PROJECT REPORT

A NOVEL METHORD FOR HAND WRITTEN DIGIT RECOGONITION SYSTEM

TEAM ID - PNT2022TMID47347

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INTRODUCTION

1.1 Project Overview

Machine learning and deep learning play an important role in computer technology and artificial intelligence. With the use of deep learning and machine learning, human effort can be reduced in recognizing, learning, predictions and in many more areas.

Handwritten Digit Recognition is the ability of computer systems to recognize handwritten digits from various sources, such as images, documents, and so on. This project aims to let users take advantage of machine learning to reduce manual tasks in recognizing digits.

1.2 Purpose

Digit recognition systems are capable of recognizing the digits from different sources like emails, bank quench, papers, images, etc. and in different real-world scenarios for online handwriting recognition on computer tablets or system, recognize number plates of vehicles, processing bank quench amounts, numeric entries in forms filled up by hand (tax forms) and so on.

LITERATURE SURVEY

2.1 Existing problem

The fundamental problem with handwritten digit recognition is that handwritten digits do not always have the same size, width, orientation, and margins since they vary from person to person. Additionally, there would be issues with identifying the numbers because of similarities between numerals like 1 and 7, 5 and 6, 3 and 8, 2 and 5, 2 and 7, etc. Finally, the individuality and variation of each individual's handwriting influence the structure and appearance of the digits.

2.2 References

S. NO	TITLE	AUTHOR	YEAR	ABOUT
1	A Novel Handwritten Digit Classification System Based on Convolution al Neural Network Approach	Ali Abdullah Yahya , Jieqing Tan and Min Hu	2019	The handwritten digit recognition problem is a topic of heated debate in recent years. Despite that there are enormous convolution al neural network algorithms proposed for handwritten digit recognition, issues such as recognition accuracy and computation time still require further improvement.
2	Handwritten Character Recognition from Images using CNN-ECOC	Mayur Bhargab Bora, Dinthisrang Daimary, Khwairakpam Amitab, Debdatta Kandar	2020	The OCR is a process of classifying the optical patterns present in a digital image to the corresponding characters.he OCR is a process of classifying the optical patterns present in a digital image to the corresponding characters.The character recognition is achieved through important steps of feature extraction and classification. The

				OCR system simulates the human capability to recognize.
3	Handwritten Digit Recognition using Machine and Deep Learning Algorithms	Ritik Dixit, Rishika Kushwah, Samay Pashine	2021	Digit recognition has many applications like number plate recognition, postal mail sorting, bank check processing, etc. In Handwritten digit recognition, we face many challenges because of different styles of writing of different peoples as it is not an Optical character recognition. This research provides a comprehensive comparison between different machine learning and deep learning algorithms for the purpose of handwritten digit recognition.
4	Deep Convolution Self-Organizing Map Network for Robust Handwritten Digit Recognition	Saleh Ally, Sultan Almotairi	2020	Deep Convolution Self-Organizing Map Network for Robust Handwritten Digit Recognition

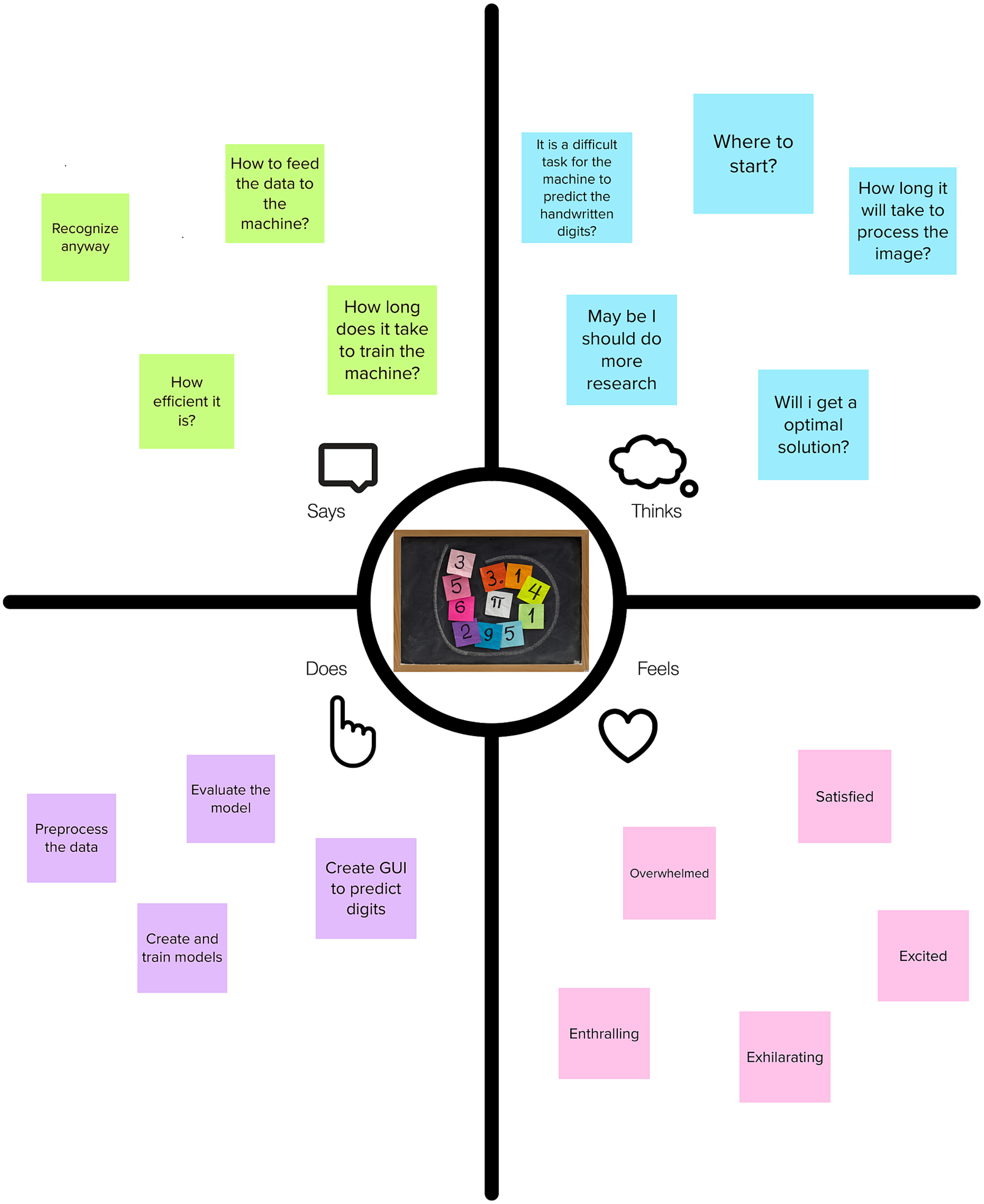
2.3 Problem Statement Definition

The problem is recognizing the human handwritten digits by system. The goal is to upload the image of the handwritten digit and identify the digit with accuracy. Digits' are a part of our everyday life, be it License plates on our cars or bikes, the price of a product, speed limit on a road, or details associated with a bank account. The recognition of digits is important because humans can't remember all these numbers ,so there is a need for a system to recognize them.

Handwritten digit recognition is the ability of computers to recognize human handwritten digits. It is a hard task for the machine because handwritten digits are not perfect and can be made with many different flavors. The main objective is to compare the accuracy of the models stated above along with their execution time to get the best possible model for digit recognitio

IDEATION & PROPOSED SOLUTION

3.1 Empathy Map Canvas



Says

How to feed the data to the machine?

Recognize anyway

How long does it take to train the machine?

How efficient it is?

Thinks

It is a difficult task for the machine to predict the handwritten digits?

Where to start?

How long it will take to process the image?

May be I should do more research

Will i get a optimal solution?

Does

Evaluate the model

Preprocess the data

Create GUI to predict digits

Create and train models

Feels

Satisfied

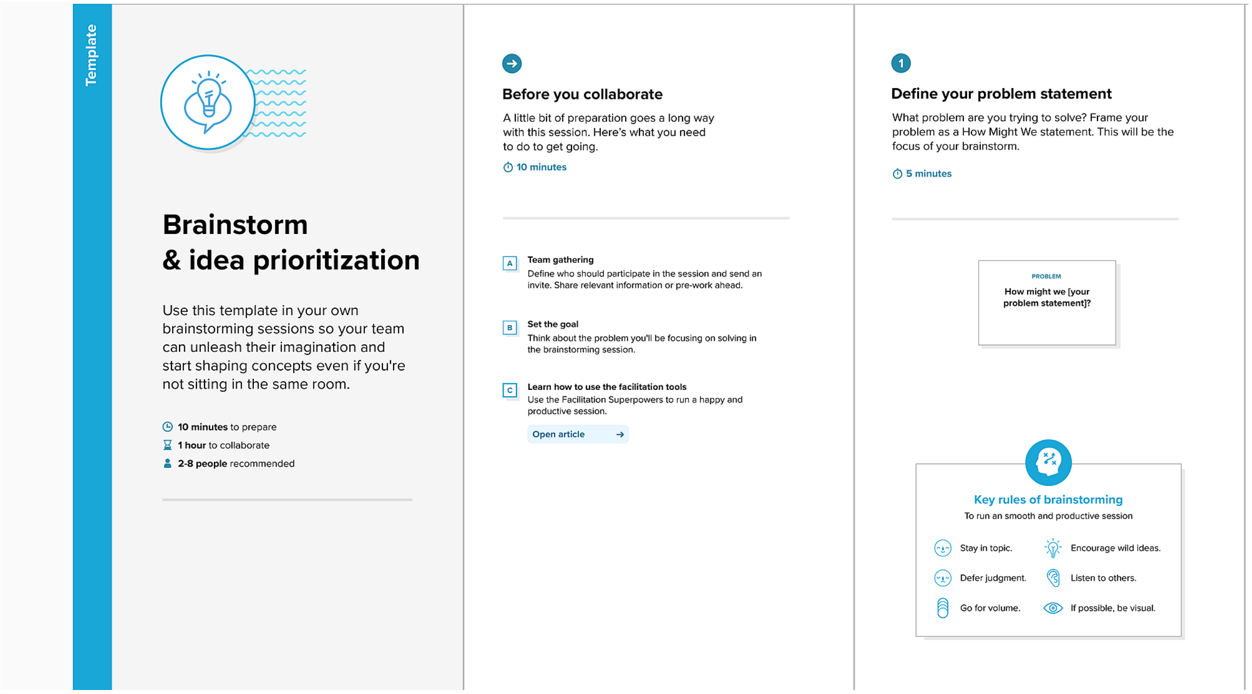
Overwhelmed

Excited

Enthralling

Exhilarating

3.2 Ideation & Brainstorming



Template

Brainstorm
& idea prioritization

Use this template in your own brainstorming sessions so your team can unleash their imagination and start shaping concepts even if you're not sitting in the same room.

