PROJECT REPORT

A Novel Method for Handwritten Digit Recognition System

Submitted by,

PNT2022TMID29644

AMRUTHA S	-	513119106006
ANITHA K	-	513119106008
DEVENDRAN M	-	513119106014
HEMAVATHY T A	-	513119106030

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
THANTHAI PERIYAR GOVERNMENT INSTITUTE OF TECHNOLOGY,
VELLORE-632002.

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CHAPTER 1
INTRODUCTION

1.1 Project Overview:

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. 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 draw a digit which is analyzed by the model and the detected result is returned on to UI.

1.2 Purpose:

The handwritten digit recognition is the ability of computers to recognize human handwritten digits. It is one of the leading applications of pattern recognition and machine learning. Despite having some limitations, handwritten recognition plays an important role in the modern world making it a very powerful technology to support many applications comes in the forefront of automated sorting of letters and bank checks to solve more complex problems and to make human's job easier.

CHAPTER 2

LITERATURE SURVEY

2.1 Existing Problem:

The elementary issue with handwritten digit recognition is that handwritten digits do not always have the same style, size, orientation, margins and width 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. The individuality and variation of each individual's handwriting influence the structure and appearance of the digits. In the case of handwriting recognition from photos, there are also awkward angles to consider. The angle the photo is taken could obscure the character, making it harder for the computer to identify.

2.2References:

- **A novel method for Handwritten Digit Recognition with Neural Networks**
  Malothu Nagu, N Vijay Shankar, K. Annapurna
  International Journal of Computer Science and Information Technologies (IJCSIT), Vol. 2 (4) 1685- 1692, 2011
- **Handwritten digits recognition with artificial Neural Network**
  K. Islam, G. Mujtaba, R.G. Raj, H.F. Nweke
  2017 International Conference on Engineering Technology and Technopreneurship (ICE2T)
- **Simplified Neural Network Design for Hand Written Digit Recognition**
  Muhammad Zubair Asghar, Hussain Ahmad, Shakeel Ahmad, Sheikh Muhammad Saqib, Bashir Ahmad, Muhammad Junaid Asghar
  International Journal of Computer Science and Information Security 9 (6), 319, 2011
- **Artificial neural network classification for handwritten digits recognition**
  Mohammed Hussein Naji Jabardi, Harleen Kaur
  International journal of advanced research in computer science 5 (3), 2014
- **Neural Network Based Handwritten Digits Recognition-An Experiment and Analysis**
  MJ Islam, QMJ Wu, M Ahmadi, MA Sid-Ahmed
  International Journal of Computer and Electrical Engineering 1 (2), 221, 2009

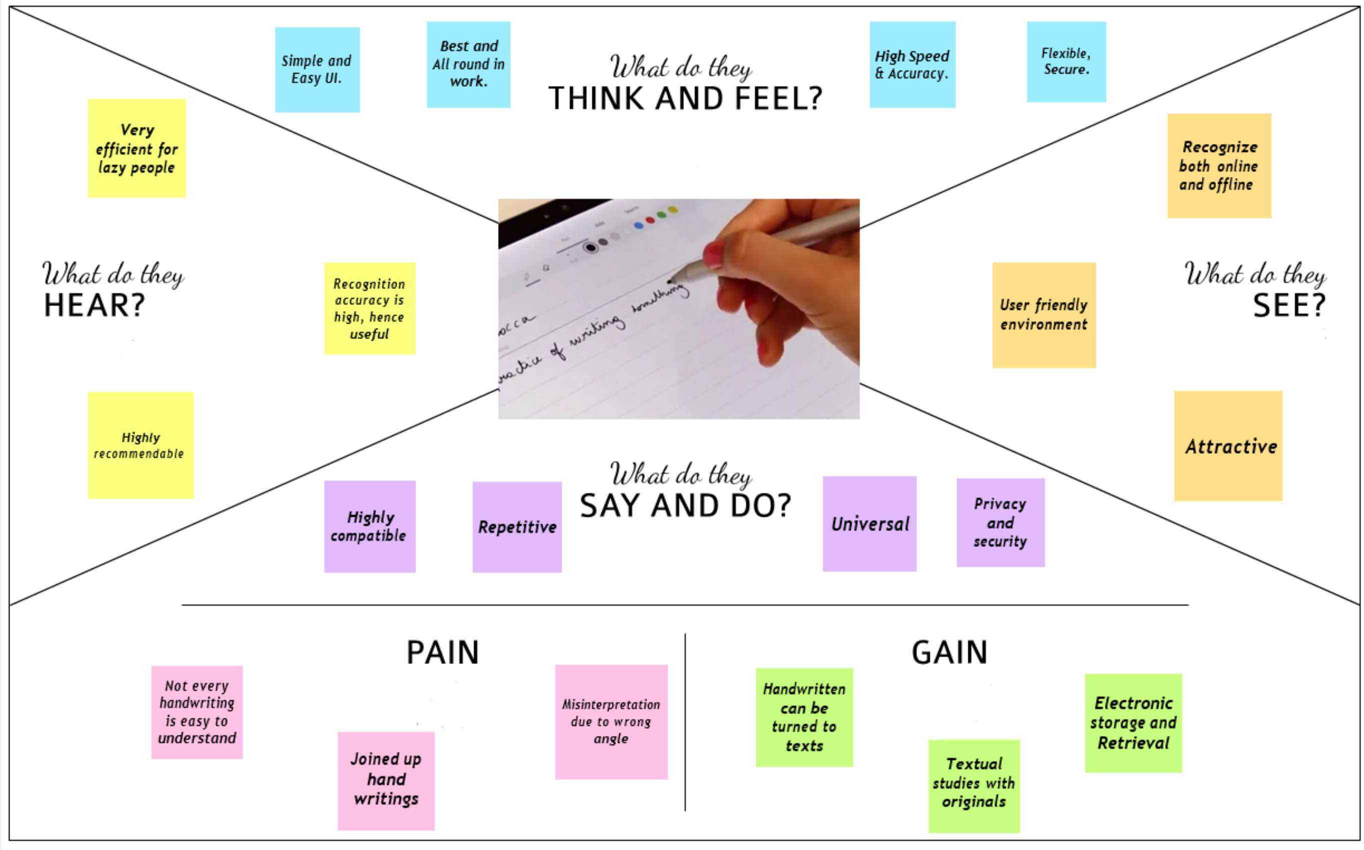
2.3Problem Statement Definition:

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. 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 draw a digit which will be taken as image for the input, this image is analyzed by the model and the detected result is returned on to UI(User Interface).

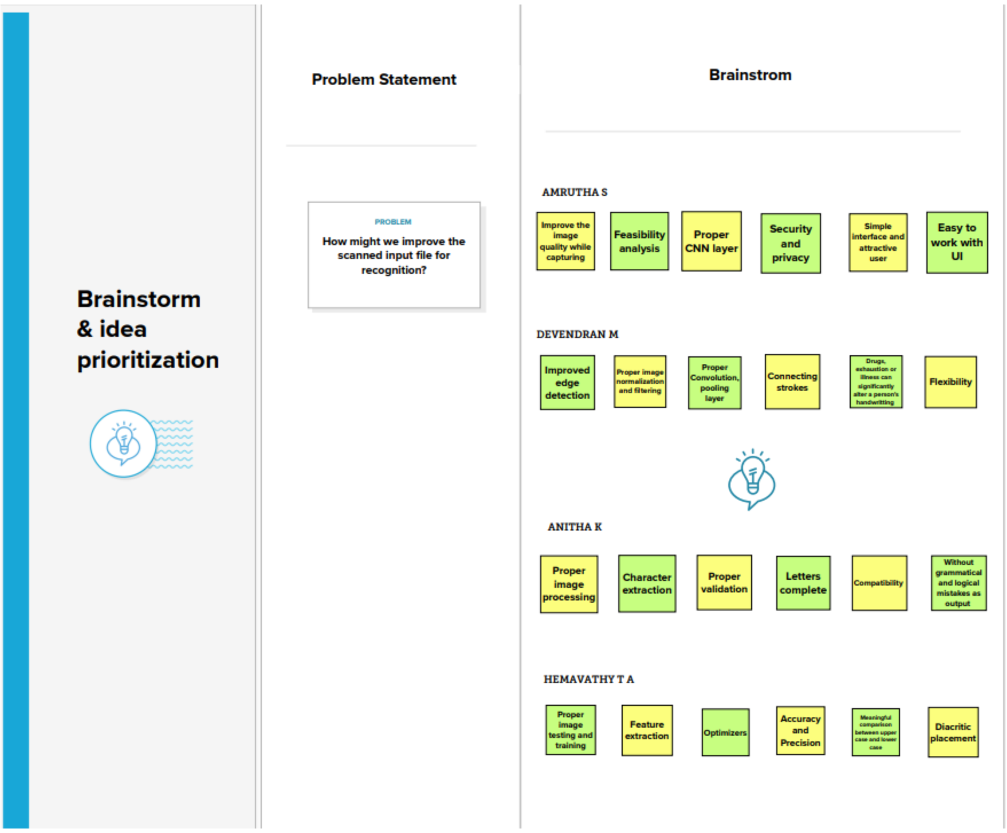
CHAPTER 3

IDEATION & PROPOSED SOLUTION

3.1 Empathy Map Canvas:


What do they THINK AND FEEL?
Simple and Easy UI.
Best and All round in work.
High Speed & Accuracy.
Flexible, Secure.
What do they HEAR?
Very efficient for lazy people
Recognition accuracy is high, hence useful
Highly recommendable
What do they SEE?
Recognize both online and offline
User friendly environment
Attractive
What do they SAY AND DO?
Highly compatible
Repetitive
Universal
Privacy and security
PAIN
Not every handwriting is easy to understand
Joined up hand writings
Misinterpretation due to wrong angle
GAIN
Handwritten can be turned to texts
Textual studies with originals
Electronic storage and Retrieval

3.2 Ideation & Brainstorming:



Brainstorm & idea prioritization

Problem Statement

PROBLEM

How might we improve the scanned input file for recognition?

Brainstrom

AMRUTHA S

Improve the image quality while capturing | Feasibility analysis | Proper CNN layer | Security and privacy | Simple interface and attractive user | Easy to work with UI

DEVENDRAN M

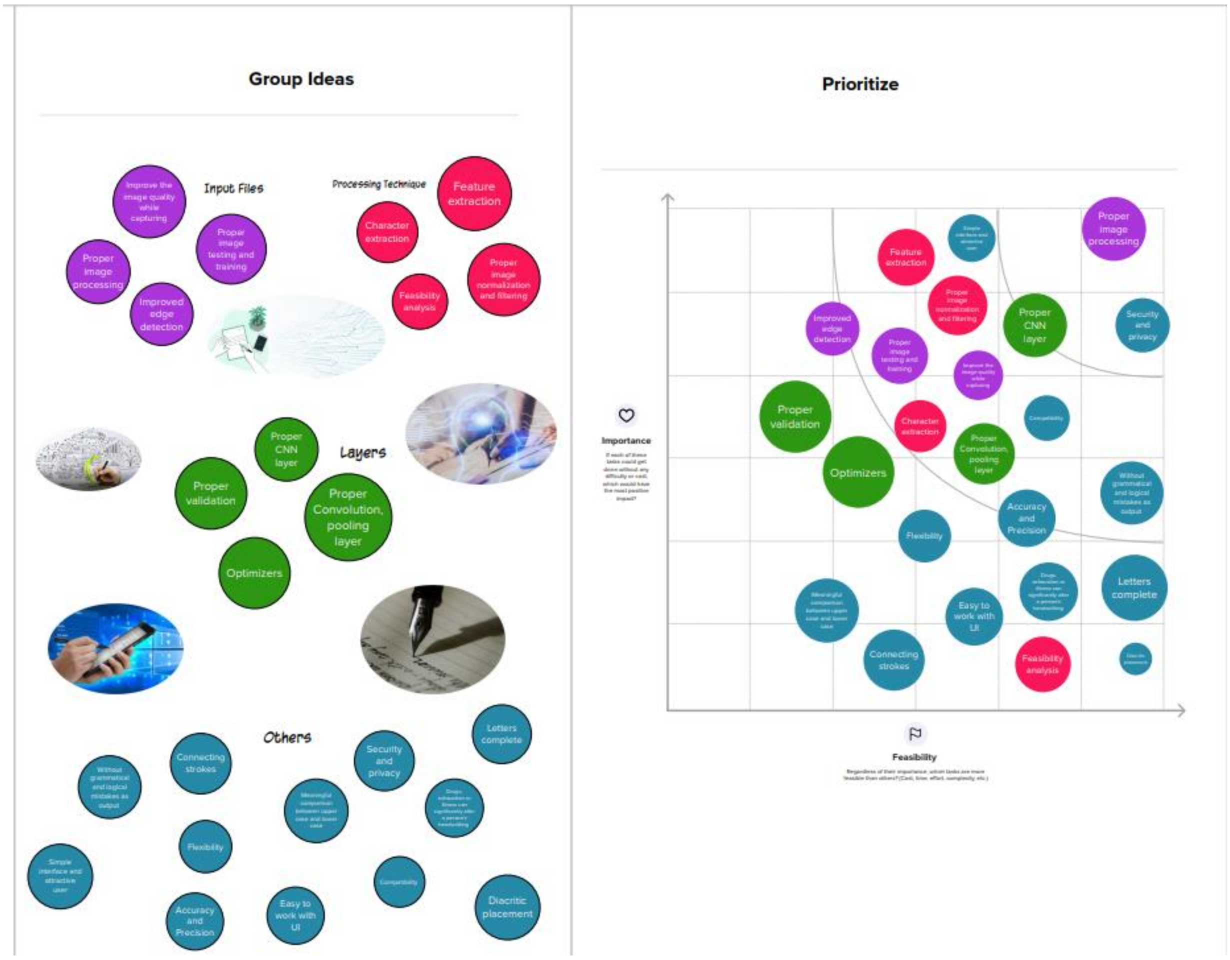
Improved edge detection | Proper image normalization and filtering | Proper Convolution, pooling layer | Connecting strokes | Drugs, exhaustion or illness can significantly alter a person's handwritting | Flexibility

