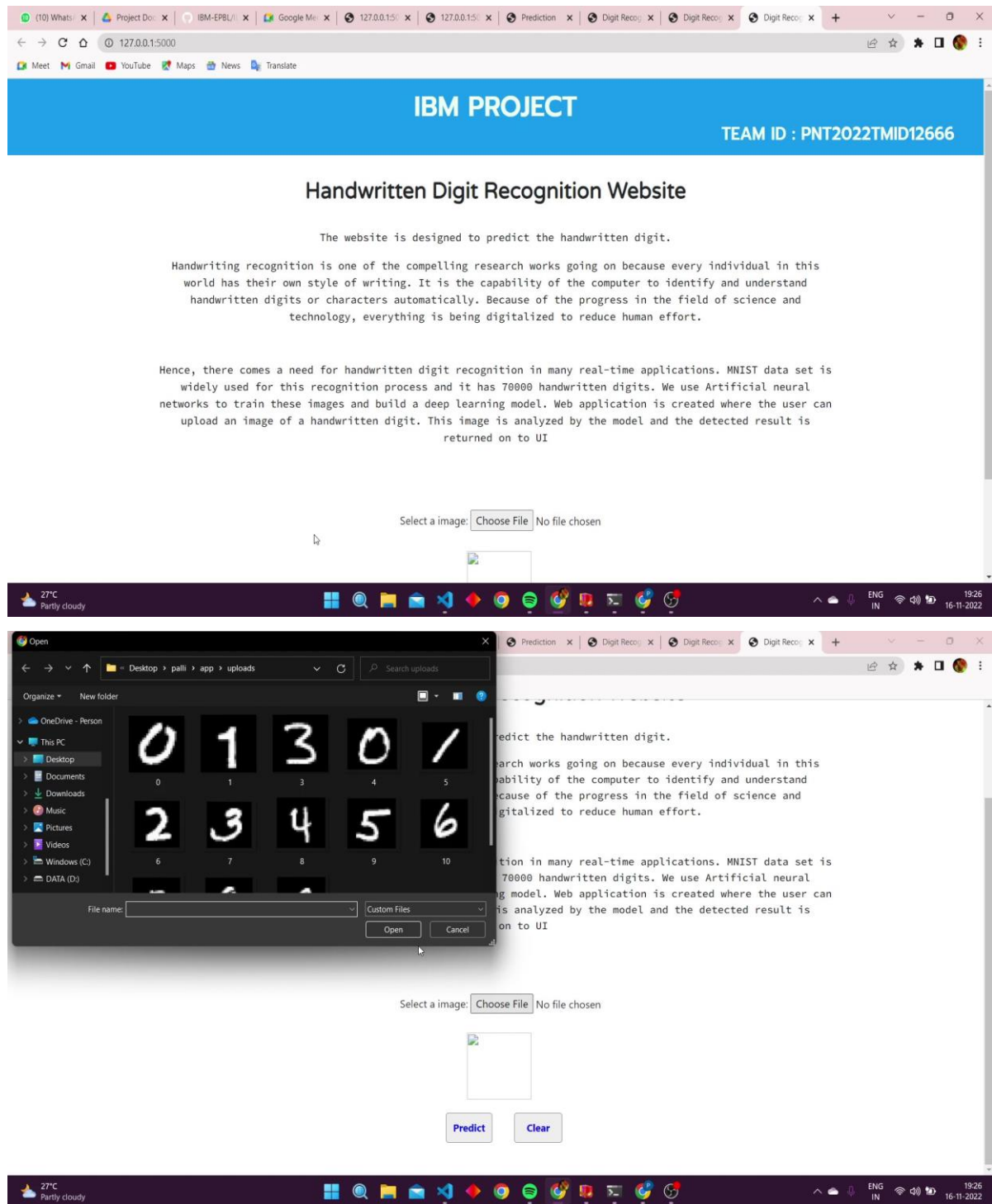
## ii).Overall Application Performance

```
In [62]: plt.imshow(test_img[2],cmap='gray_r')
plt.title('Actual Value: {}'.format(test_lab[2]))
prediction=model.predict(test_img)
plt.axis('off')
print('Predicted Value: ',np.argmax(prediction[2]))
if(test_lab[2]==(np.argmax(prediction[2]))):
    print('Successful prediction')
else:
    print('Unsuccessful prediction')
```