10 minutes to prepare

1 hour to collaborate

2-8 people recommended

Before you collaborate

A little bit of preparation goes a long way with this session. Here's what you need to do to get going.

10 minutes

A **Team gathering**
Define who should participate in the session and send an invite. Share relevant information or pre-work ahead.

B **Set the goal**
Think about the problem you'll be focusing on solving in the brainstorming session.

C **Learn how to use the facilitation tools**
Use the Facilitation Superpowers to run a happy and productive session.

Open article →

1

Define your problem statement

What problem are you trying to solve? Frame your problem as a How Might We statement. This will be the focus of your brainstorm.

5 minutes

PROBLEM

How might we [your problem statement]?

Key rules of brainstorming

To run an smooth and productive session

Stay in topic.

Encourage wild ideas.

Defer judgment.

Listen to others.

Go for volume.

If possible, be visual.

3

Group ideas

The common idea among the individual idea

COMMON IDEA

Create the own data set.

Save the input image for Future Reference

After the recognition store the input image and use that for data set

DATA SET

Use the input for create a new dataset

Add the input to the already existing data set

Train the Model with new Dataset

STORAGE

Use the Cloud as storage medium for dataset

Use SQLite for store the input

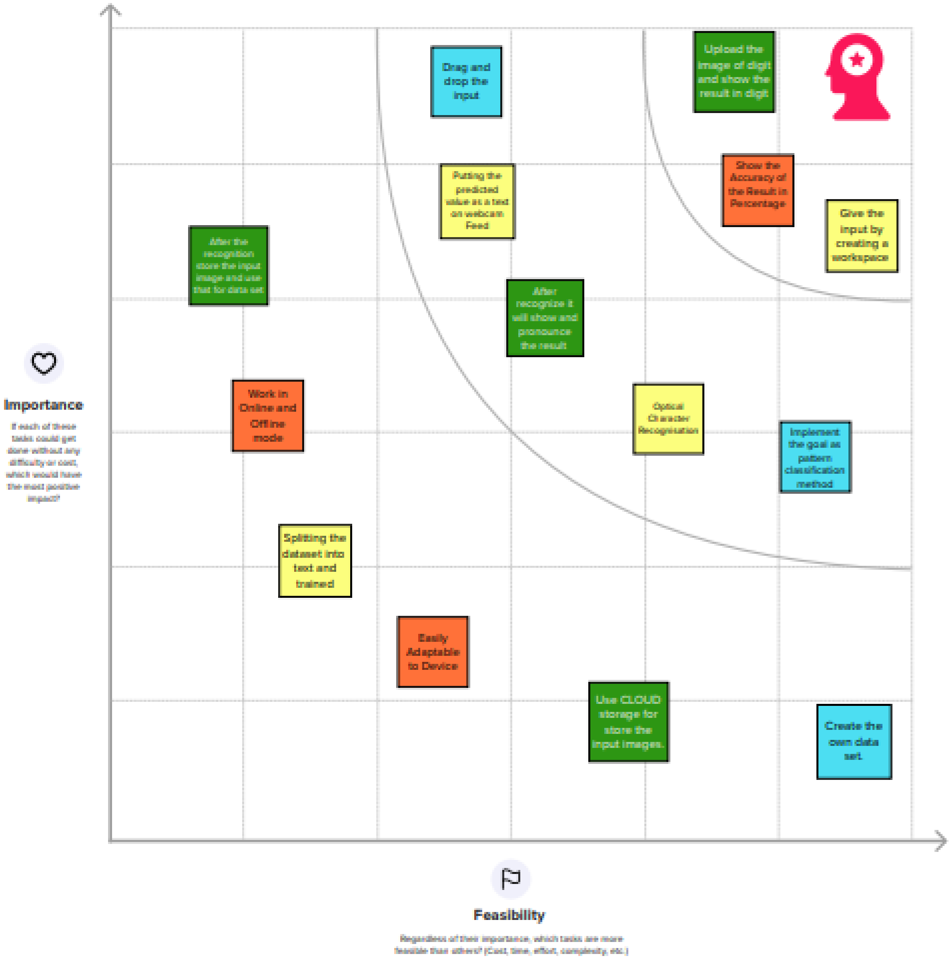
LANGUAGE

Use PYTHON for access the data set.

4

Prioritize

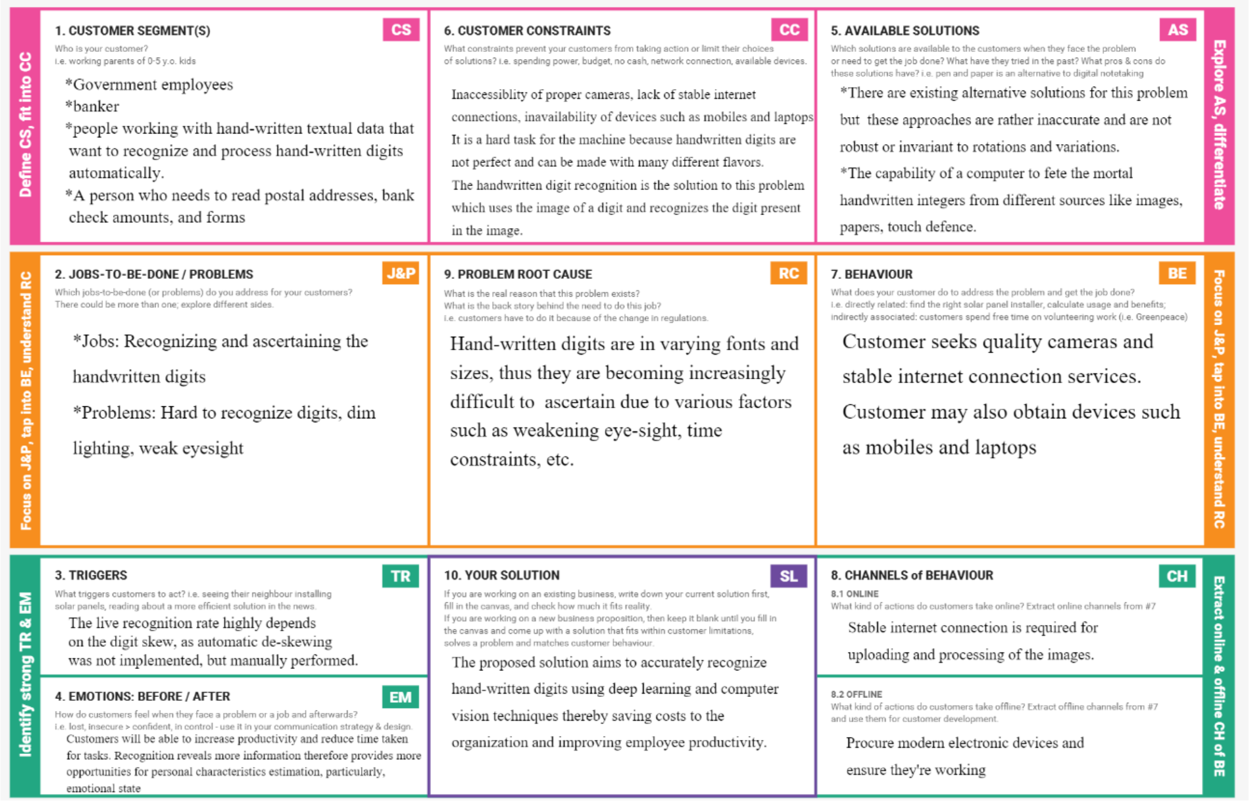
The classification of the idea is based on the important and feasibility.


Drag and drop the input
Upload the image of digit and show the result in digit
Putting the predicted value as a text on webcam Feed
Show the Accuracy of the Result in Percentage
Give the input by creating a workspace
After the recognition store the input image and use that for data set
After recognize it will show and pronounce the result
Importance
If each of these tasks could get done without any difficulty or cost, which would have the most positive impact?
Work in Online and Offline mode
Optical Character Recognisation
Implement the goal as pattern classification method
Splitting the dataset into text and trained
Easily Adaptable to Device
Use CLOUD storage for store the input images.
Create the own data set.
Feasibility
Regardless of their importance, which tasks are more feasible than others? (Cost, time, effort, complexity, etc.)