ANITHA K

Proper image processing | Character extraction | Proper validation | Letters complete | Compatibility | Without grammatical and logical mistakes as output

HEMAVATHY T A

Proper image testing and training | Feature extraction | Optimizers | Accuracy and Precision | Meaningful comparison between upper case and lower case | Diacritic placement



Group Ideas

Input Files
Improve the image quality while capturing
Proper image processing
Proper image testing and training
Improved edge detection
Processing Technique
Feature extraction
Character extraction
Proper image normalization and filtering
Feasibility analysis
Layers
Proper CNN layer
Proper validation
Proper Convolution, pooling layer
Optimizers
Others
Without grammatical and logical mistakes as output
Connecting strokes
Security and privacy
Letters complete
Meaningful comparison between upper case and lower case
Drugs, exhaustion or illness can significantly alter a person's handwriting
Flexibility
Simple interface and attractive user
Accuracy and Precision
Easy to work with UI
Compatibility
Diacritic placement

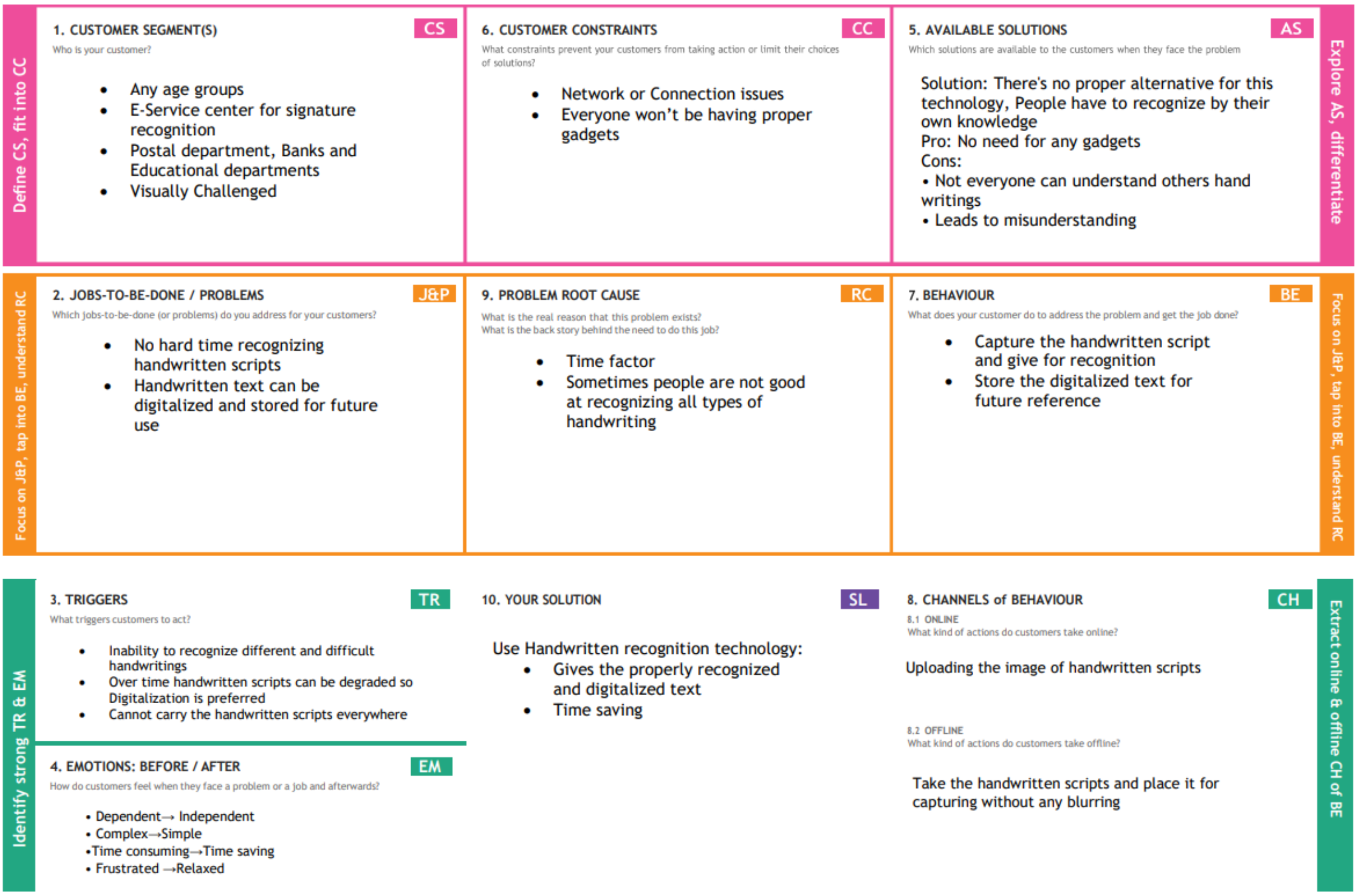
Prioritize

Importance
If each of these tasks could get done without any difficulty or cost, which would have the most positive impact?
Feasibility
Regardless of their importance, which tasks are more feasible than others? (Cost, time, effort, complexity, etc.)
Feature extraction
Simple interface and attractive user
Proper image processing
Proper image normalization and filtering
Improved edge detection
Proper CNN layer
Security and privacy
Proper image testing and training
Improve the image quality while capturing
Proper validation
Character extraction
Compatibility
Proper Convolution, pooling layer
Optimizers
Without grammatical and logical mistakes as output
Accuracy and Precision
Flexibility
Drugs, exhaustion or illness can significantly alter a person's handwriting
Letters complete
Meaningful comparison between upper case and lower case
Easy to work with UI
Connecting strokes
Feasibility analysis
Diacritic placement

3.3 Proposed Solution:

S.No.	Parameter	Description
1.	Problem Statement (Problem to besolved)	• This is a collection of thousands of handwritten pictures used to train classification models using Machine Learning techniques. • As a part of this problem statement, we will train a multilayer perceptron using Tensorflow-v2 to recognize the handwritten digits.
2.	Idea / Solution description	• 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.
3.	Novelty / Uniqueness	• 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.
4.	Social Impact / Customer Satisfaction	• 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. • The generative models can perform recognition driven segmentation.
5.	Business Model (Revenue Model)	• Input module • Image processing module Segmentation • module Feature extraction module • Data set training module Classification module
6.	Scalability of the Solution	• The accuracy of the result for the training data set is 99.98%, and 99.40% with 50% noise by using MNIST. Even we can improve this model to achieve the better resultsby training different types of datasets.

3.4 Problem Solution fit:



Define CS, fit into CC

1. CUSTOMER SEGMENT(S) CS

Who is your customer?

- Any age groups
- E-Service center for signature recognition
- Postal department, Banks and Educational departments
- Visually Challenged

6. CUSTOMER CONSTRAINTS CC

What constraints prevent your customers from taking action or limit their choices of solutions?

- Network or Connection issues
- Everyone won't be having proper gadgets

5. AVAILABLE SOLUTIONS AS

Which solutions are available to the customers when they face the problem

Solution: There's no proper alternative for this technology, People have to recognize by their own knowledge

Pro: No need for any gadgets

Cons:

- Not everyone can understand others hand writings
- Leads to misunderstanding

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?

- No hard time recognizing handwritten scripts
- Handwritten text can be digitalized and stored for future use

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?

- Time factor
- Sometimes people are not good at recognizing all types of handwriting

7. BEHAVIOUR BE

What does your customer do to address the problem and get the job done?

- Capture the handwritten script and give for recognition
- Store the digitalized text for future reference

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

Identify strong TR & EM

3. TRIGGERS TR

What triggers customers to act?

- Inability to recognize different and difficult handwritings
- Over time handwritten scripts can be degraded so Digitalization is preferred
- Cannot carry the handwritten scripts everywhere

4. EMOTIONS: BEFORE / AFTER EM

How do customers feel when they face a problem or a job and afterwards?

- Dependent→ Independent
- Complex→Simple
- Time consuming→Time saving
- Frustrated →Relaxed

10. YOUR SOLUTION SL

Use Handwritten recognition technology:

- Gives the properly recognized and digitalized text
- Time saving

8. CHANNELS of BEHAVIOUR CH

8.1 ONLINE
What kind of actions do customers take online?

Uploading the image of handwritten scripts

8.2 OFFLINE
What kind of actions do customers take offline?

Take the handwritten scripts and place it for capturing without any blurring

Extract online & offline CH of BE

CHAPTER 4

REQUIREMENT ANALYSIS

4.1 Functional requirements:

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	The product essentially convertshandwritten digits to digital form.	The user is first asked to draw a number on the canvas, and the model that is built is then utilised to compare the data and provide an output in digitalized form.
FR-2	Recognizing the handwrittendigit and displaying.	Recognizing the handwritten digit and displaying.
FR-3	Import dataset file directly to theprogram from a command that will download the dataset from its website. Save the dataset file in the same directory as theprogram	Installing packages and applications.
FR-4	Build a Neural Network with anumber of nodes in the input layer equal to the number of pixels in the arrays	Nil
FR-5	Activating the Neural Network	Packages – tensorflow

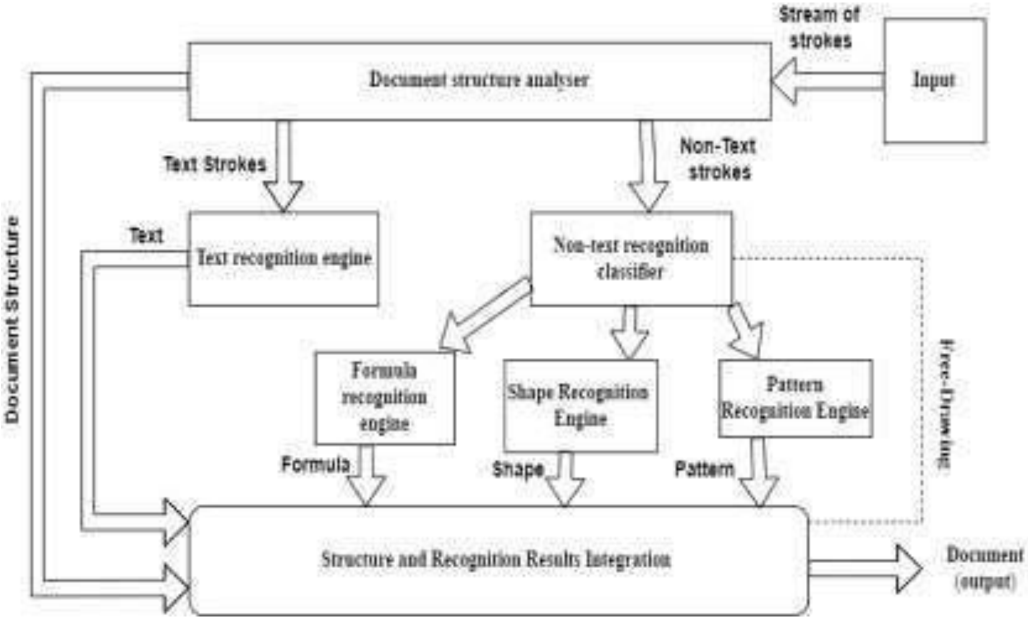
4.2 Non-Functional requirements:

FR No.	Non-Functional Requirement	Description
NFR-1	Usability	System design should be easily understood and user friendly to users. Furthermore, users of all skill levels of users should be able to navigate it withoutproblems.
NFR-2	Security	The system should automatically be able to authenticate all users with their unique username and password
NFR-3	Performance	Should reduce the delay in information when hundreds of requests are given.
NFR-4	Availability	Information is restricted to each users limited access
NFR-5	Scalability	The system should be able to handle 10000 usersaccessing the site at the same time