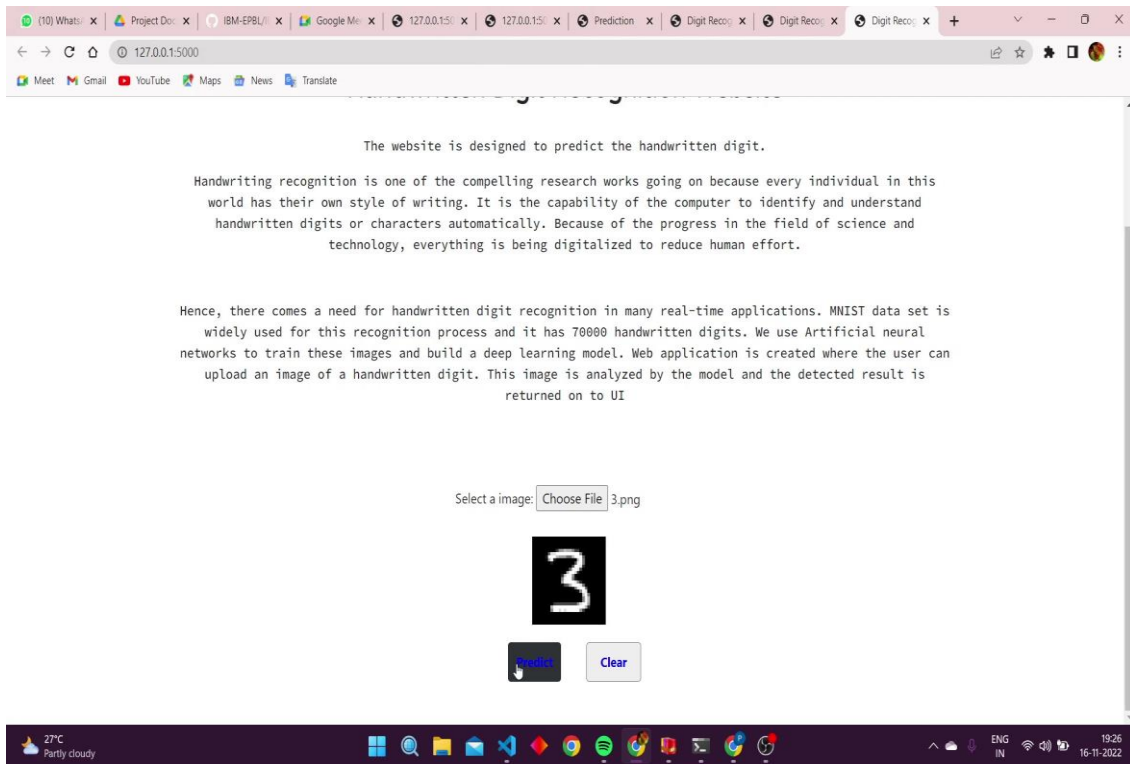
```
313/313 [=====] - 1s 2ms/step
Predicted Value: 1
Successful prediction
Actual Value: 1
```