3.3 Proposed Solution

S.NO	PARAMETER	DESCRIPTION
1	Problem Statement	The problem is recognizing the human handwritten digits by system. The goal is to upload the image of the handwritten digit and identify the digit with accuracy
2	Idea/Solution Description	The training and testing has been conducted from publicly available MNIST handwritten databases. Web based, offline and online handwritten digit recognition system is developed by using Convolutional Neural Network.
3	Novelty/Uniqueness	OCR technology provides higher than 99% accuracy with typed characters in high-quality images. However, the diversity in human writing, spacing differences, and irregularities of handwriting causes less accurate character recognition, as you can see in the featured image.
4	Social Impact/Customer Satisfaction	Handwritten Digit Recognition has various uses such as less time consumption. It is used in the detection of vehicle numbers, banks for reading cheques, post offices for arranging letters, and other tasks.
5	Business Model	The main objective of this work is to ensure effective and reliable approaches for recognition of handwritten digits and make banking operations easier and error free.
6	Scalability of Solution	Recently handwritten digit recognition becomes vital scope and it is appealing many researchers because of its using in variety of machine learning and computer vision applications

3.4 Problem Solution fit



Define CS, fit into CC

1. CUSTOMER SEGMENT(S) CS

Who is your customer?
i.e. working parents of 0-5 y.o. kids

*Government employees
*banker
*people working with hand-written textual data that want to recognize and process hand-written digits automatically.
*A person who needs to read postal addresses, bank check amounts, and forms

6. CUSTOMER CONSTRAINTS CC

What constraints prevent your customers from taking action or limit their choices of solutions? i.e. spending power, budget, no cash, network connection, available devices.

Inaccessiblity of proper cameras, lack of stable internet connections, inavailability of devices such as mobiles and laptops
It is a hard task for the machine because handwritten digits are not perfect and can be made with many different flavors.
The handwritten digit recognition is the solution to this problem which uses the image of a digit and recognizes the digit present in the image.

5. AVAILABLE SOLUTIONS AS

Which solutions are available to the customers when they face the problem or need to get the job done? What have they tried in the past? What pros & cons do these solutions have? i.e. pen and paper is an alternative to digital notetaking

*There are existing alternative solutions for this problem but these approaches are rather inaccurate and are not robust or invariant to rotations and variations.
*The capability of a computer to fete the mortal handwritten integers from different sources like images, papers, touch defence.

Explore AS, differentiate

Focus on J&P, tap into BE, understand RC

2. JOBS-TO-BE-DONE / PROBLEMS J&P

Which jobs-to-be-done (or problems) do you address for your customers? There could be more than one; explore different sides.

*Jobs: Recognizing and ascertaining the handwritten digits
*Problems: Hard to recognize digits, dim lighting, weak eyesight

9. PROBLEM ROOT CAUSE RC

What is the real reason that this problem exists?
What is the back story behind the need to do this job?
i.e. customers have to do it because of the change in regulations.

Hand-written digits are in varying fonts and sizes, thus they are becoming increasingly difficult to ascertain due to various factors such as weakening eye-sight, time constraints, etc.

7. BEHAVIOUR BE

What does your customer do to address the problem and get the job done?
i.e. directly related: find the right solar panel installer, calculate usage and benefits; indirectly associated: customers spend free time on volunteering work (i.e. Greenpeace)

Customer seeks quality cameras and stable internet connection services.
Customer may also obtain devices such as mobiles and laptops

Focus on J&P, tap into BE, understand RC

Identify strong TR & EM

3. TRIGGERS TR

What triggers customers to act? i.e. seeing their neighbour installing solar panels, reading about a more efficient solution in the news.

The live recognition rate highly depends on the digit skew, as automatic de-skewing was not implemented, but manually performed.

4. EMOTIONS: BEFORE / AFTER EM

How do customers feel when they face a problem or a job and afterwards?
i.e. lost, insecure > confident, in control - use it in your communication strategy & design.

Customers will be able to increase productivity and reduce time taken for tasks. Recognition reveals more information therefore provides more opportunities for personal characteristics estimation, particularly, emotional state

10. YOUR SOLUTION SL

If you are working on an existing business, write down your current solution first, fill in the canvas, and check how much it fits reality.
If you are working on a new business proposition, then keep it blank until you fill in the canvas and come up with a solution that fits within customer limitations, solves a problem and matches customer behaviour.

The proposed solution aims to accurately recognize hand-written digits using deep learning and computer vision techniques thereby saving costs to the organization and improving employee productivity.

8. CHANNELS of BEHAVIOUR CH

8.1 ONLINE
What kind of actions do customers take online? Extract online channels from #7

Stable internet connection is required for uploading and processing of the images.

8.2 OFFLINE
What kind of actions do customers take offline? Extract offline channels from #7 and use them for customer development.

Procure modern electronic devices and ensure they're working

Extract online & offline CH of BE

REQUIREMENT ANALYSIS

4.1 Functional requirement

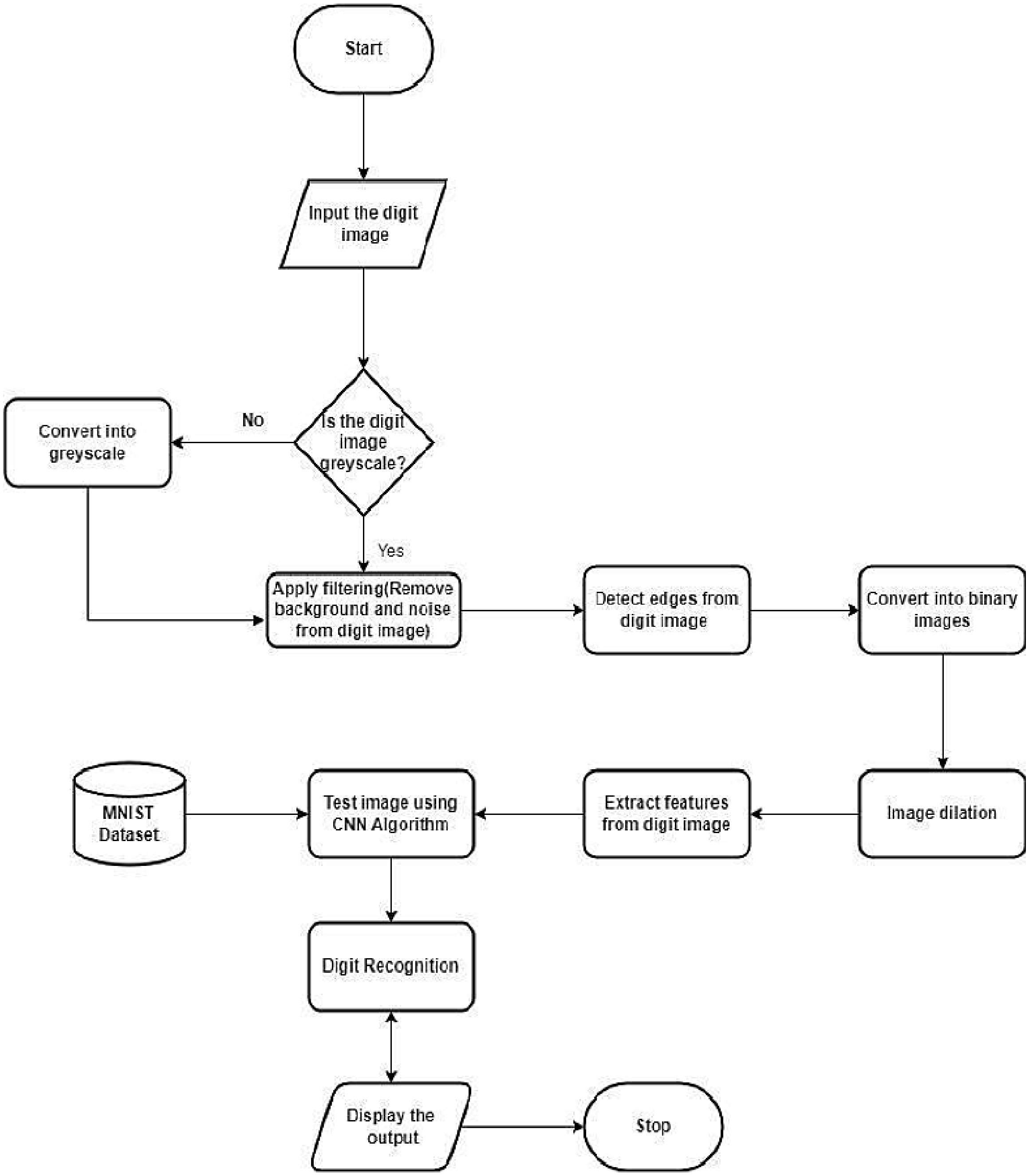
FR NO	FUNCTIONAL REQUIREMENT AND DESCRIPTION
FR-1	Image Data: Handwritten digit recognition is the ability of a computer to recognize the human handwritten digits from different sources like images, papers, touch screens, etc, and classify them into 10 predefined classes (0-9). This has been a topic of boundless-research in the field of deep learning.
FR-2	Website: 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.
FR-3	Digit_Classifier_Model: 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.
FR-4	MNIST dataset: The MNIST dataset is an acronym that stands for the Modified National Institute of Standards and Technology dataset
FR-5	databases, software, virtual storage, and networking, among others. In layman's terms, Cloud Computing is defined as a virtual platform that allows you to store and access your data over the internet without any limitations.