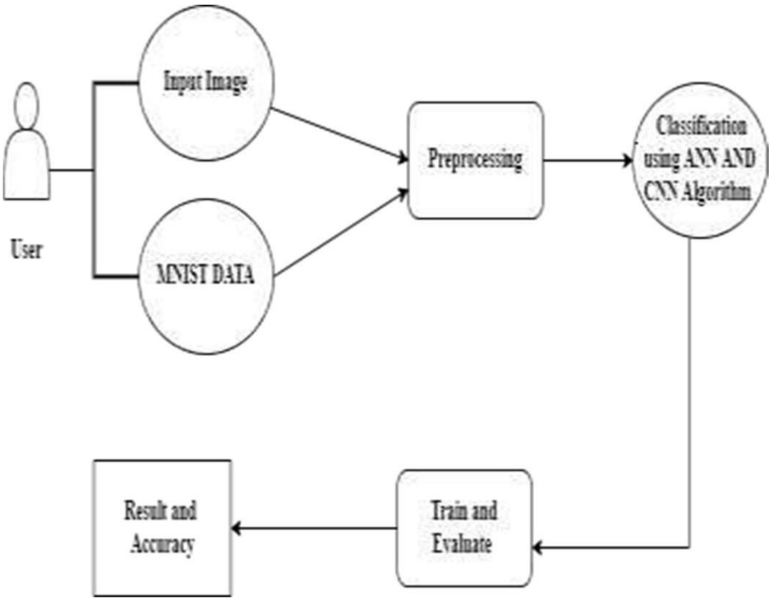
CHAPTER 5

PROJECT DESIGN

5.1 Data Flow Diagram:

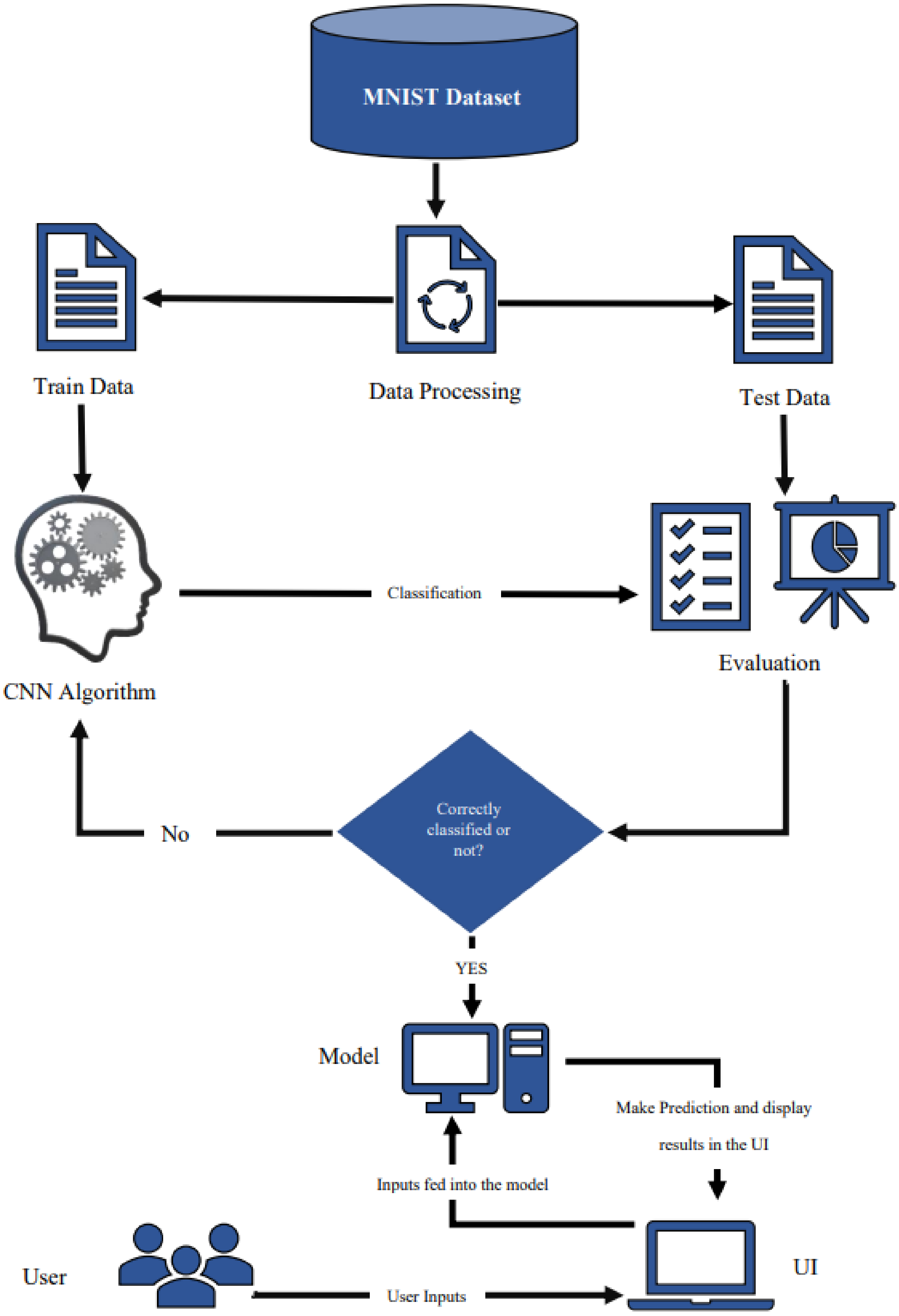


Simplified Diagram:

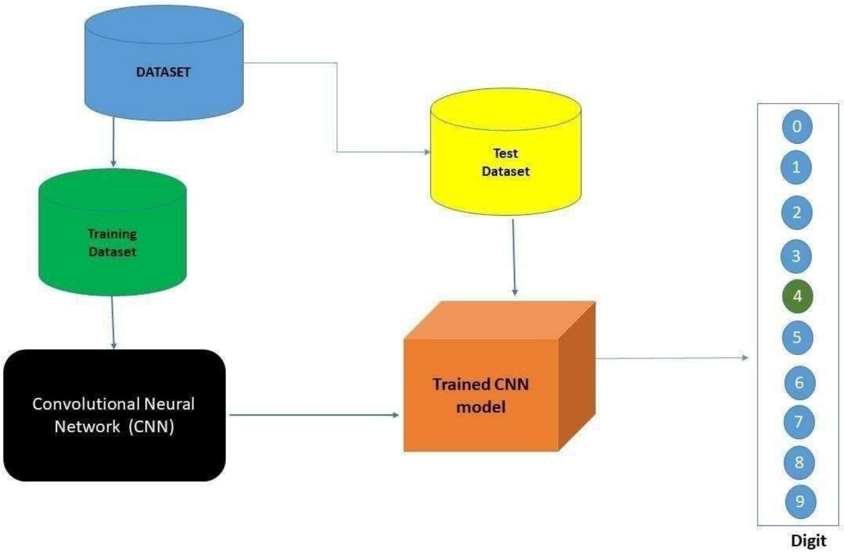


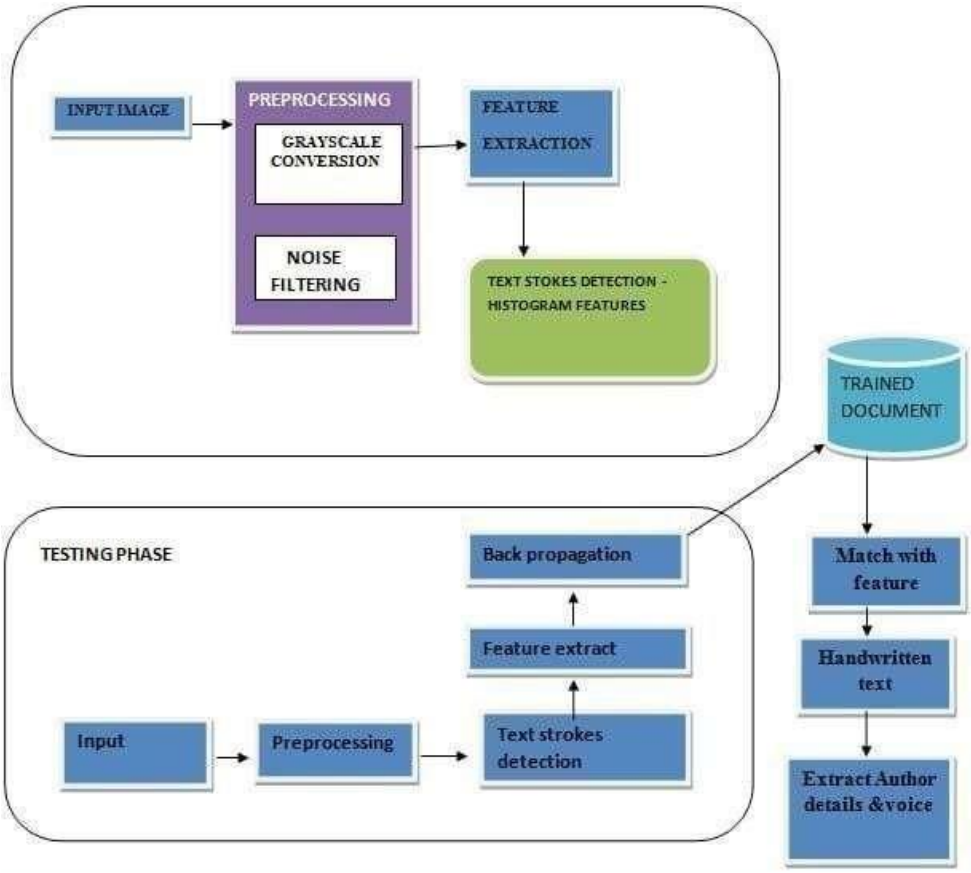
5.2 Solution & Technical Architecture:

Solution Architecture:



Technical Architecture:





5.3 User Stories:

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Customer (Mobile user)	Home	USN-1	As a user, I can view the guide and awareness to use this application.	I can view the awarenessto use this application and its limitations.	Low	Sprint-1
		USN-2	As a user, I’m allowed to view the guidedvideo to use the interface of this application.	I can gain knowledge touse this application by apractical method.	Low	Sprint-1
		USN-3	As a user, I can read the instructions to usethis application.	I can read instructionsalso to use it in a user-friendly method.	Low	Sprint-2
	Recognize	USN-4	As a user, In this prediction page I get tochoose the image.	I can choose the imagefrom our local system and predict the output.	High	Sprint-2
	Predict	USN-5	As a user, I’m Allowed to upload andchoose the image to be uploaded	I can upload and choosethe image from the system storage and alsoin any virtual storage.	Medium	Sprint-3
		USN-6	As a user, I will train and test the input toget the maximum accuracy of output.	I can able to train and test the application untilit gets maximum accuracy of the result.	High	Sprint-4
		USN-7	As a user, I can access the MNIST data set	I can access the MNISTdata set to produce the accurate result.	Medium	Sprint-3

Customer (Web user)	Home	USN-8	As a user, I can view the guide to use theweb app.	I can view the awareness of this application and itslimitations.	High	Sprint-1
	Recognize	USN-9	As a user, I can use the web application virtually anywhere.	I can use the applicationportably anywhere.	High	Sprint-1
		USN-10	As it is an open source, can use it costfreely.	I can use it without any payment to be paid for itto access.	Medium	Sprint-2
		USN-11	As it is a web application, it is installationfree	I can use it without theinstallation of the application or any software.	Medium	Sprint-4
	Predict	USN-12	As a user, I’m Allowed to upload andchoose the image to be uploaded	I can upload and choosethe image from the system storage and alsoin any virtual storage.	Medium	Sprint-3

CHAPTER 6

PROJECT PLANNING & SCHEDULING

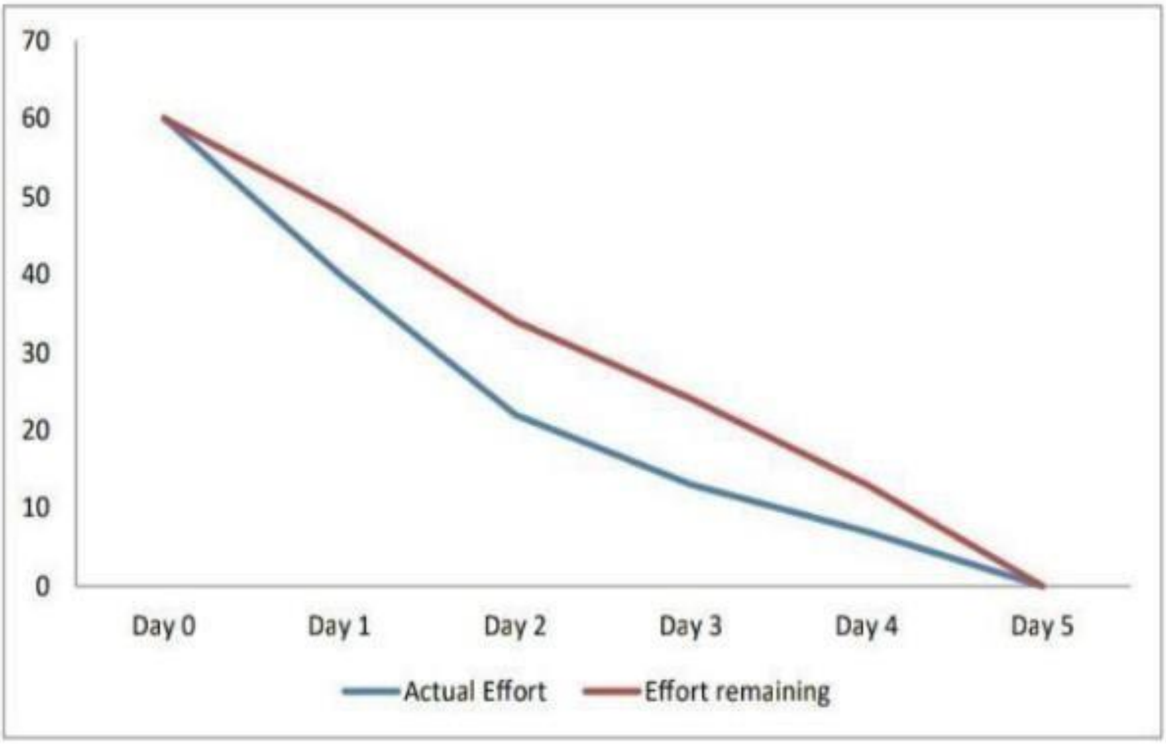
6.1 Sprint Planning & Estimation:

Sprint	Functional Requirement (Epic)	US Number	User Story/Task	Points	Priority	Team members
Sprint-1	Home	USN-1	As a user, I can view the guide andawareness to use this application.	1	Medium	Amrutha S, Anitha K, Devendran M, Hemavathy T A
Sprint-1		USN-2	As a user, I'm allowed to view the guided video to use the interface of this application.	3	High	Amrutha S, Anitha K, Devendran M, Hemavathy T A
Sprint-1		USN-3	As a user, I can read the instructions to usethis application.	2	Low	Amrutha S, Anitha K, Devendran M, Hemavathy T A
Sprint-2	Recognize	USN-4	As a user, In this recognition page I get to choose the image.	4	High	Amrutha S, Anitha K, Devendran M, Hemavathy T A
Sprint-3	Predict	USN-5	As a user, I'm Allowed to upload andchoose the image to be uploaded	3	Low	Amrutha S, Anitha K, Devendran M, Hemavathy T A
Sprint-3		USN-6	As a user, I will train and test the inputto get the maximum accuracy of output.	4	High	Amrutha S, Anitha K, Devendran M, Hemavathy T A
Sprint-3		USN-7	As a user, I can access the MNIST data set	2	Medium	Amrutha S, Anitha K, Devendran M, Hemavathy T A

6.2 Sprint Delivery Schedule:

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date(planned)	Story Points Completed	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

6.3 Reports from JIRA:



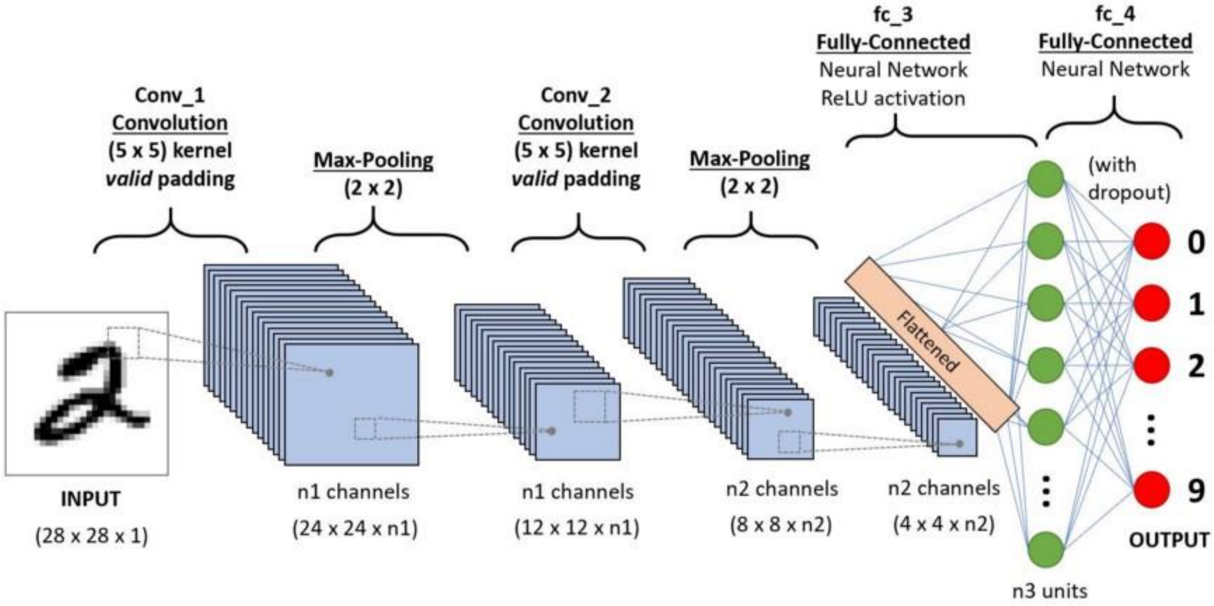
CHAPTER 7

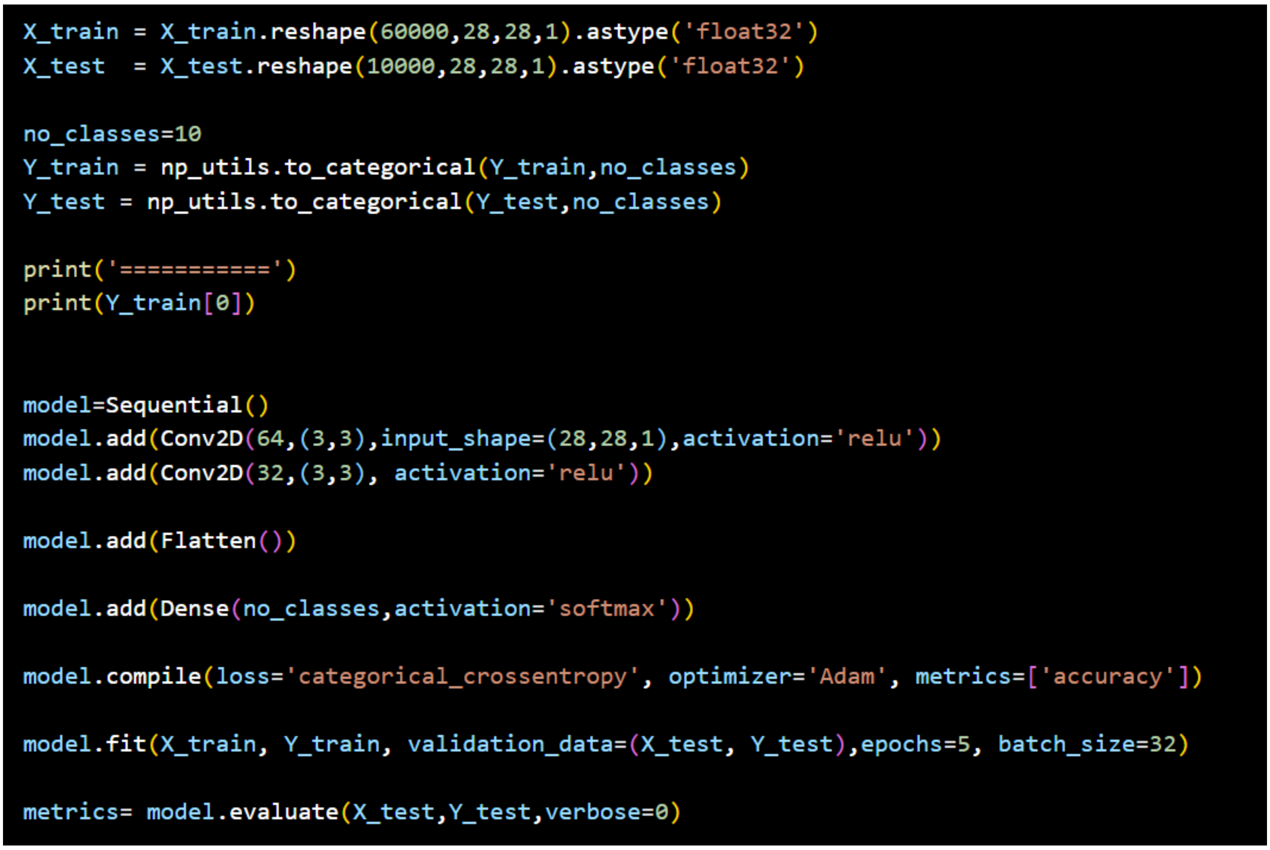
CODING & SOLUTIONING

7.1 Feature:

CNN Algorithm

In deep learning, a convolutional neural network (CNN/ConvNet) is a class of deep neural networks, most commonly applied to analyze visual imagery. Now when we think of a neural network we think about matrix multiplications but that is not the case with ConvNet. It uses a special technique called Convolution. Now in mathematics convolution is a mathematical operation on two functions that produces a third function that expresses how the shape of one is modified by the other.





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

no_classes=10
Y_train = np_utils.to_categorical(Y_train,no_classes)
Y_test = np_utils.to_categorical(Y_test,no_classes)

print('==========')
print(Y_train[0])


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(no_classes,activation='softmax'))

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

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

metrics= model.evaluate(X_test,Y_test,verbose=0)
```

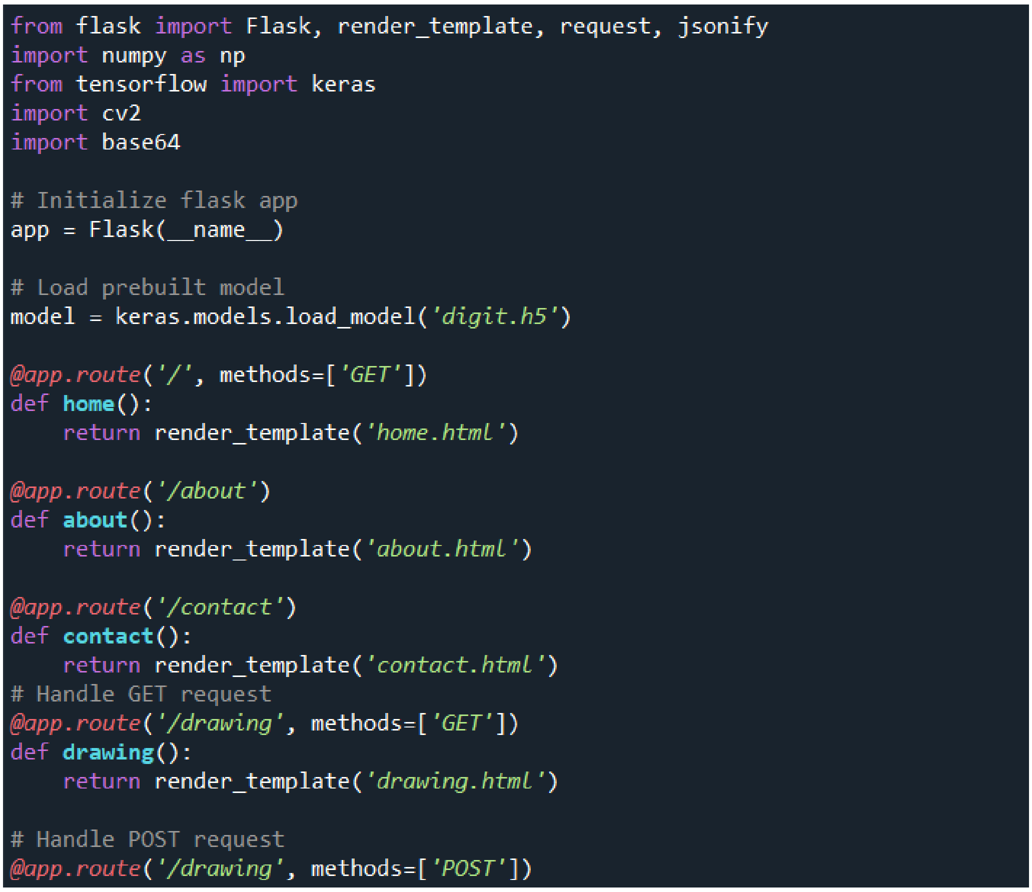
7.2 Feature 2

Flask Application

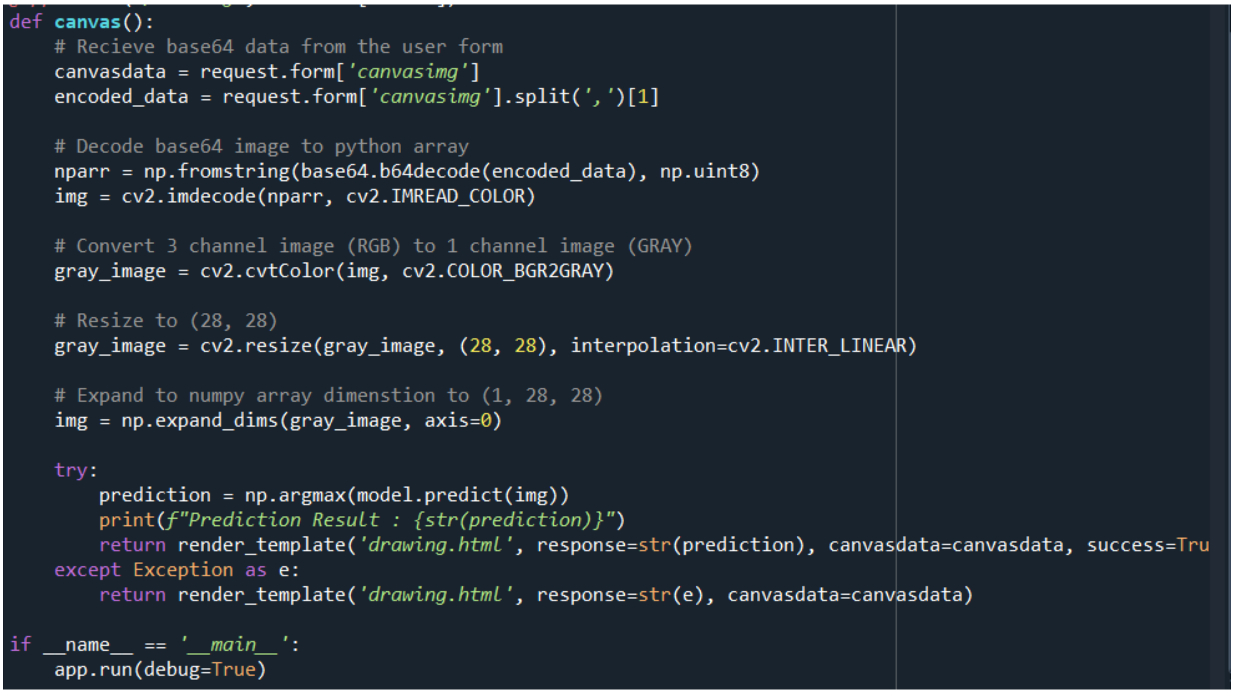
(class) Flask:

The flask object implements a WSGI application and acts as the central object. It is passed the name of the module or package of the application. Once it is created it will act as a central registry for the view functions, the URL rules, template configuration and much more.

The name of the package is used to resolve resources from inside the package or the folder the module is contained in depending on if the package parameter resolves to an actual python package (a folder with an _init_.py file inside) or a standard module (just a .py file).