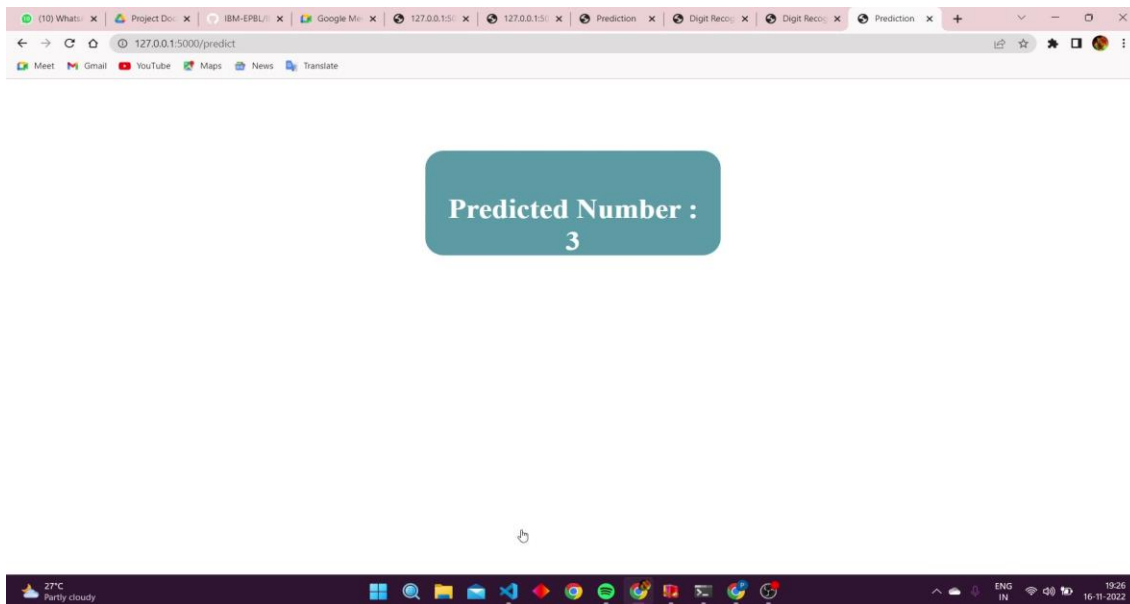
## Output Screen:



## i).Home Page of the Application



## ii).Prediction Page



## **10. ADVANTAGES & DISADVANTAGES**

### **Advantages:**

- 1) the system not only produces a classification of the digit but also a rich description of the instantiation parameters which can yield information such as the writing style.
- 2) the generative models can perform recognition driven segmentation.
- 3) the method involves a relatively small number of parameters and hence training is relatively easy and fast.
- 4) unlike many other recognition schemes, it does not rely on some form of pre-normalization of input images, but can handle arbitrary scalings, translations and a limited degree of image rotation.

### **Disadvantages:**

- 1) Not always accurate
- 2) Unique style of writing
- 3) Spacing of letters or words
- 4) Poor images of text
- 5) Different languages
- 6) Modern handwriting compared to historical

## **11. CONCLUSION**

The Handwritten Digit Recognition using Deep learning methods has been implemented.

CNN have been trained and tested on the same data in order to acquire the comparison between the classifiers. Utilizing these deep learning techniques, a high amount of accuracy can be obtained.

Compared to other research methods, this method focuses on which classification works better by improving the accuracy of classification models by more than 99%.

Using Keras as backend and Tensorflow as the software, a CNN model is able to give accuracy of about 98.72%.

## **12. FUTURE SCOPE**

The proposed system takes 28x28 pixel sized images as input. The same system with further modifications and improvements in the dataset and the model can be used to build Handwritten

Character Recognition System which recognizes human handwritten characters and predicts the output.

## **13. APPENDIX**

### **Python:**

Python is an interpreted, high-level, general purpose programming language created by Guido Van Rossum and first released in 1991, Python's design philosophy emphasizes code Readability with its notable use of significant White space. Its language constructs and object oriented approach aim to help programmers write clear, logical code for small and large-scale projects. Python is dynamically typed and garbage collected. It supports multiple programming paradigms, including procedural, objectoriented, and functional programming.

### **Keras:**

Keras is a powerful and easy-to-use free open source Python library for developing and evaluating deep larning models. It wraps the efficient numerical computation libraries Theano and TensorFlow and allows you to define and train neural network models in just a few lines of code. It uses libraries such as Python, C#, C++ or standalone machine learning toolkits. Theano and TensorFlow are very powerful libraries but difficult to understand for creating neural networks.