4.2 Non-Functional requirements

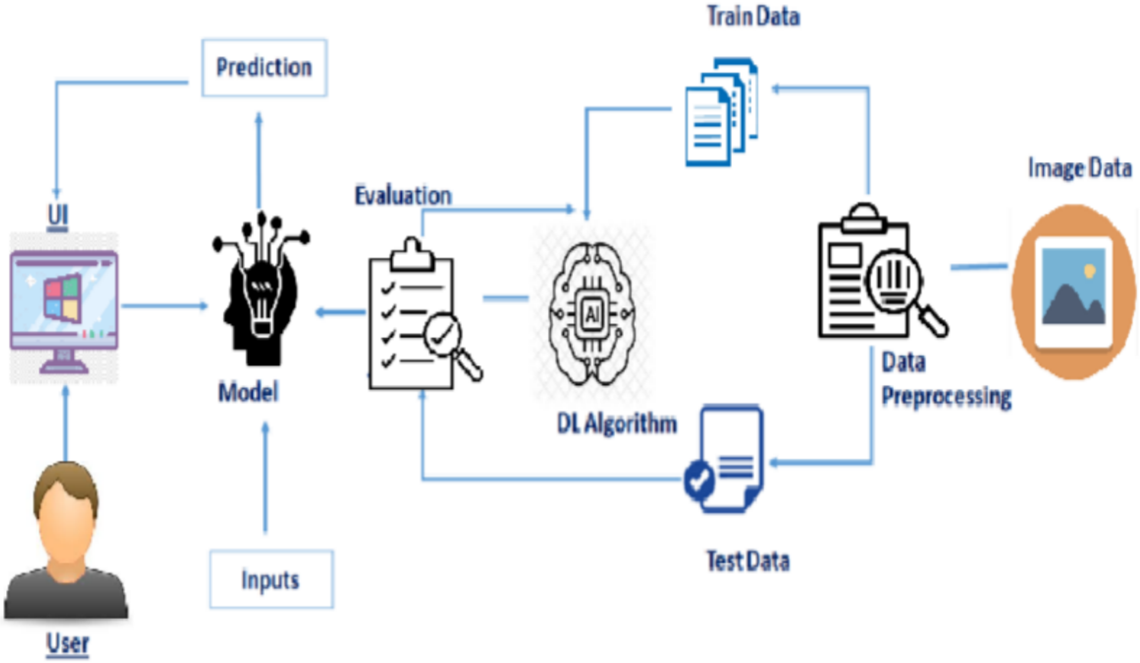
NFR NO	NON-FUNCTIONAL REQUIREMENT
NFR-1	Usability: Handwritten character recognition is one of the practically important issues in pattern recognition applications. The applications of digit recognition include postal mail sorting, bank check processing, form data entry, etc.
NFR-2	Reliability: 1) The 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 relative.
NFR-3	Performance: The neural network uses the examples to automatically infer rules for recognizing handwritten digits. 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 Deep Learning/CNN, SVM, Gaussian Naive Bayes, KNN, Decision Trees, Random Forests, etc.
NFR-4	Accuracy: Optical Character Recognition (OCR) technology provides higher than 99% accuracy with typed characters in high quality images. However, the diversity in human writing types, spacing differences, and irregularities of handwriting causes less accurate character recognition.

PROJECT DESIGN

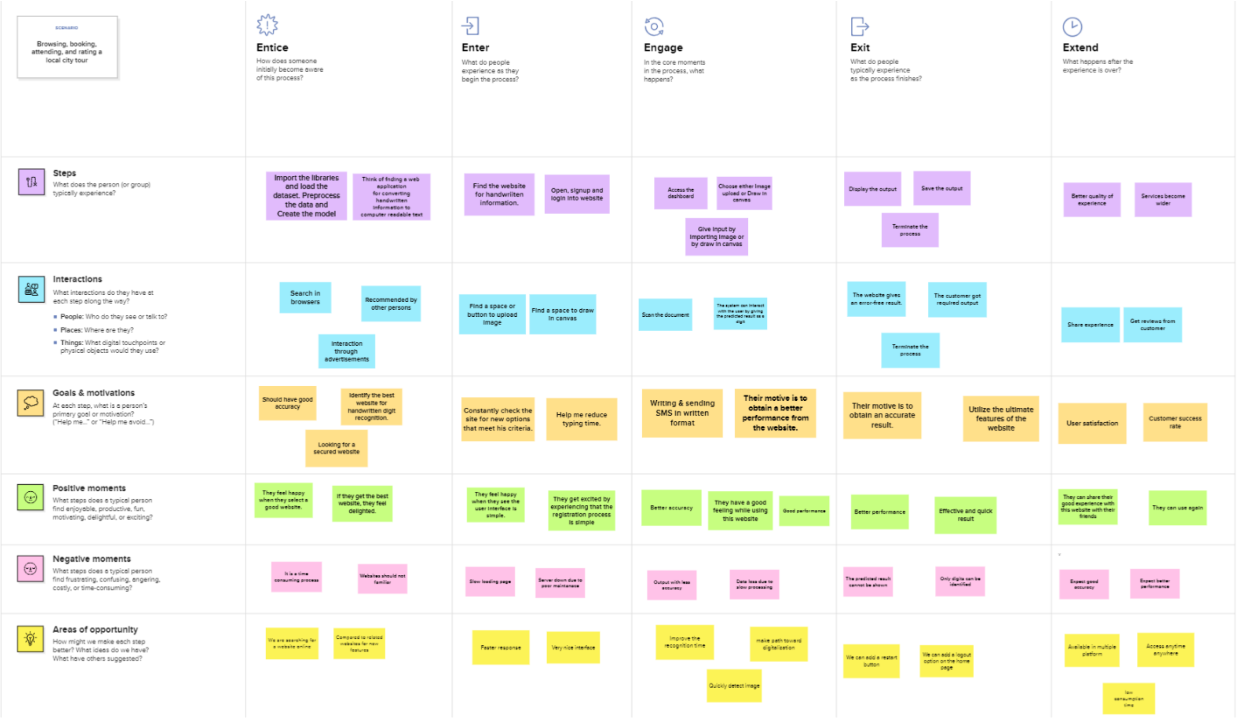
5.1 Data Flow Diagrams


Start
Input the digit image
Is the digit image greyscale?
No
Convert into greyscale
Yes
Apply filtering(Remove background and noise from digit image)
Detect edges from digit image
Convert into binary images
Image dilation
Extract features from digit image
Test image using CNN Algorithm
MNIST Dataset
Digit Recognition
Display the output
Stop

5.2 Solution & Technical Architecture



5.3 User Stories



SCENARIO Browsing, booking, attending, and rating a local city tour	**Entice** How does someone initially become aware of this process?	**Enter** What do people experience as they begin the process?	**Engage** In the core moments in the process, what happens?	**Exit** What do people typically experience as the process finishes?	**Extend** What happens after the experience is over?
Steps What does the person (or group) typically experience?	Import the libraries and load the dataset. Preprocess the data and Create the model Think of finding a web application for converting handwritten information to computer readable text	Find the website for handwriiten information. Open, signup and login into website	Access the dashboard Choose either Image upload or Draw in canvas Give input by importing image or by draw in canvas	Display the output Save the output Terminate the process	Better quality of experience Services become wider
Interactions What interactions do they have at each step along the way? ▪ People: Who do they see or talk to? ▪ Places: Where are they? ▪ Things: What digital touchpoints or physical objects would they use?	Search in browsers Recommended by other persons Interaction through advertisements	Find a space or button to upload image Find a space to draw in canvas	Scan the document The system can interact with the user by giving the predicted result as a digit	The website gives an error-free result. The customer got required output Terminate the process	Share experience Get reviews from customer
Goals & motivations At each step, what is a person's primary goal or motivation? ("Help me..." or "Help me avoid...")	Should have good accuracy Identify the best website for handwritten digit recognition. Looking for a secured website	Constantly check the site for new options that meet his criteria. Help me reduce typing time.	Writing & sending SMS in written format Their motive is to obtain a better performance from the website.	Their motive is to obtain an accurate result. Utilize the ultimate features of the website	User satisfaction Customer success rate
Positive moments What steps does a typical person find enjoyable, productive, fun, motivating, delightful, or exciting?	They feel happy when they select a good website. If they get the best website, they feel delighted.	They feel happy when they see the user interface is simple. They get excited by experiencing that the registration process is simple	Better accuracy They have a good feeling while using this website Good performance	Better performance Effective and quick result	They can share their good experience with this website with their friends They can use again
Negative moments What steps does a typical person find frustrating, confusing, angering, costly, or time-consuming?	It is a time consuming process Websites should not familiar	Slow loading page Server down due to poor maintenance	Output with less accuracy Data loss due to slow processing	The predicted result cannot be shown Only digits can be identified	Expect good accuracy Expect better performance
Areas of opportunity How might we make each step better? What ideas do we have? What have others suggested?	We are searching for a website online Compared to related websites for new features	Faster response Very nice interface	Improve the recognition time make path toward digitalization Quickly detect image	We can add a restart button We can add a logout option on the home page	Available in multiple platform Access anytime anywhere low consumption time