```python
from flask import Flask, render_template, request, jsonify
import numpy as np
from tensorflow import keras
import cv2
import base64

# Initialize flask app
app = Flask(__name__)

# Load prebuilt model
model = keras.models.load_model('digit.h5')

@app.route('/', methods=['GET'])
def home():
    return render_template('home.html')

@app.route('/about')
def about():
    return render_template('about.html')

@app.route('/contact')
def contact():
    return render_template('contact.html')
# Handle GET request
@app.route('/drawing', methods=['GET'])
def drawing():
    return render_template('drawing.html')

# Handle POST request
@app.route('/drawing', methods=['POST'])
```



```python
def canvas():
    # Recieve base64 data from the user form
    canvasdata = request.form['canvasimg']
    encoded_data = request.form['canvasimg'].split(',')[1]

    # Decode base64 image to python array
    nparr = np.fromstring(base64.b64decode(encoded_data), np.uint8)
    img = cv2.imdecode(nparr, cv2.IMREAD_COLOR)

    # Convert 3 channel image (RGB) to 1 channel image (GRAY)
    gray_image = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

    # Resize to (28, 28)
    gray_image = cv2.resize(gray_image, (28, 28), interpolation=cv2.INTER_LINEAR)

    # Expand to numpy array dimenstion to (1, 28, 28)
    img = np.expand_dims(gray_image, axis=0)

    try:
        prediction = np.argmax(model.predict(img))
        print(f"Prediction Result : {str(prediction)}")
        return render_template('drawing.html', response=str(prediction), canvasdata=canvasdata, success=Tru
    except Exception as e:
        return render_template('drawing.html', response=str(e), canvasdata=canvasdata)

if __name__ == '__main__':
    app.run(debug=True)
```

CHAPTER 8

TESTING

8.1 Test Cases:

Defect Analysis:

Resolution	Severity 1	Severity 2	Severity 3	Severity 4	Subtotal
By Design	8	3	2	3	16
Duplicate	0	1	0	3	4
External	4	1	0	5	10
Fixed	13	4	3	19	39
Not Reproduced	1	1	0	1	3
Skipped	1	0	1	1	3
Won't Fix	0	0	2	3	5
Totals	27	10	8	35	80

Test Case Analysis:

Section	Total Cases	Not Tested	Fail	Pass
Register	20	0	5	15
Login	30	0	6	24
Redirect to recognition page	68	0	10	58
User input (Drawing)	10	0	0	10
Output prediction	70	0	59	11
Final Model Output	70	0	54	16
Security	20	0	2	18

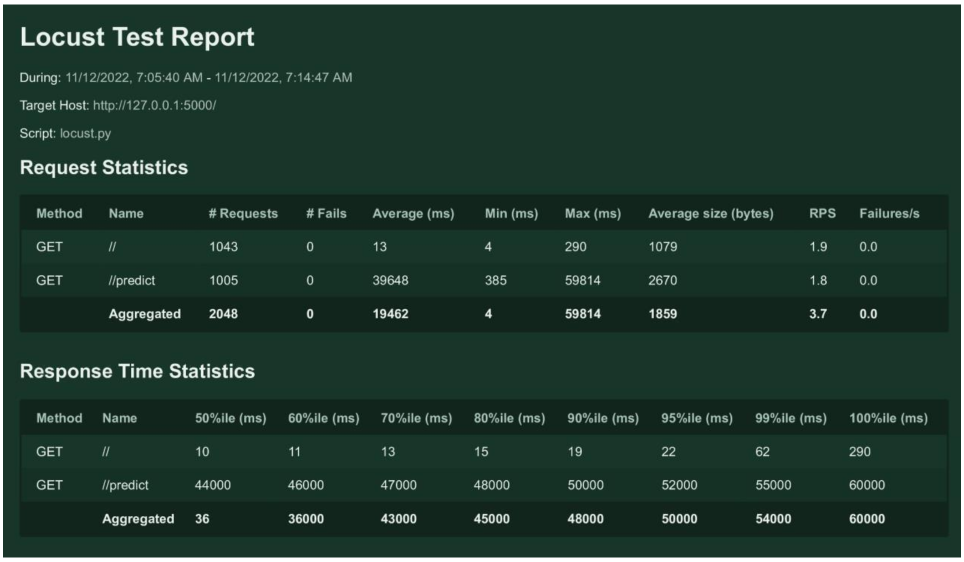
8.2 User Acceptance Testing:

Test case ID	Feature type	Component	Test Scenario	Pre-Requisite	Steps To Execute	Test Data	Expected Result	Actual Result	Status	Comments	TC for Automation(Y/N)	BUG ID	Executed By
Detection 01	User Interface webpage	Register Page	Verify user is able to see the Registration page	Active server and internet connection with frontend code for Detection	1.Enter Website URL and Search the URL 2.Display the Register Page to the user	http://127.0.0.1:5000	Register Page will display withthe Process of Front end	Worked as expected	Pass	User can view the registration page	Yes	--	PNT2022TMID29644 Team
Detection 02	User interface webpage	Register page	Verify user is able to register with user credentials	Active server and internet connection with frontendcode for Detection	1.Enter Website URLand Search the URL 2.Display the Register Page to the User 3.Able to register in registration page	http://127.0.0.1:5000	Successfully registered	Worked as expected	Pass	User can register	Yes	--	PNT2022TMID29644 Team
Detection 03	User interface webpage	Login page	Verify user is able to see the login page	Active server and internet connection with frontendcode for Detection HTML Search Tag with the valid URL	1.Enter Website URL and .Search the URL 2.Display the login Page to the user	http://127.0.0.1:5000	Login Page will be display with the Process of Front end	Worked as expected	Pass	User can view the login page	Yes	--	PNT2022TMID29644 Team
Detection 04	User interface webpage	Login page	Verify user is able to login using user credentials	Active server and internet connection with frontendcode for Detection HTML Search Tag with the valid URL	1.Enter Website URL and Search the URL 2.Display the Login Page to the User 3.Able to login in login page	http://127.0.0.1:5000	Successful login	Worked as expected	Pass	User can login into web app	Yes	--	PNT2022TMID29644 Team
Detection 04	Conversion	Detection Page	Verify user is able to see the recognition page	Active server and internet connection	1.Enter URL (https://127.0.0.1:5000)and check 2.The URL will redirect to theconversion page	http://127.0.0.1:5000	Able to see Recognize page	Worked as expected	Pass	User can see the recognition page	Yes	--	PNT2022TMID29644 Team
Detection 06	Prediction	Detection Page	Verify user can able to draw the digit	Active server and internet connection	1.Enter URL (https://127.0.0.1:5000)and check 2.The URL will redirect to theconversion page 3.Draw the digit	http://127.0.0.1:5000	Able to draw the digit	Worked as expected	Pass	User can draw the digit in the recognition page	Yes	--	PNT2022TMID29644 Team
Detection 07	Prediction	Detection Page	Verify the user able to get the predicted result of the digit drawn	Active server and internet connection	1.Enter URL (https://127.0.0.1:5000)and check 2.The URL will redirect to theconversion page 3.Draw the digit 4.Get predicted output	http://127.0.0.1:5000	Able to get the predicted digit	Worked as expected	Pass	User can get the predicted digit as output	Yes	--	PNT2022TMID29644 Team

CHAPTER 9

RESULTS

Performance Metrics:



Locust Test Report

During: 11/12/2022, 7:05:40 AM - 11/12/2022, 7:14:47 AM

Target Host: http://127.0.0.1:5000/

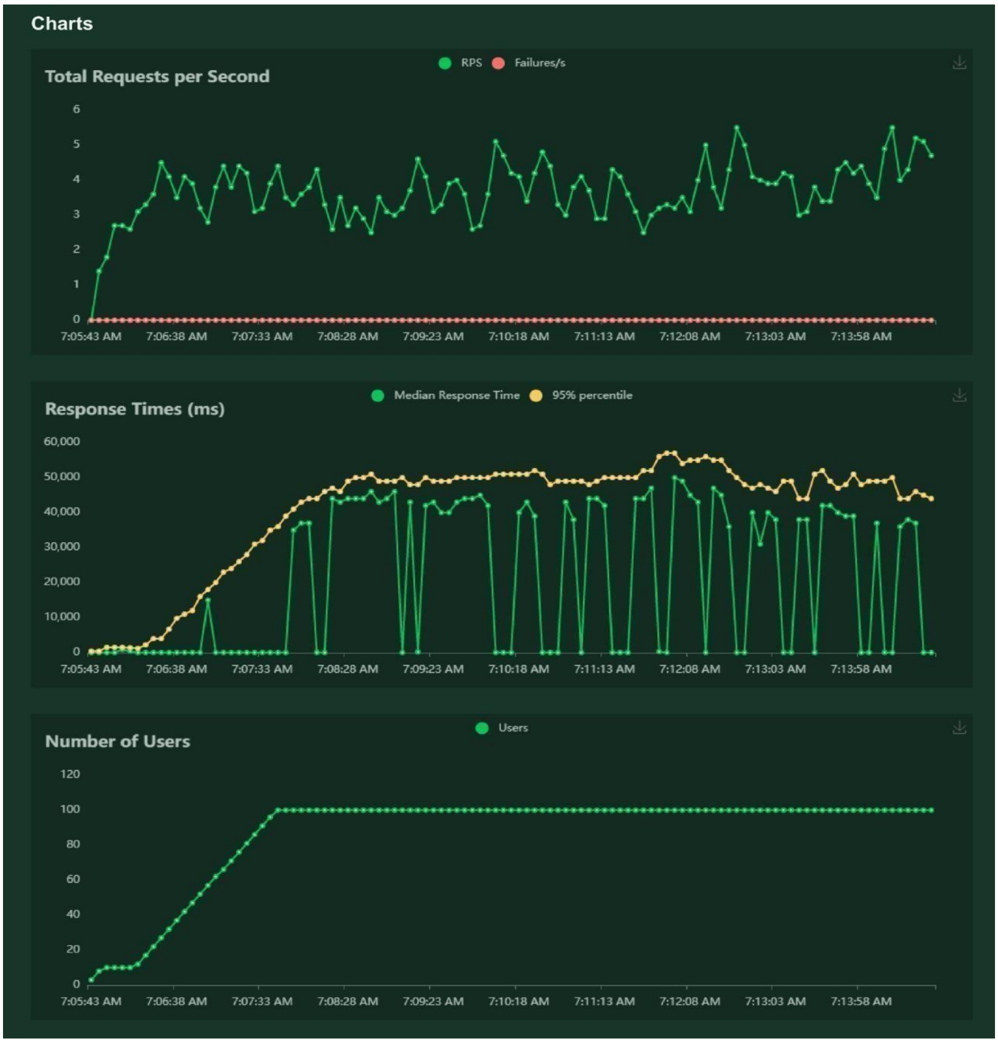
Script: locust.py

Request Statistics

Method	Name	# Requests	# Fails	Average (ms)	Min (ms)	Max (ms)	Average size (bytes)	RPS	Failures/s
GET	//	1043	0	13	4	290	1079	1.9	0.0
GET	//predict	1005	0	39648	385	59814	2670	1.8	0.0
	Aggregated	**2048**	**0**	**19462**	**4**	**59814**	**1859**	**3.7**	**0.0**

Response Time Statistics

Method	Name	50%ile (ms)	60%ile (ms)	70%ile (ms)	80%ile (ms)	90%ile (ms)	95%ile (ms)	99%ile (ms)	100%ile (ms)
GET	//	10	11	13	15	19	22	62	290
GET	//predict	44000	46000	47000	48000	50000	52000	55000	60000
	Aggregated	**36**	**36000**	**43000**	**45000**	**48000**	**50000**	**54000**	**60000**



CHAPTER 10

ADVANTAGES & DISADVANTAGES

Advantages:

- It reduces human effort and labour cost.
- It saves times for arranging and sorting huge amount of data
- Only requires far less physical space than the storage of the physical copies.
- Recognising multiple digits on a single frame using sequential model in Keras.
- Data storage, for an example, there are many files, contracts and some personal records that contains some handwritten digits.
- This can be used for sorting through mail by postal code

Disadvantages:

- The system build is complex and holds difficulty
- The handwriting of every individual varies which proves to be a challenge for the system to predict
- Possible unemployment of labour that is typical of technology growth
- The accuracy is not guarantees and there are risks of errors

CHAPTER 11

CONCLUSION

Our project Hand Written Digit Recognition's main purpose is to build an automatic handwritten digit recognition method for the recognition of handwritten digit strings. This project demonstrated a web application that uses machine learning to recognize handwritten numbers. It is done using MNIST dataset and Deep Learning algorithm- multilayer CNN, the use of Keras with Tensorflow that grant the absolute best accuracy. Flask, HTML, CSS, JavaScript, and a few other technologies were used to build this project. 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. Digit recognition is an excellent prototype problem for learning about neural networks and it gives a great way to develop more advanced techniques of deep learning and there is so much room for improvement, which can be implemented in subsequent versions.

CHAPTER 12

FUTURE SCOPE

In future, different architectures of CNN, namely, hybrid CNN, viz., CNN-RNN and CNN-HMM models, and domain-specific recognition systems, can be investigated. The future development of the applications based on algorithms of deep and machine learning is practically boundless.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 from digits multiple images and save the results
- 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

CHAPTER 13

APPENDIX

Source Code:

App:

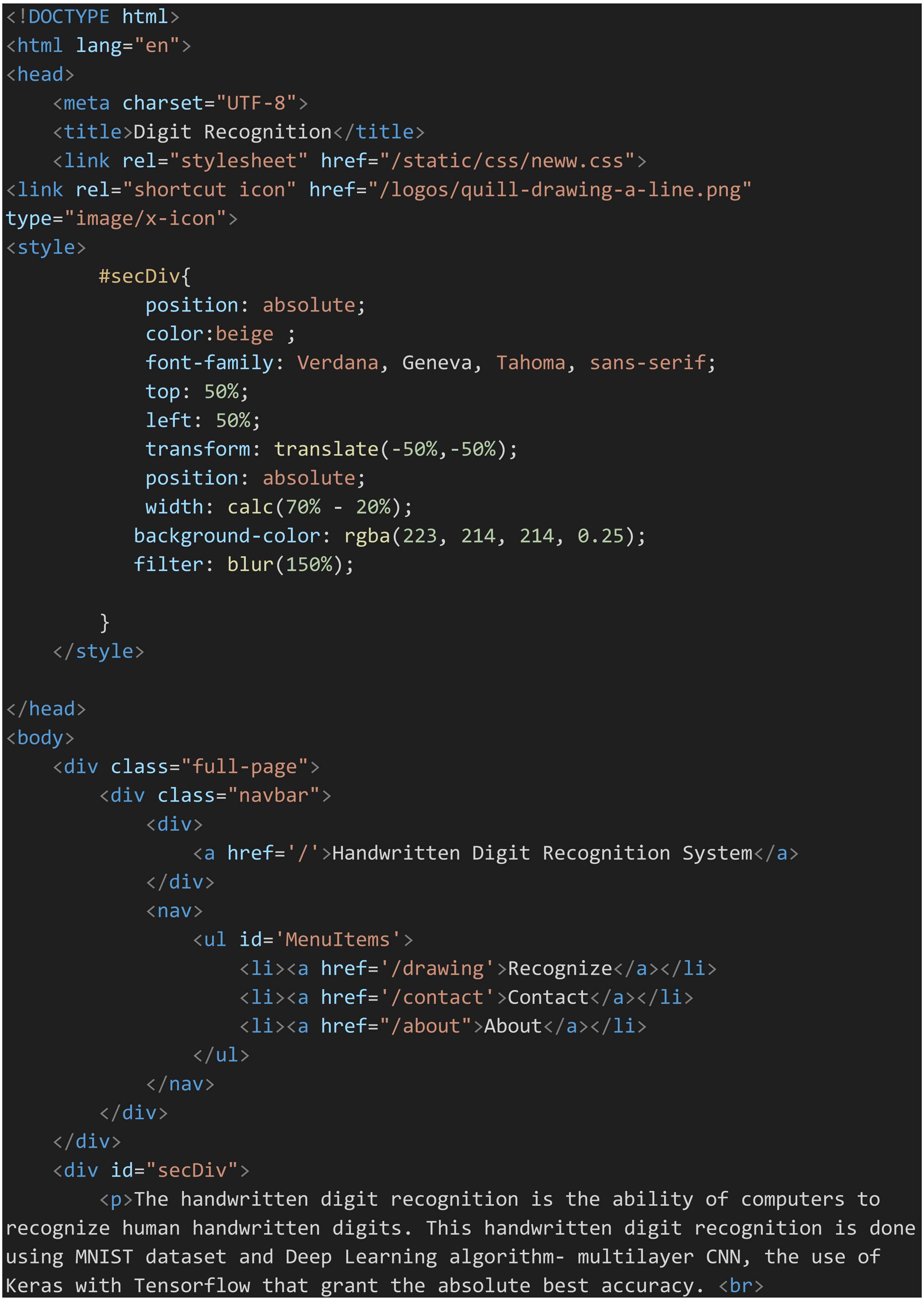
```
from flask import Flask, render_template, request, jsonify
import numpy as np
from tensorflow import keras
import cv2
import base64
# Initialize flask app
app = Flask(__name__)
# Load prebuilt model
model = keras.models.load_model('digit.h5')
@app.route('/', methods=['GET'])
def home():
    return render_template('home.html')
@app.route('/about')
def about():
    return render_template('about.html')
@app.route('/contact')
def contact():
    return render_template('contact.html')
# Handle GET request
@app.route('/drawing', methods=['GET'])
def drawing():
    return render_template('drawing.html')
# Handle POST request
@app.route('/drawing', methods=['POST'])
def canvas():
    # Recieve base64 data from the user form
    canvasdata = request.form['canvasimg']
    encoded_data = request.form['canvasimg'].split(',')[1]