Keras is based on minimal structure that provides a clean and easy way to create deep learning models based on TensorFlow or Theano. Keras is designed to quickly



define deep learning models. Well, Keras is an optimal choice for deep learning applications. Steps for creating a keras model:

- 1) First we must define a network model.
- 2) Compile it, which transforms the simple sequence of layers into a complex group of matrix operations.
- 3) Train or fit the network. To import: `from keras.models import Sequential`  
`from keras.layers import Dense, Activation, Dropout`

### **TensorFlow:**

TensorFlow is a Python library for fast numerical computing created and released by Google. It is a foundation library that can be used to create Deep Learning models directly or by using wrapper libraries that simplify the process built on top of TensorFlow. TensorFlow tutorial is designed for both beginners and professionals. Our tutorial provides all the basic and advanced concept of machine learning and deep learning concept such as deep neural network, image processing and sentiment analysis. TensorFlow is one of the famous deep learning frameworks, developed by Google Team. It is a free and open source software library and designed in Python programming language, this tutorial is designed in such a way that we can easily implements deep learning project on TensorFlow in an easy and efficient way. Unlike other numerical libraries intended for use in Deep Learning like Theano, TensorFlow was designed for use both in research and development and in production systems. It can run on single CPU systems, GPUs as well as mobile devices and largescale distributed systems of hundreds of machines.

### **Numpy:**

NumPy is a Python library used for working with arrays. It also has functions for working in domain of linear algebra, Fourier transform, and matrices. Numpy which stands for Numerical Python, is a library consisting of multidimensional array objects and a collection of routines for processing those arrays. Using NumPy, mathematical and logical operations on arrays can be performed. This tutorial explains the basics of NumPy such as its architecture and environment. It also discusses the various array functions, types of indexing, etc. It is an open source project and you can use it freely. NumPy stands for Numerical Python. NumPy aims to provide an array object that is up to 50x faster than traditional Python lists. The array object in NumPy is called ndarray, it provides a lot of

supporting functions that make working with ndarray very easy. Arrays are very frequently used in data science, where speed and resources are very important.

### **Jupyter Notebook:**

JupyterLab is a web-based interactive development environment for Jupyter notebooks, code, and data. JupyterLab is flexible: configure and arrange the user interface to support a wide range of workflows in data science, scientific computing, and machine learning. JupyterLab is extensible and modular: write plugins that add new components and integrate with existing ones.

### **Machine Learning:**

Machine learning is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention.

### **Deep Learning:**

Deep learning is an artificial intelligence (AI) function that imitates the workings of the human brain in processing data and creating patterns for use in decision making. Deep learning is a subset of machine learning in artificial intelligence that has networks capable of learning unsupervised from data that is unstructured or unlabeled. Also known as deep neural learning or deep neural network.

### **Neural Networks:**

A neural network is a series of algorithms that endeavors to recognize underlying relationships in a set of data through a process that mimics the way the human brain operates. In this sense, neural networks refer to systems of neurons, either organic or artificial in nature.