6. PROJECT PLANNING & SCHEDULING

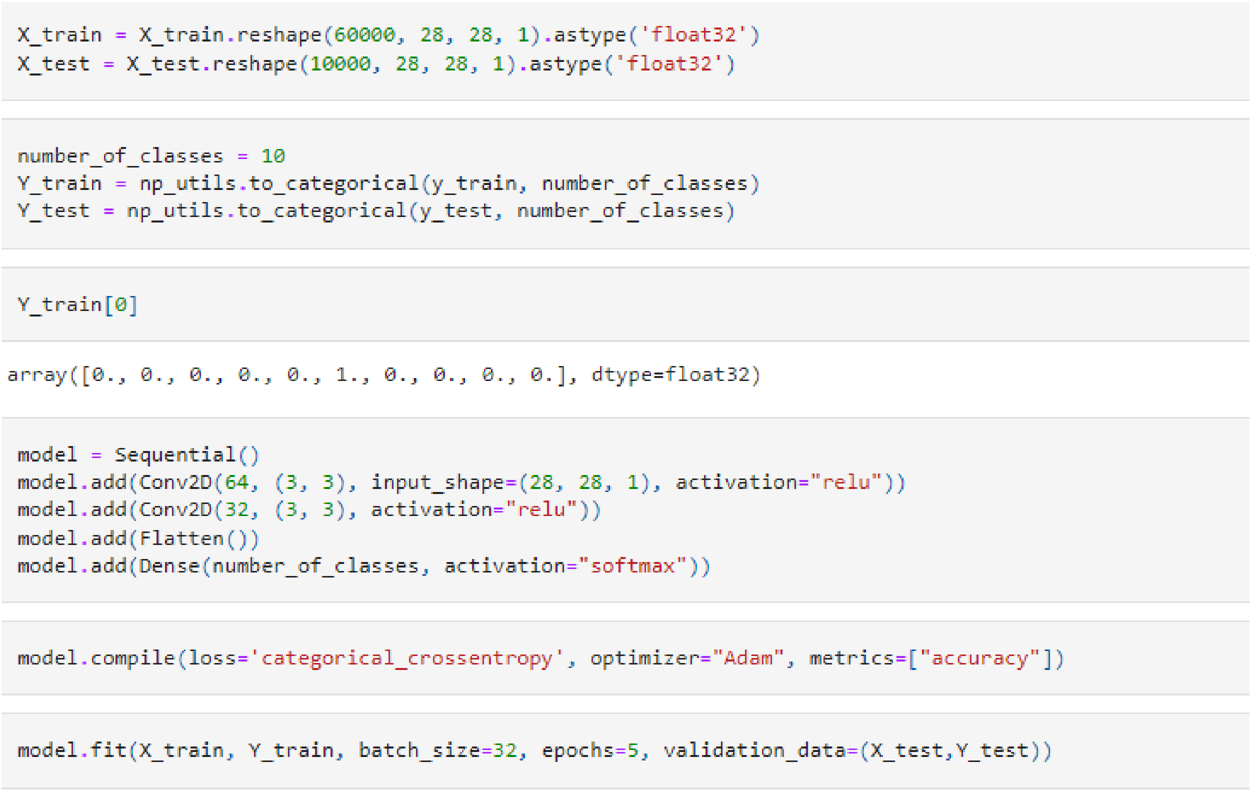
6.1 Sprint Planning & Estimation

Sprint	Functional Requirement	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Data Collection	USN-1	Import the required libraries and Collect Dataset .	**2**	High	Kowshalya S, Khavya priya S
Sprint-1		USN-2	Reshape the data and apply one hot encoding	**1**	Medium	Savithri R, Kavya M
Sprint-2	Model Building	USN-3	Add the necessary layers and compile the model	**2**	High	KIavya M, Khavya priya S
Sprint-2		USN-4	Training the image classification model using CNN	**1**	Medium	Savithri R, Gayathri T
Sprint-3	Training and Testing	USN-5	Building Python code and run the application	**2**	High	Kowshalya S, Kavya M, Savithri R, Gayathri T, Khavya priya S
Sprint-4	Implementation of the application and deployment on cloud	USN-5	Training the model on IBM cloud.	**2**	High	Kowshalya S, Kavya M, Savithri R, Gayathri T, Khavya priya S

6.2 Sprint Delivery Schedule

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	20	6 Days	24 Oct 2022	29 Oct 2022	20	29 Oct 2022
Sprint-2	20	6 Days	31 Oct 2022	05 Nov 2022	20	05 Nov 2022
Sprint-3	20	6 Days	07 Nov 2022	12 Nov 2022	20	12 Nov 2022
Sprint-4	20	6 Days	14 Nov 2022	19 Nov 2022	20	19 Nov 2022

7. CODING & SOLUTIONING



```
X_train = X_train.reshape(60000, 28, 28, 1).astype('float32')
X_test = X_test.reshape(10000, 28, 28, 1).astype('float32')
```

```
number_of_classes = 10
Y_train = np_utils.to_categorical(y_train, number_of_classes)
Y_test = np_utils.to_categorical(y_test, number_of_classes)
```

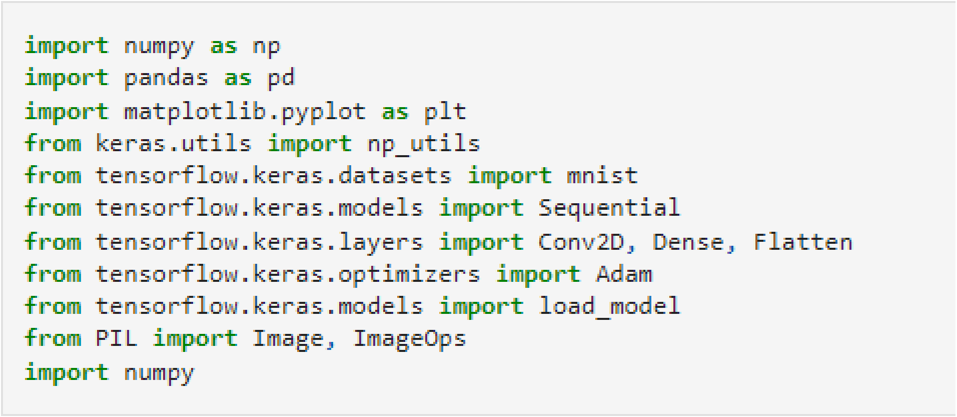
```
Y_train[0]
```

```
array([0., 0., 0., 0., 0., 1., 0., 0., 0., 0.], dtype=float32)
```

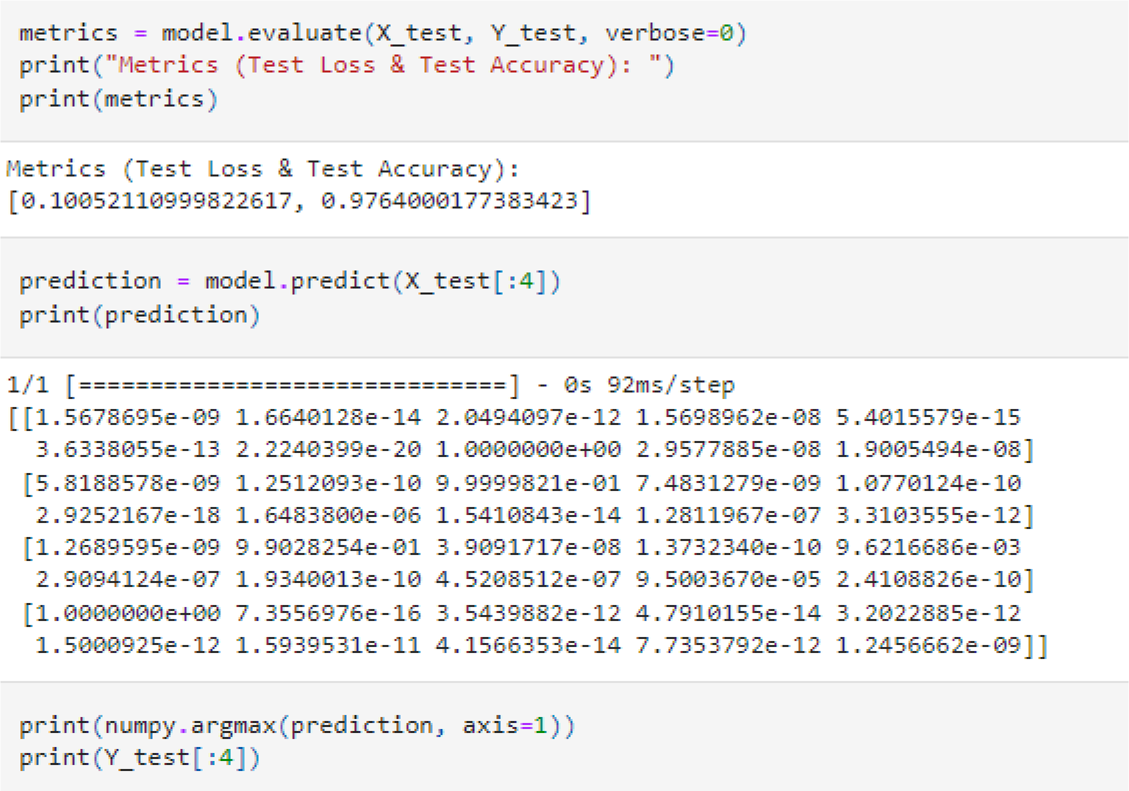
```
model = Sequential()
model.add(Conv2D(64, (3, 3), input_shape=(28, 28, 1), activation="relu"))
model.add(Conv2D(32, (3, 3), activation="relu"))
model.add(Flatten())
model.add(Dense(number_of_classes, activation="softmax"))
```

```
model.compile(loss='categorical_crossentropy', optimizer="Adam", metrics=["accuracy"])
```

```
model.fit(X_train, Y_train, batch_size=32, epochs=5, validation_data=(X_test,Y_test))
```



```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from keras.utils import np_utils
from tensorflow.keras.datasets import mnist
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, Dense, Flatten
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.models import load_model
from PIL import Image, ImageOps
import numpy
```



```
metrics = model.evaluate(X_test, Y_test, verbose=0)
print("Metrics (Test Loss & Test Accuracy): ")
print(metrics)
```

```
Metrics (Test Loss & Test Accuracy):
[0.10052110999822617, 0.9764000177383423]
```