    # Decode base64 image to python array
    nparr = np.fromstring(base64.b64decode(encoded_data), np.uint8)
    img = cv2.imdecode(nparr, cv2.IMREAD_COLOR)

    # Convert 3 channel image (RGB) to 1 channel image (GRAY)
    gray_image = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

    # Resize to (28, 28)
    gray_image = cv2.resize(gray_image, (28, 28), interpolation=cv2.INTER_LINEAR)

    # Expand to numpy array dimenstion to (1, 28, 28)
    img = np.expand_dims(gray_image, axis=0)

    try:
        prediction = np.argmax(model.predict(img))
        print(f"Prediction Result : {str(prediction)}")
        return render_template('drawing.html', response=str(prediction), canvasdata=canvasdata, success=True)
    except Exception as e:
        return render_template('drawing.html', response=str(e), canvasdata=canvasdata)

if __name__ == '__main__':
    app.run(debug=True)
```

Model:

```
from tensorflow import keras
import numpy as np
from keras.datasets import mnist
from keras.models import Sequential
from keras import layers
from keras.layers import Dense, Flatten, Conv2D
from keras.optimizer_v1 import Adam
from keras.utils import np_utils
import matplotlib.pyplot as plt
(X_train, Y_train), (X_test, Y_test) = mnist.load_data()
print('*'*20)
print(X_train.shape)
print(X_test.shape)
print('*'*20)
print(X_train[0])
print('===============')
print(Y_train)
print('-------------')
plt.imshow(X_train[0])
X_train = X_train.reshape(60000,28,28,1).astype('float32')
X_test  = X_test.reshape(10000,28,28,1).astype('float32')
no_classes=10
Y_train = np_utils.to_categorical(Y_train,no_classes)
Y_test = np_utils.to_categorical(Y_test,no_classes)
print('===========')
print(Y_train[0])
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(no_classes,activation='softmax'))
model.compile(loss='categorical_crossentropy', optimizer='Adam', metrics=['accuracy'])
model.fit(X_train, Y_train, validation_data=(X_test, Y_test),epochs=5, batch_size=32)
metrics= model.evaluate(X_test,Y_test,verbose=0)
print("Metrics")
print(metrics)
prediction=model.predict(X_test[:4])
print(prediction)
print(np.argmax(prediction,axis=1))
print(Y_test[:4])
model.save('digit.h5')
```

HTML:

Homepage:

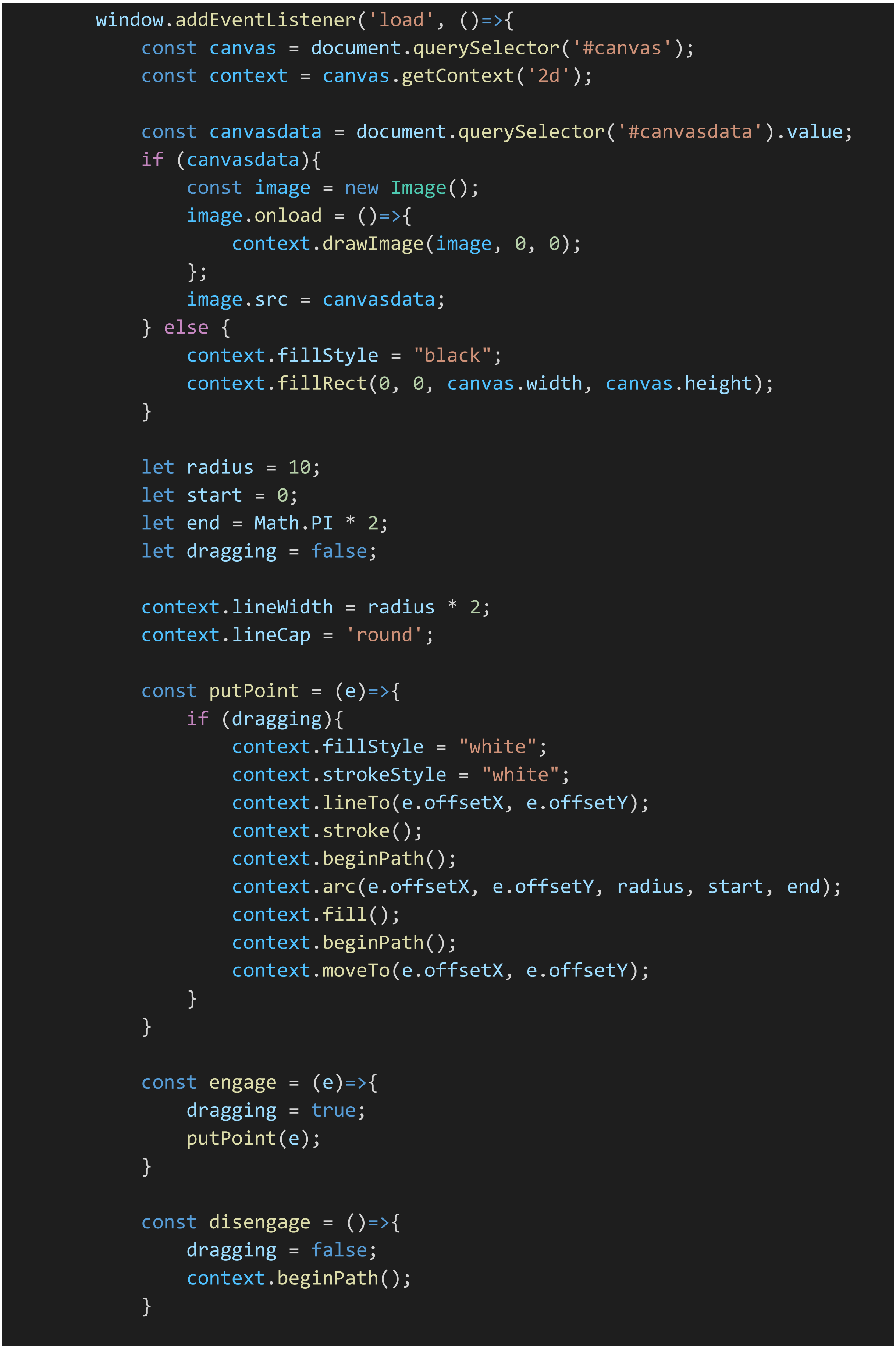


```
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <title>Digit Recognition</title>
    <link rel="stylesheet" href="/static/css/neww.css">
<link rel="shortcut icon" href="/logos/quill-drawing-a-line.png"
type="image/x-icon">
<style>
        #secDiv{
            position: absolute;
            color:beige ;
            font-family: Verdana, Geneva, Tahoma, sans-serif;
            top: 50%;
            left: 50%;
            transform: translate(-50%,-50%);
            position: absolute;
            width: calc(70% - 20%);
           background-color: rgba(223, 214, 214, 0.25);
           filter: blur(150%);