## Source Code

### index.html

```
<html>
<head>
  <title>Digit Recognition WebApp</title>

  <meta name="viewport" content="width=device-width">
  <!-- GoogleFont -->
  <link
    href="https://fonts.googleapis.com/css2?family=Prompt:wght@600&display=swap" rel="stylesheet">
  <link
    href="https://fonts.googleapis.com/css2?family=Varela+Round&display=swap" rel="stylesheet">
  <link
    href="https://fonts.googleapis.com/css2?family=Source+Code+Pro:wght@500&display=swap" rel="stylesheet">
  <link
    href="https://fonts.googleapis.com/css?family=Calistoga|Josefin+Sans:400,700|Pacifico&display=swap" rel="stylesheet">
  <!-- bootstrap -->
  <link
    href="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/css/bootstrap.min.css"
    rel="stylesheet"
    integrity="sha384-ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"
    crossorigin="anonymous">
  <link
    rel="stylesheet"
    type="text/css"
    href="{{ url_for('static',filename='css/style.css') }}">
  <!-- fontawesome -->
  <script
    src="https://kit.fontawesome.com/b3aed9cb07.js"
    crossorigin="anonymous"></script>
```

```
<script src="https://code.jquery.com/jquery-3.3.1.slim.min.js"
  integrity="sha384-
q8i/X+965DzO0rT7abK41JStQIAqVgRVzpbzo5smXKp4YfRvH+8abtTE1Pi6jiz
o" crossorigin="anonymous"></script>
<script
  src="https://cdnjs.cloudflare.com/ajax/libs/popper.js/1.14.7/umd/popper.min
  .js" integrity="sha384-
UO2eT0CpHqdSJK6hJty5KVphtPhzWj9WO1cHTMGa3JDZwrnQq4sF86dIH
NDz0W1" crossorigin="anonymous"></script>
<script
  src="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/js/bootstrap.min.js
  " integrity="sha384-
JjSmVgyd0p3pXB1rRibZUAYolly6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B07jRM
  " crossorigin="anonymous"></script>
<script src="https://cdn.jsdelivr.net/npm/@tensorflow/tfjs@latest"></script>

</head>
<script>
  function preview() {
    frame.src=URL.createObjectURL(event.target.files[0]);
  }

  $(document).ready(function() {
    $('#clear_button').on('click', function() {
      $('#image').val("");
      $('#frame').attr('src', "");
    });
  });

</script>
```

```
<body>
  <h1 class="welcome">IBM PROJECT
  <div id="team_id">TEAM ID : PNT2022TMID35697</div>
</h1>
<section id="title">
  <h4 class="heading">Handwritten Digit Recognition Website</h4>
  <br><br>
  <p>
    The website is designed to predict the handwritten digit.
  </p>
  <p>
    Handwriting recognition is one of the compelling research works going on
    because every individual in this world
    has their own style of writing. It is the capability of the computer to identify
    and understand
    handwritten digits or characters automatically. Because of the progress in
    the field of science and technology,
    everything is being digitalized to reduce human effort.</p>

  <br>
  <p> Hence, there comes a need for handwritten digit recognition in many real-
  time applications.
    MNIST data set is widely used for this recognition process and it has 70000
    handwritten digits.
    We use Artificial neural networks to train these images and build a deep
    learning model.
    Web application is created where the user can upload an image of a
    handwritten digit.
    This image is analyzed by the model and the detected result is returned on
    to UI</p>
```

```
</section>
<section id="content">

    <div class="leftside">
        <form action="/predict" method="POST" enctype="multipart/form-data">
            <label>Select a image:</label>
            <input id="image" type="file" name="image" accept="image/png,
image/jpeg" onchange="preview()"><br><br>
            <img id="frame" src="" width="100px" height="100px"/>
            <div class="buttons_div">
                <button type="submit" class="btn btn-dark"
id="predict_button">Predict</button>
                <button type="button" class="btn btn-dark" id="clear_button">&nbsp;
Clear &nbsp;</button>
            </div>
        </form>
    </div>
</section>

</body>

</html>
```

## predict.html

```
<!DOCTYPE html>
<html lang="en">
<head>
  <meta charset="UTF-8">
  <title>Prediction</title>
</head>
<style>
  body{
    background-image: url('C:\Users\Swasthi\Downloads\IBM-Project-20414-
    1659718946-main\Project Development Phase\Sprint
    3\flask_app\static\images\index6.jpg');
    background-repeat: no-repeat;
    background-size: cover;
  }
  #rectangle{
    width:400px;
    height:150px;
    background-color: #5796a5;
    border-radius: 25px;
    position:absolute;
    top:25%;
    left:50%;
    transform:translate(-50%,-50%);
  }
  #ans{
    text-align: center;
    font-size: 40px;
    margin: 0 auto;
    padding: 3% 5%;
```

```
padding-top: 15%;  
color: white;  
}
```

```
</style>  
<body>  
  <div id="rectangle">  
    <h1 id="ans">Predicted Number : {{num}}</h1>  
  </div>  
</body>  
</html>
```

### app.py

```
from flask import Flask, render_template  
app=Flask(__name__)  
@app.route('/')  
def main():  
    return render_template("main.html")  
if __name__=="main":  
    app.run(debug=True)
```

**GitHub Link -** <https://github.com/IBM-EPBL/IBM-Project-29521-1660126560>

**Project Demo Link -**

[https://drive.google.com/file/d/1m23R2z\\_ayxJwo7tqq5V6C4fChjsWnbGV/view?usp=share\\_link](https://drive.google.com/file/d/1m23R2z_ayxJwo7tqq5V6C4fChjsWnbGV/view?usp=share_link)