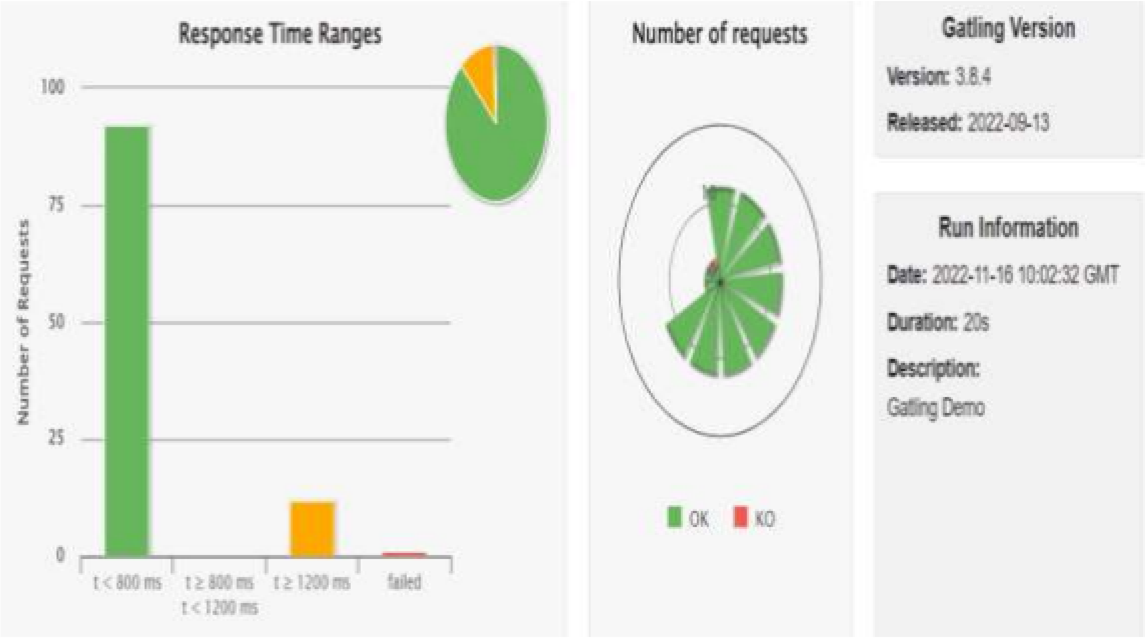
```
prediction = model.predict(X_test[:4])
print(prediction)
```

```
1/1 [==============================] - 0s 92ms/step
[[1.5678695e-09 1.6640128e-14 2.0494097e-12 1.5698962e-08 5.4015579e-15
  3.6338055e-13 2.2240399e-20 1.0000000e+00 2.9577885e-08 1.9005494e-08]
 [5.8188578e-09 1.2512093e-10 9.9999821e-01 7.4831279e-09 1.0770124e-10
  2.9252167e-18 1.6483800e-06 1.5410843e-14 1.2811967e-07 3.3103555e-12]
 [1.2689595e-09 9.9028254e-01 3.9091717e-08 1.3732340e-10 9.6216686e-03
  2.9094124e-07 1.9340013e-10 4.5208512e-07 9.5003670e-05 2.4108826e-10]
 [1.0000000e+00 7.3556976e-16 3.5439882e-12 4.7910155e-14 3.2022885e-12
  1.5000925e-12 1.5939531e-11 4.1566353e-14 7.7353792e-12 1.2456662e-09]]
```

```
print(numpy.argmax(prediction, axis=1))
print(Y_test[:4])
```