        }
    </style>

</head>
<body>
    <div class="full-page">
        <div class="navbar">
            <div>
                <a href='/'>Handwritten Digit Recognition System</a>
            </div>
            <nav>
                <ul id='MenuItems'>
                    <li><a href='/drawing'>Recognize</a></li>
                    <li><a href='/contact'>Contact</a></li>
                    <li><a href="/about">About</a></li>
                </ul>
            </nav>
        </div>
    </div>
    <div id="secDiv">
        <p>The handwritten digit recognition is the ability of computers to
recognize human handwritten digits. This handwritten digit recognition is done
using MNIST dataset and Deep Learning algorithm- multilayer CNN, the use of
Keras with Tensorflow that grant the absolute best accuracy. <br>
```

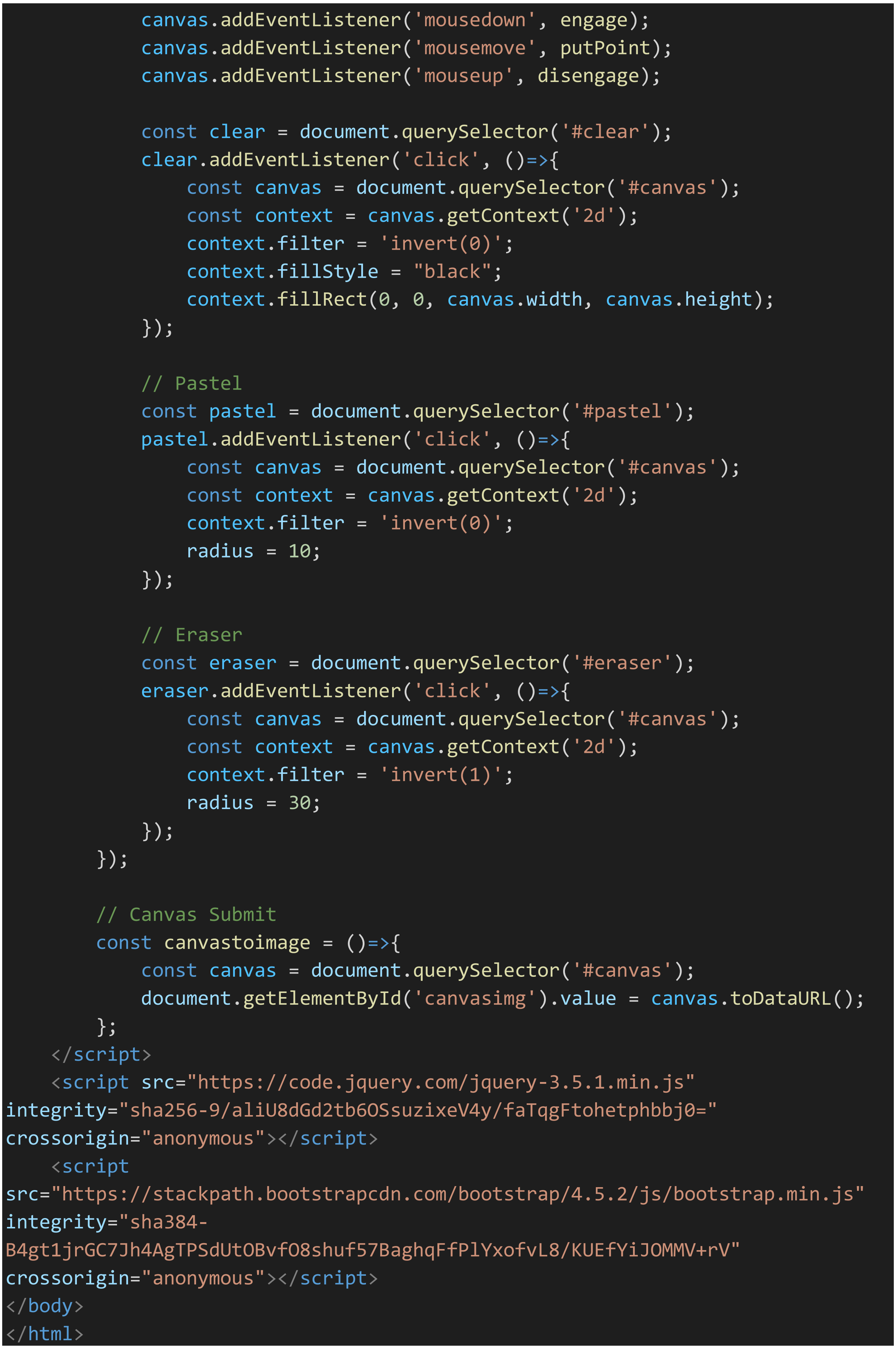
```
            Accuracy : 97%
            <br>

            Software used: Python, Jupyter notebook.

        </p>
    </div>
</body>
</html>
```

Drawing Page:

```
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <title>Number Recognizer</title>
    <link rel="stylesheet"
href="https://stackpath.bootstrapcdn.com/bootstrap/4.5.2/css/bootstrap.min.css
" integrity="sha384-
JcKb8q3iqJ61gNV9KGb8thSsNjpSL0n8PARn9HuZOnIxN0hoP+VmmDGMN5t9UJ0Z"
crossorigin="anonymous">
    <style>
        .tools {
            width:400px;
            position:absolute;
            left: 50%;
            transform: translate(-50%,-100%);
        }
        .tools button{
            border: 2px solid rgb(0, 0, 0);
            width: 400px;
            border-radius: 0px;
        }
        .container.mt-4{
            /* background-color: red; */
            top: 50%;
            position: absolute;
            left: 50%;
            transform: translate(-50%,-30%);
            /* box-shadow: black 0 0 50px; */
        }
        #send{
            border-radius: 0 0 8px 8px;
        }

        .navbar.text-light.bg-info{
            background-color: rgb(62, 12, 142)!important;
        }

    </style>
</head>
<body>
    <nav class="navbar text-light bg-info" >
        <div class="mx-auto"><h1 style="font-family: arial">Number 
Recognizer</h1></div>
    </nav>
    {% if response %}
        {% if success %}
            <p class="alert alert-success m-4 text-center">Prediction Result : 
{{ response }}</p>
        {% else %}
            <p class="alert alert-success m-4 text-center">{{ response }}</p>
        {% endif %}
    {% endif %}
    <div class="container mt-4" >
        <div class="row" style="width: 280px; margin: auto;" >
            <div class="tools d-flex justify-content-between">
                <button class="btn btn-danger" id="clear">Clear</button>
                <button class="btn btn-success" id="pastel" 
onclick="pastel()">Pastel</button>
                <button class="btn btn-warning" id="eraser" 
onclick="eraser()">Eraser</button>
            </div>
        </div>
        <form action="/drawing" method="POST" onsubmit="canvastoimage()">
            <div class="row">
                <div class="col d-flex justify-content-center">
                    <input type="hidden" id="canvasimg" name="canvasimg">
                    <input type="hidden" id="canvasdata" name="canvasdata" 
value="{{ canvasdata }}">
                    <canvas id="canvas" width="400" height="280"></canvas>
                </div>
            </div>
            <div class="row">
                <div class="col d-flex justify-content-center">
                    <button style="width: 400px;" class="btn btn-success" 
id="send" type="submit">Detect Number</button>
                </div>
            </div>
        </form>
    </div>

    <script>
        // Canvas Drawing
```

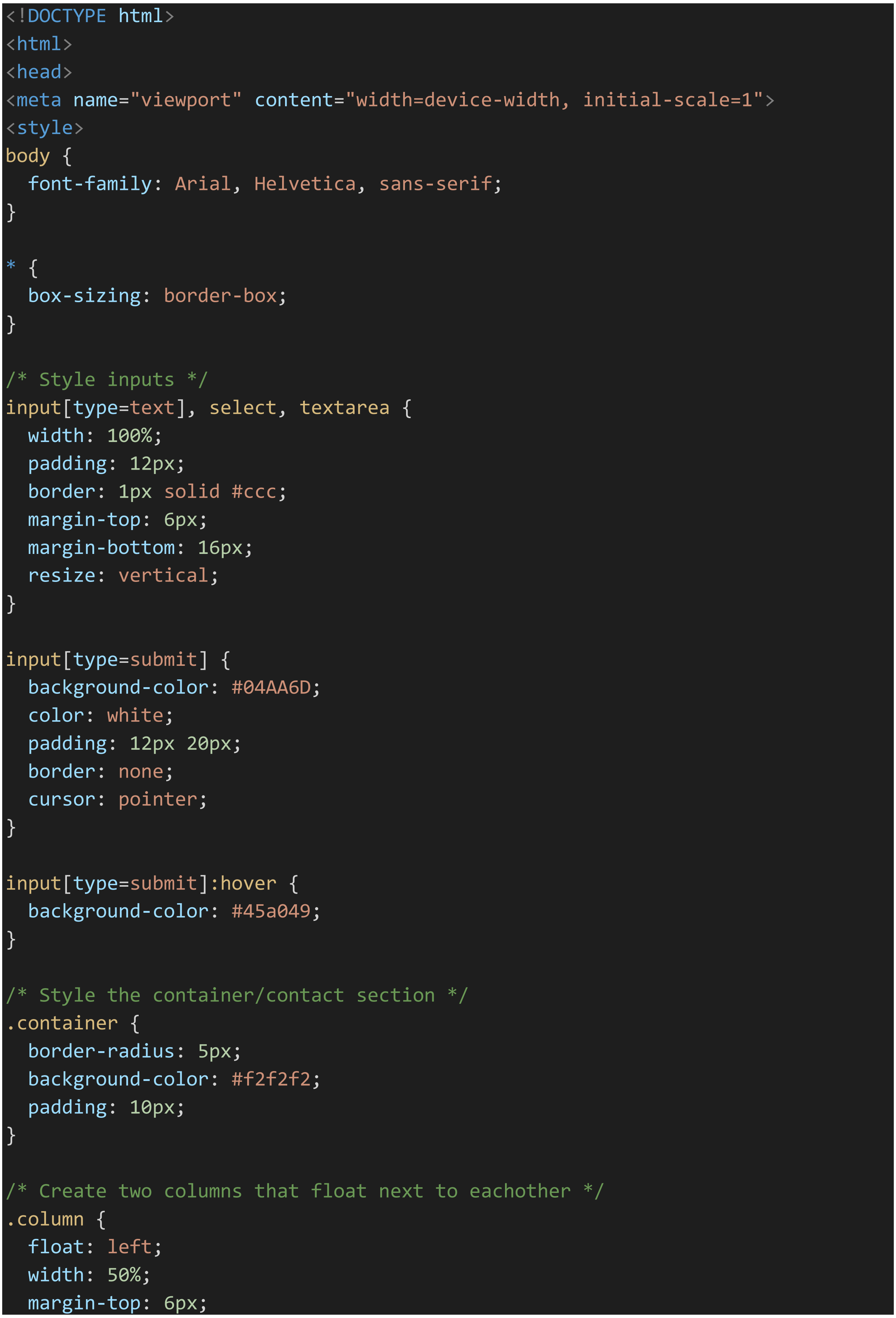


```
window.addEventListener('load', ()=>{
    const canvas = document.querySelector('#canvas');
    const context = canvas.getContext('2d');

    const canvasdata = document.querySelector('#canvasdata').value;
    if (canvasdata){
        const image = new Image();
        image.onload = ()=>{
            context.drawImage(image, 0, 0);
        };
        image.src = canvasdata;
    } else {
        context.fillStyle = "black";
        context.fillRect(0, 0, canvas.width, canvas.height);
    }

    let radius = 10;
    let start = 0;
    let end = Math.PI * 2;
    let dragging = false;

    context.lineWidth = radius * 2;
    context.lineCap = 'round';

    const putPoint = (e)=>{
        if (dragging){
            context.fillStyle = "white";
            context.strokeStyle = "white";
            context.lineTo(e.offsetX, e.offsetY);
            context.stroke();
            context.beginPath();
            context.arc(e.offsetX, e.offsetY, radius, start, end);
            context.fill();
            context.beginPath();
            context.moveTo(e.offsetX, e.offsetY);
        }
    }

    const engage = (e)=>{
        dragging = true;
        putPoint(e);
    }

    const disengage = ()=>{
        dragging = false;
        context.beginPath();
    }
```

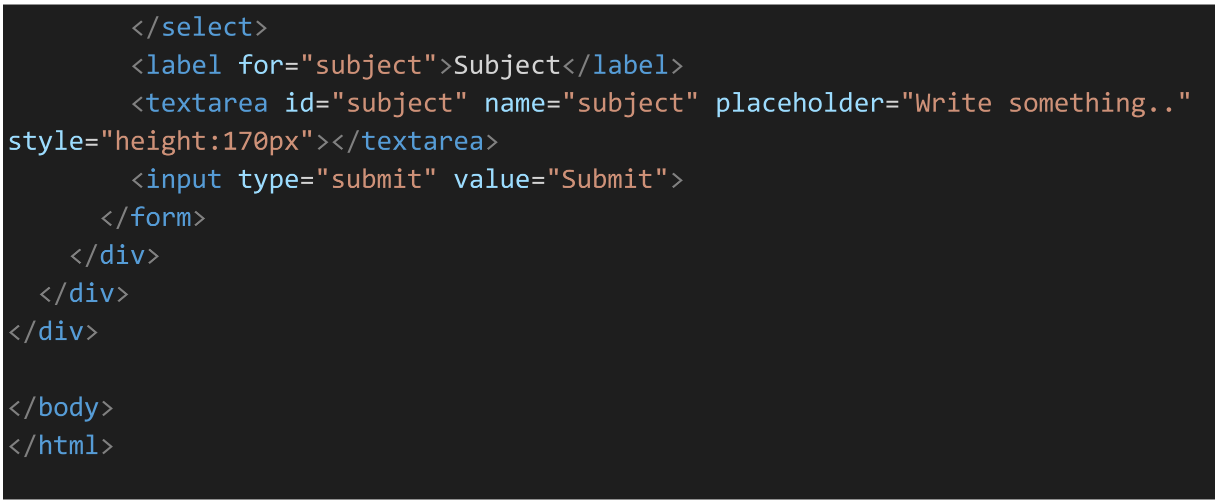


```
            canvas.addEventListener('mousedown', engage);
            canvas.addEventListener('mousemove', putPoint);
            canvas.addEventListener('mouseup', disengage);

            const clear = document.querySelector('#clear');
            clear.addEventListener('click', ()=>{
                const canvas = document.querySelector('#canvas');
                const context = canvas.getContext('2d');
                context.filter = 'invert(0)';
                context.fillStyle = "black";
                context.fillRect(0, 0, canvas.width, canvas.height);
            });

            // Pastel
            const pastel = document.querySelector('#pastel');
            pastel.addEventListener('click', ()=>{
                const canvas = document.querySelector('#canvas');
                const context = canvas.getContext('2d');
                context.filter = 'invert(0)';
                radius = 10;
            });

            // Eraser
            const eraser = document.querySelector('#eraser');
            eraser.addEventListener('click', ()=>{
                const canvas = document.querySelector('#canvas');
                const context = canvas.getContext('2d');
                context.filter = 'invert(1)';
                radius = 30;
            });
        });