8. TESTING

8.1 Test Cases



Gatling Version

Version: 3.8.4

Released: 2022-09-13

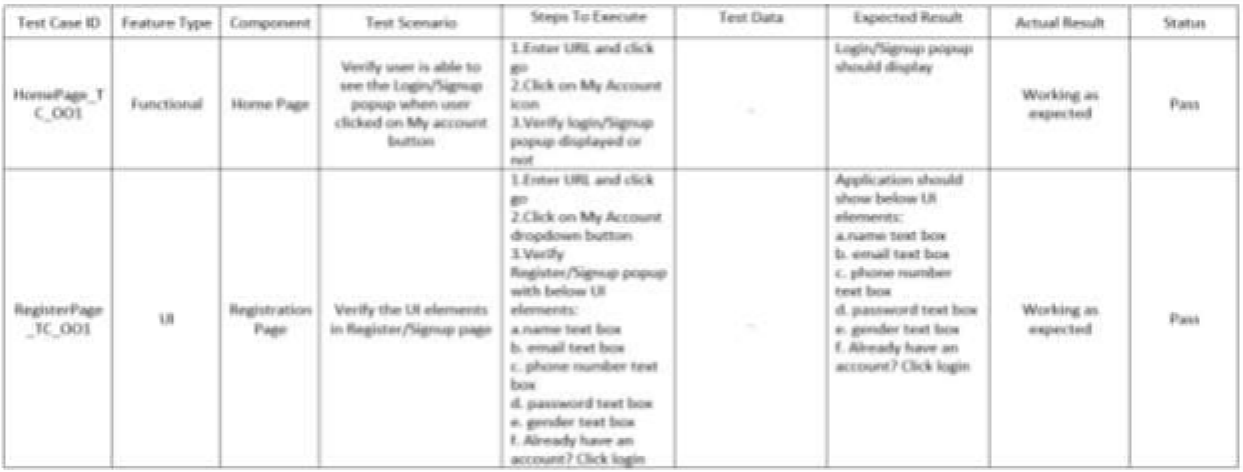
Run Information

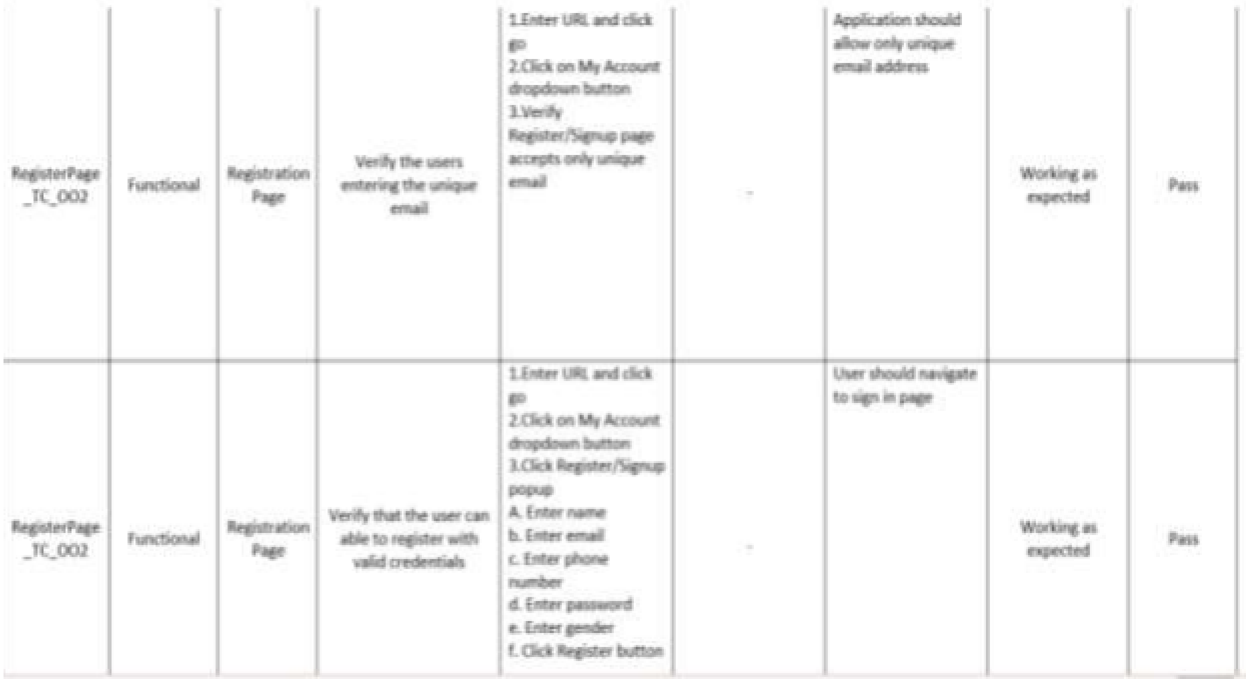
Date: 2022-11-16 10:02:32 GMT

Duration: 20s

Description:
Gatling Demo

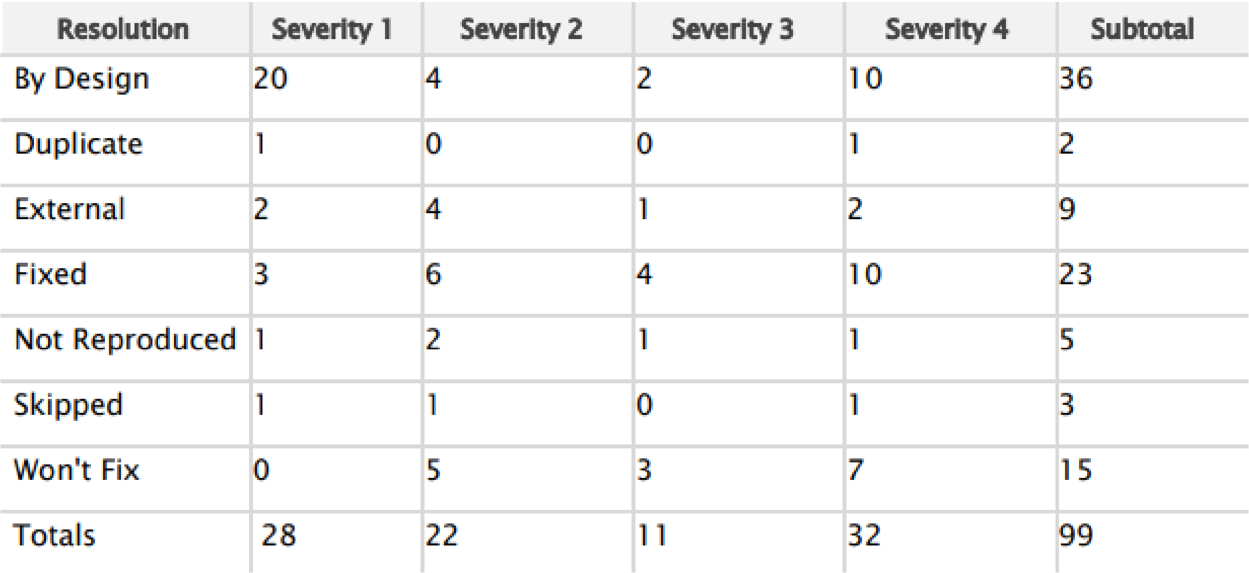
8.2 User Acceptance Testing





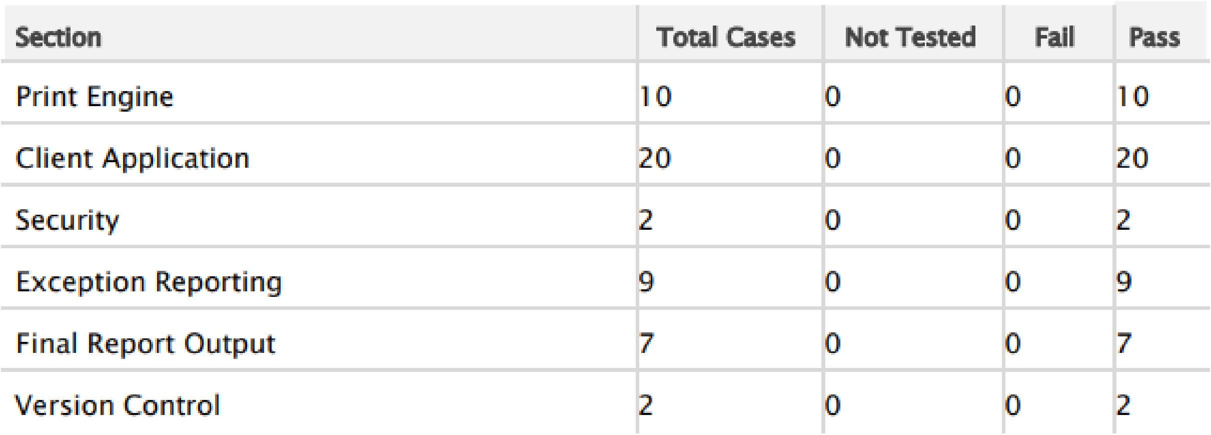
Test Case ID	Feature Type	Component	Test Scenario	Steps To Execute	Test Data	Expected Result	Actual Result	Status
HomePage_TC_001	Functional	Home Page	Verify user is able to see the Login/Signup popup when user clicked on My account button	1.Enter URL and click go 2.Click on My Account icon 3.Verify login/Signup popup displayed or not	-	Login/Signup popup should display	Working as expected	Pass
RegisterPage _TC_001	UI	Registration Page	Verify the UI elements in Register/Signup page	1.Enter URL and click go 2.Click on My Account dropdown button 3.Verify Register/Signup popup with below UI elements: a.name text box b. email text box c. phone number text box d. password text box e. gender text box f. Already have an account? Click login	-	Application should show below UI elements: a.name text box b. email text box c. phone number text box d. password text box e. gender text box f. Already have an account? Click login	Working as expected	Pass
RegisterPage _TC_002	Functional	Registration Page	Verify the users entering the unique email	1.Enter URL and click go 2.Click on My Account dropdown button 3.Verify Register/Signup page accepts only unique email	-	Application should allow only unique email address	Working as expected	Pass
RegisterPage _TC_002	Functional	Registration Page	Verify that the user can able to register with valid credentials	1.Enter URL and click go 2.Click on My Account dropdown button 3.Click Register/Signup popup A. Enter name b. Enter email c. Enter phone number d. Enter password e. Enter gender f. Click Register button	-	User should navigate to sign in page	Working as expected	Pass

8.2.1 Defect Analysis



Resolution	Severity 1	Severity 2	Severity 3	Severity 4	Subtotal
By Design	20	4	2	10	36
Duplicate	1	0	0	1	2
External	2	4	1	2	9
Fixed	3	6	4	10	23
Not Reproduced	1	2	1	1	5
Skipped	1	1	0	1	3
Won't Fix	0	5	3	7	15
Totals	28	22	11	32	99

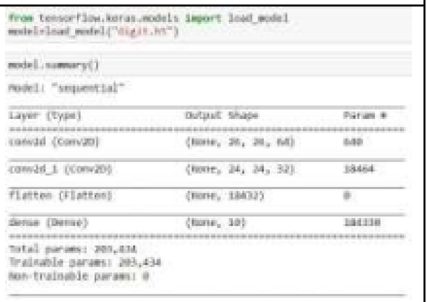
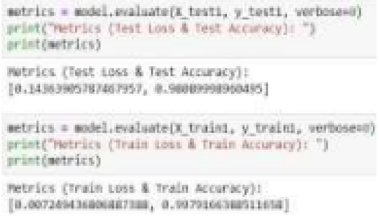
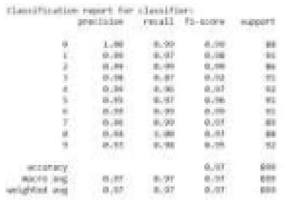
8.2.2 Testcase Analysis



Section	Total Cases	Not Tested	Fail	Pass
Print Engine	10	0	0	10
Client Application	20	0	0	20
Security	2	0	0	2
Exception Reporting	9	0	0	9
Final Report Output	7	0	0	7
Version Control	2	0	0	2

9. RESULTS

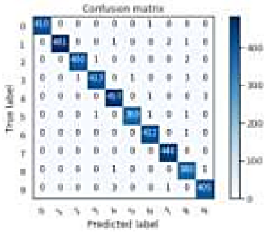
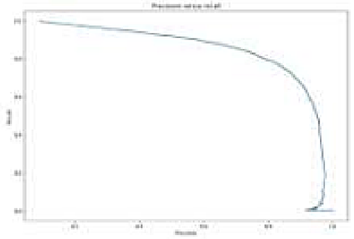
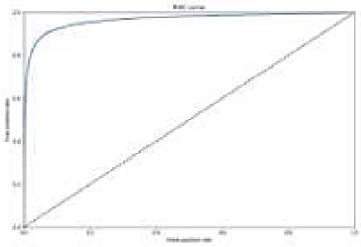
9.1 Performance Metrics

S.No.	Parameter	Values	Screenshot
1.	Model Summary	Model: "sequential" Layer (type) Output Shape Param # conv2d (Conv2D) (None, 26, 26, 64) 640 conv2d_1 (Conv2D) (None, 24, 24, 32) 18464 flatten (Flatten) (None, 18432) 0 dense (Dense) (None, 10) 184330 Total params: 203,434 Trainable params: 203,434 Non-trainable params: 0	
2.	Accuracy	Training Accuracy -0.9979166388511658 Validation Accuracy -0.98089998960495	
3. `	Metrics	**Classification Model:** precision,recall,f1-score,support	

```
from tensorflow.keras.models import load_model
model=load_model("digit.h5")

model.summary()

Model: "sequential"
_________________________________________________________________
Layer (type)                Output Shape              Param #
=================================================================
conv2d (Conv2D)             (None, 26, 26, 64)        640

conv2d_1 (Conv2D)           (None, 24, 24, 32)        18464

flatten (Flatten)           (None, 18432)             0

dense (Dense)               (None, 10)                184330

=================================================================
Total params: 203,434
Trainable params: 203,434
Non-trainable params: 0
_________________________________________________________________
```

```
metrics = model.evaluate(X_test1, y_test1, verbose=0)
print("Metrics (Test Loss & Test Accuracy): ")
print(metrics)

Metrics (Test Loss & Test Accuracy):
[0.14363905787467957, 0.98089998960495]

metrics = model.evaluate(X_train1, y_train1, verbose=0)
print("Metrics (Train Loss & Train Accuracy): ")
print(metrics)

Metrics (Train Loss & Train Accuracy):
[0.007249436806487388, 0.9979166388511658]
```

```
Classification report for classifier:
              precision    recall  f1-score   support

           0       1.00      0.99      0.99        88
           1       0.99      0.97      0.98        91
           2       0.99      0.99      0.99        86
           3       0.98      0.87      0.92        91
           4       0.99      0.96      0.97        92
           5       0.95      0.97      0.96        91
           6       0.99      0.99      0.99        91
           7       0.96      0.99      0.97        89
           8       0.88      1.00      0.93        88
           9       0.93      0.98      0.95        92

    accuracy                           0.97       899
   macro avg       0.97      0.97      0.97       899
weighted avg       0.97      0.97      0.97       899
```

4.	Metrics	Confusion Matrix	
5.	Metrics	Precision-Recall or PR curve	
6.	Metrics	ROC (Receiver Operating Characteristics) curve	

10. ADVANTAGES & DISADVANTAGES

ADVANTAGES

- Reduces manual work
- More accurate than average human
- Capable of handling a lot of data
- Can be used anywhere from any device

DISADVANTAGES

- Cannot handle complex data
- All the data must be in digital format
- Requires a high performance server for faster predictions
- Prone to occasional errors

11. CONCLUSION

This project demonstrated a web application that uses machine learning to recognize handwritten numbers. Flask, HTML, CSS, JavaScript, and a few other technologies were used to create this project. The model predicts the handwritten digit using a CNN network. During testing, the model achieved a 98% recognition rate. The proposed project is scalable and can easily handle a huge number of users. Since it is a web application, it is compatible with any device that can run a browser. This project is extremely useful in real-world scenarios such as recognizing number plates of vehicles, processing bank cheque amounts, numeric entries in forms filled up by hand (tax forms) and so on. There is so much room for improvement, which can be implemented in subsequent versions.

12. FUTURE SCOPE

This project is far from complete and there is a lot of room for improvement. Some of the improvements that can be made to this project are as follows:

- Add support to detect digits from manual writing in canvas
- Add support to detect multiple digits
- Improve model to detect digits from complex images
- Add support to different languages to help users from all over the world

This project has endless potential and can always be enhanced to become better. Implementing this concept in the real world will benefit several industries and reduce the workload on many workers, enhancing overall work efficiency.

13. APPENDIX

DEMO LINK - https://drive.google.com/file/d/1q54LR063baXH4EIPgeh9PS2-pfrSq5L2/view?usp=drivesdk

13.1 Source Code

MODEL CREATION:

```
from keras.datasets import mnist
from matplotlib import pyplot
(X_train,y_train),(X_test,y_test)=mnist.load_data()
print('X_train:' +str(X_train.shape))
print('y_train:' +str(y_train.shape))
print('X_test:' +str(X_test.shape))
print('y_test:' +str(y_test.shape))
from matplotlib import pyplot
for i in range(9):
  pyplot.subplot(330+1+i)
  pyplot.imshow(X_train[i],cmap=pyplot.get_cmap('gray'))
  pyplot.show()
```

RECOGNIZER(PYTHON):

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from keras.utils import np_utils
from tensorflow.keras.datasets import mnist
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, Dense, Flatten
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.models import load_model
from PIL import Image, ImageOps import numpy
```

INDEX PAGE(HTML):

```
<!DOCTYPE html>
<html lang="en">
<head>
 <meta charset="UTF-8">
 <meta http-equiv="X-UA-Compatible" content="IE=edge">
 <meta name="viewport" content="width=device-width, initial-scale=1.0">
 <title>User Account Dropdown Menu Using Html CSS & Vanilla Javascript</title>
 <link rel="stylesheet" href="style.css">
 <link
href="https://fonts.googleapis.com/css2?family=Poppins:wght@200;300;400;600&display=swa
p"
rel="stylesheet">
 <link
href="https://fonts.googleapis.com/css?family=Material+Icons|Material+Icons+Outlined|Materia
l+Icons+Two+
Tone|Material+Icons+Round|Material+Icons+Sharp" rel="stylesheet">
 <style>
 *{
 font-family: "poppins", sans-serif;
 margin: 0;
 padding: 0;
 }
.icons-size{
 color: white;
 font-size: 14px;
}
.text{
 position: fixed;
 right: 950px;
 top:22px
}
.action{
 position: fixed;
 right: 1450px;
 top:20px
```

```
}
.action .profile{
 border-radius: 50%;
 cursor: pointer;
 height: 60px;
 overflow: hidden;
 position: relative;
 width: 60px;
}
.action .profile img{
 width: 100%;
 top:0;
 position: absolute;
 object-fit: cover;
 left: 0;
 height: 100%;
}
.action .menu{
 background-color:#FFF;
 box-sizing:0 5px 25px rgba(0,0,0,0.1);
 border-radius: 15px;
 padding: 10px 20px;
position: absolute;
 left: -10px;
 width: 200px;
 transition: 0.5s;
 top: 120px;
 visibility: hidden;
 opacity: 0;
}
.action .menu.active{
 opacity: 1;
 top: 80px;
 visibility: visible;
}
.action .menu::before{
 background-color:#fff;
 content: ";
 height: 20px;
 position: absolute;
 right: 190px;
 transform:rotate(45deg);
 top:-5px;
 width: 20px;
}
.action .menu h3{
 color: #555;
 font-size: 16px;
 font-weight: 600;
 line-height: 1.3em;
 padding: 20px 0px;
 text-align: left;
 width: 100%;
}
.action .menu h3 div{
 color: #818181;
 font-size: 14px;
font-weight: 400;
}
.action .menu ul li{
 align-items: center;
 border-top:1px solid rgba(0,0,0,0.05);
 display: flex;
 justify-content: left;
 list-style: none;
 padding: 10px 0px;
}
.action .menu ul li img{
 max-width: 20px;
 margin-right: 10px;
 opacity: 0.5;
 transition:0.5s
}
.action .menu ul li a{
 display: inline-block;
 color: #555;
 font-size: 14px;
 font-weight: 600;
 padding-left: 15px;
 text-decoration: none;
 text-transform: uppercase;
 transition: 0.5s;
}
.action .menu ul li:hover img{
 opacity: 1;
}
.action .menu ul li:hover a{
 color:#ff00ff;
}
.msg{
 position: fixed;
 right: 950px;
left:0px;
 top:250px
}
 .image {
 background-image: url("{{ url_for('static', filename='images/index2.jpg') }}");
 background-color: #cccccc;
 height: 753px;
 width: 1536px;
 background-position: center;
 background-repeat: no-repeat;
 background-size: cover;
 }
 </style>
</head>
<body>
 <div class="image">
 <div class="action">
 <div class="profile" onclick="menuToggle();">
 <img src="{{ url_for('static', filename='images/user.jpg') }}" alt="">
 </div>
 <div class="menu">
 <h3>
 User Account
 </h3>
 <ul>
 <li>
 <span class="material-icons icons-size">person</span>
 <a href="/register/">Sign-up</a>
 </li>
 <li>
 <span class="material-icons icons-size">mode</span>
 <a href="/login">Sign-in</a>
 </li>
 </ul>
 </div>
</div>
 <div class="text">
 <h1 style="color: white;">Handwritten digit Recognisor</h1>
 </div>
 <div class="msg">
 <h1 style="color: white;font-size: 50px;">
 <pre>
 Numbers
 Rule
 The
 Universe
 </pre>
 </h1>
 </div>
 </div>
 <script>
 function menuToggle(){
 const toggleMenu = document.querySelector('.menu');
 toggleMenu.classList.toggle('active')
 }
 </script></body>
```

HOME PAGE (HTML):

```
<!DOCTYPE html>
<html lang="en">
 <head>
 <!-- Required meta tags -->
 <meta charset="utf-8">
 <meta name="viewport" content="width=device-width, initial-scale=1, shrink-to-fit=no">
 <link rel="stylesheet" type="text/css" href="{{ url_for('static',filename='css/style.css')}}">
 <!-- Bootstrap CSS -->
 <link rel="stylesheet"
href="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/css/bootstrap.min.css"
integrity="sha384-
ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"
crossorigin="anonymous">
 <title>Handwritten Digit Recognition</title>
 </head>
<body>
<div class="bg-nav text-light d-flex flex-column flex-md-row align-items-center p-3 px-md-4
mb-3 bg-dark
border-bottom shadow-sm" >
 <h5 class="my-0 mr-md-auto" style="color: black;font-weight: bolder;">Handwritten Digit
Recognisor</h5>
 <a class="btn btn-outline-primary" href="/logout" style="color: whitesmoke;">Log Out</a>
</div>
 <main role="main">
 <section class="album py-3 text-center">
 <form action="/predictpage" method="post">
 <div class="button">
 <input type="submit" class="btn btn-primary btn-block btn-lg" value="Proceed to recognise the
handwritten
digits">
 </div>
 </form>
 </section>
 <div class="jumbotron py-8 bg-dark">
 <div class="container">
```

```
<div class="row">
 <div class="card mb-2 shadow-sm">
 <div class="card-body" style="border:5px solid black;">
 <h3 style="text-align: center;">Description</h3><br>
 <p class="card-text" style="font-size: 20px;">The handwritten digit recognition is the ability of
computers to recognize human handwritten digits.
 It is a hard task for the machine because handwritten digits are not perfect, vary from person-to-
person
and can be made with many different flavors.
 The handwritten digit recognition is the solution to this problem which uses the image of a digit
and
recognizes the digit present in the image.</p>
 </div>
 </div><br><br>
 </div>
 </div>
 </div>
</main>
 <script src="https://code.jquery.com/jquery-3.3.1.slim.min.js" integrity="sha384-
q8i/X+965DzO0rT7abK41JStQIAqVgRVzpbzo5smXKp4YfRvH+8abtTE1Pi6jizo"
crossorigin="anonymous"></script>
 <script src="https://cdn.jsdelivr.net/npm/popper.js@1.14.7/dist/umd/popper.min.js"
integrity="sha384-
UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHNDz0W1"
crossorigin="anonymous"></script>
 <script src="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/js/bootstrap.min.js"
integrity="sha384-
JjSmVgyd0p3pXB1rRibZUAYoIIy6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B07jRM"
crossorigin="anonymous"></script>
</body>
</html>
```

HOME PAGE (CSS):

```
.bg-nav
{
 background: #e704c9; /* fallback for old browsers */
 background: -webkit-linear-gradient(to right, #E5E5BE, #db0ac2); /* Chrome 10-25, Safari 5.1-
6 */
 background: linear-gradient(to right, #E5E5BE, #f104b6); /* W3C, IE 10+/ Edge, Firefox 16+,
Chrome 26+,
Opera 12+, Safari 7+ */
}
.row{
 margin-top:80px;
```