        // Canvas Submit
        const canvastoimage = ()=>{
            const canvas = document.querySelector('#canvas');
            document.getElementById('canvasimg').value = canvas.toDataURL();
        };
    </script>
    <script src="https://code.jquery.com/jquery-3.5.1.min.js"
integrity="sha256-9/aliU8dGd2tb6OSsuzixeV4y/faTqgFtohetphbbj0="
crossorigin="anonymous"></script>
    <script
src="https://stackpath.bootstrapcdn.com/bootstrap/4.5.2/js/bootstrap.min.js"
integrity="sha384-
B4gt1jrGC7Jh4AgTPSdUtOBvfO8shuf57BaghqFfPlYxofvL8/KUEfYiJOMMV+rV"
crossorigin="anonymous"></script>
</body>
</html>
```

Contact Page:

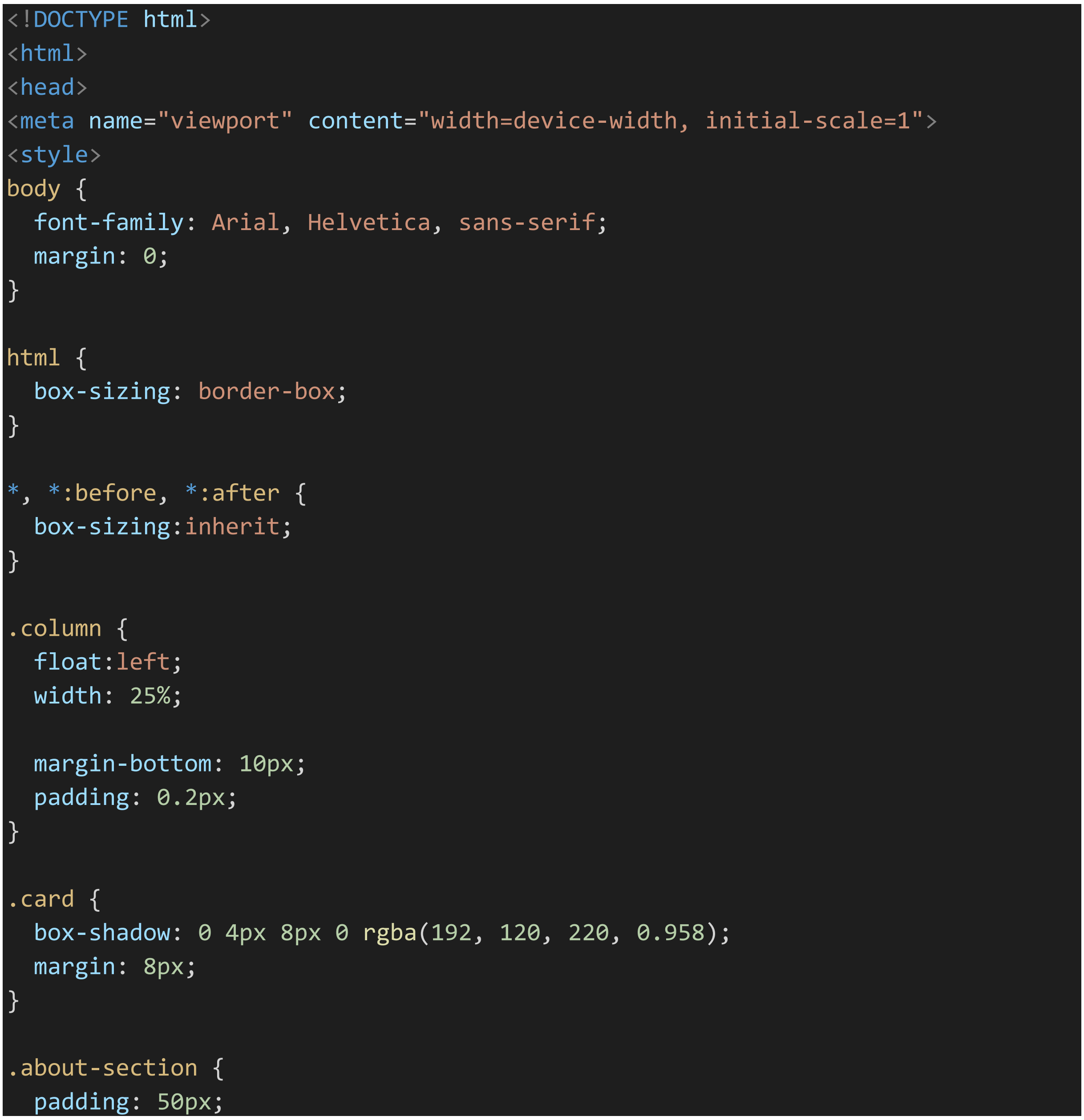


```
<!DOCTYPE html>
<html>
<head>
<meta name="viewport" content="width=device-width, initial-scale=1">
<style>
body {
  font-family: Arial, Helvetica, sans-serif;
}

* {
  box-sizing: border-box;
}

/* Style inputs */
input[type=text], select, textarea {
  width: 100%;
  padding: 12px;
  border: 1px solid #ccc;
  margin-top: 6px;
  margin-bottom: 16px;
  resize: vertical;
}

input[type=submit] {
  background-color: #04AA6D;
  color: white;
  padding: 12px 20px;
  border: none;
  cursor: pointer;
}

input[type=submit]:hover {
  background-color: #45a049;
}

/* Style the container/contact section */
.container {
  border-radius: 5px;
  background-color: #f2f2f2;
  padding: 10px;
}

/* Create two columns that float next to eachother */
.column {
  float: left;
  width: 50%;
  margin-top: 6px;
  padding: 20px;
}

/* Clear floats after the columns */
.row:after {
  content: "";
  display: table;
  clear: both;
}

/* Responsive layout - when the screen is less than 600px wide, make the two
columns stack on top of each other instead of next to each other */
@media screen and (max-width: 600px) {
  .column, input[type=submit] {
    width: 100%;
    margin-top: 0;
  }
}
</style>
</head>
<body>

<h2>Contact Section</h2>


<div class="container">
  <div style="text-align:center">
    <h2>Contact Us</h2>
    <p>Swing by for a cup of coffee, or leave us a message:</p>
  </div>
  <div class="row">
    <div class="column">
      <img src="https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcSNP3-
yYMQmqgEqqM1QZkERCYLyesnaylta9w&usqp=CAU" style="width:30%">
    </div>
    <div class="column">
      <form action="/action_page.php">
        <label for="fname">First Name</label>
        <input type="text" id="fname" name="firstname" placeholder="Your
name..">
        <label for="lname">Last Name</label>
        <input type="text" id="lname" name="lastname" placeholder="Your last
name..">
        <label for="city">City</label>
        <select id="city" name="city">
          <option value="Chennai">Chennai</option>
          <option value="Delhi">Delhi</option>
          <option value="Mumbai">Mumbai</option>
          <option value="Vellore">Vellore</option>
```

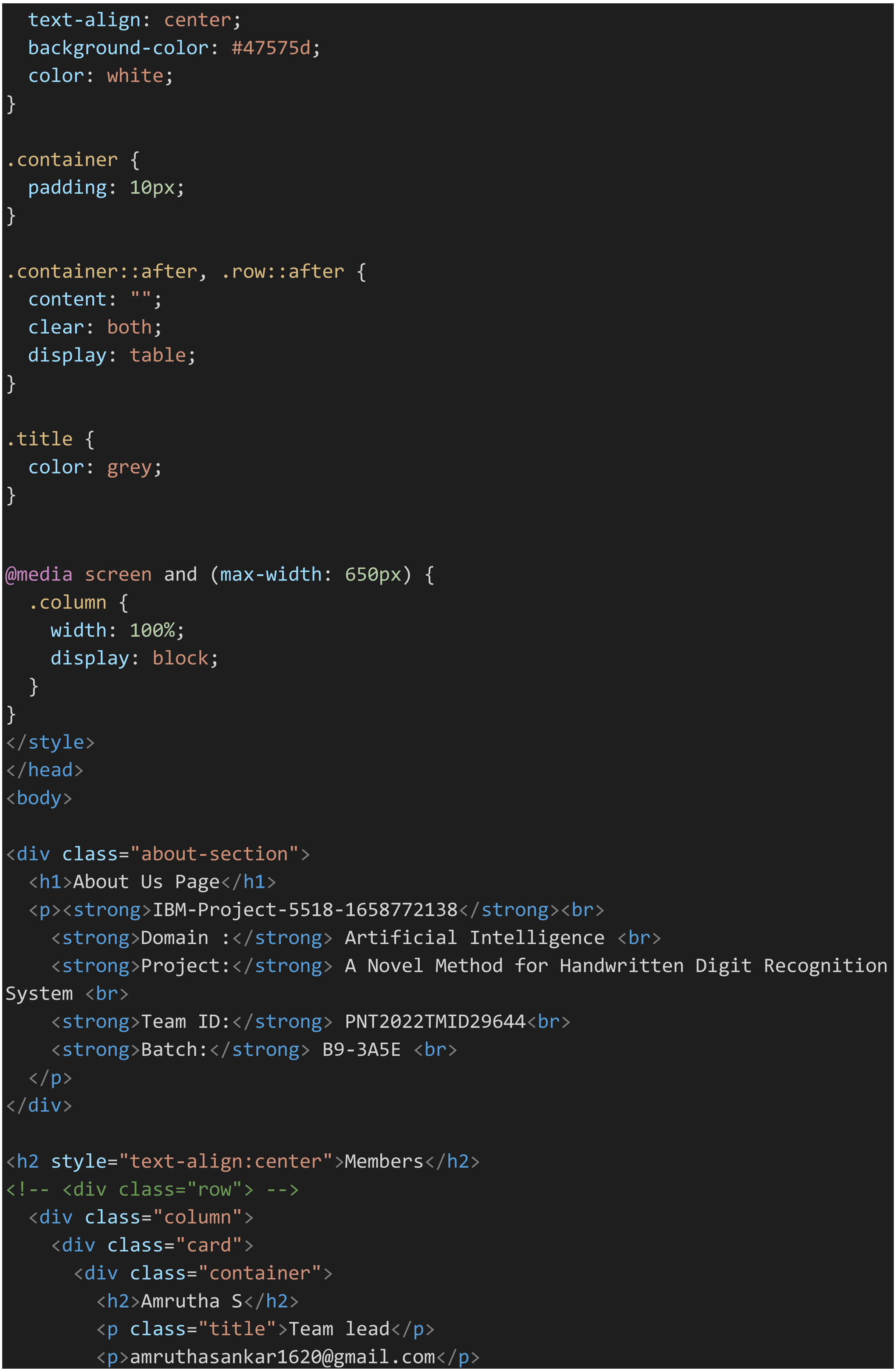


```
        </select>
        <label for="subject">Subject</label>
        <textarea id="subject" name="subject" placeholder="Write something.."
style="height:170px"></textarea>
        <input type="submit" value="Submit">
      </form>
    </div>
  </div>
</div>

</body>
</html>
```

About:



```
<!DOCTYPE html>
<html>
<head>
<meta name="viewport" content="width=device-width, initial-scale=1">
<style>
body {
  font-family: Arial, Helvetica, sans-serif;
  margin: 0;
}

html {
  box-sizing: border-box;
}

*, *:before, *:after {
  box-sizing:inherit;
}

.column {
  float:left;
  width: 25%;

  margin-bottom: 10px;
  padding: 0.2px;
}

.card {
  box-shadow: 0 4px 8px 0 rgba(192, 120, 220, 0.958);
  margin: 8px;
}

.about-section {
  padding: 50px;
```



```
  text-align: center;
  background-color: #47575d;
  color: white;
}

.container {
  padding: 10px;
}

.container::after, .row::after {
  content: "";
  clear: both;
  display: table;
}

.title {
  color: grey;
}


@media screen and (max-width: 650px) {
  .column {
    width: 100%;
    display: block;
  }
}
</style>
</head>
<body>

<div class="about-section">
  <h1>About Us Page</h1>
  <p><strong>IBM-Project-5518-1658772138</strong><br>
    <strong>Domain :</strong> Artificial Intelligence <br>
    <strong>Project:</strong> A Novel Method for Handwritten Digit Recognition
System <br>
    <strong>Team ID:</strong> PNT2022TMID29644<br>
    <strong>Batch:</strong> B9-3A5E <br>
  </p>
</div>

<h2 style="text-align:center">Members</h2>
<!-- <div class="row"> -->
  <div class="column">
    <div class="card">
      <div class="container">
        <h2>Amrutha S</h2>
        <p class="title">Team lead</p>
        <p>amruthasankar1620@gmail.com</p>
```

```
   </div>
  </div>
 </div>
 </div>

 <div class="column">
  <!-- <div class="row"> -->
  <div class="card">
   <div class="container">
    <h2>Anitha K</h2>
    <p class="title">Member1</p>
    <p>anithavelv@gmail.com</p>
   </div>
  </div>
  </div>
 </div>
<!--
 <div class="row"> -->
 <div class="column">
  <div class="card">
   <div class="container">
    <h2>Devendran M</h2>
    <p class="title">Member2</p>
    <p>devashiva8778@gmail.com</p>
   </div>
  </div>
 </div>
</div>

<div class="row">
<div class="column">
  <div class="card">
   <div class="container">
    <h2>Hemavathy T A</h2>
    <p class="title">Member3</p>
    <p>hemaumaamar@gmail.com</p>
   </div>
  </div>
 </div>
</div>

<h3> About Project:</h3>
<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. 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>

</body>
</html>
```

GitHub Link:

https://github.com/IBM-EPBL/IBM-Project-5518-1658772138

Project Demo Link:

https://github.com/IBM-EPBL/IBM-Project-5518-1658772138/blob/main/Final%20Deliverables/Demo%20Video/Demo%20Video.mp4