

PROJECT REPORT

A NOVEL METHOD FOR HANDWRITTEN DIGIT RECOGNITION

submitted by

PNT2022TMID27288

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CHAPTER 1

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 recognise 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 cheque, 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 cheque amounts, numeric entries in forms filled up by hand (tax forms) and so on.

CHAPTER 2

LITERATURE SURVEY

2.1 EXISTING PROBLEM

The main issue with handwritten digit recognition is that because handwriting varies from person to person, handwritten digits do not always have the same size, width, orientation, and margins. 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 distinctiveness and variety of each person's handwriting have an impact on the digits' shape and appearance.

2.2 REFERENCES

Improved Handwritten Digit Recognition Using Convolutional Neural Networks (CNN) (2020)

Ahlawat, Savita and Choudhary, Amit and Nayyar, Anand and Singh, Saurabh and Yoon, Byungun

This paper's primary goal was to enhance handwritten digit recognition ability. To avoid difficult pre-processing, expensive feature extraction, and a complex ensemble (classifier combination) method of a standard recognition system, they examined different convolutional neural network variations. Their current work makes suggestions on the function of several hyper-parameters through thorough evaluation utilizing an MNIST dataset. They also confirmed that optimizing hyper-parameters is crucial for enhancing CNN architecture performance. With the Adam optimizer for the MNIST database, they were able to surpass many previously

published results with a recognition rate of 99.89%. Through the trials, it is made abundantly evident how the performance of handwritten digit recognition is affected by the number of convolutional layers in CNN architecture. According to the paper, evolutionary algorithms can be explored for optimizing convolutional filter kernel sizes, CNN learning parameters, and the quantity of layers and learning rates.

An Efficient And Improved Scheme For Handwritten Digit Recognition Based On Convolutional Neural Network (2019)

Ali, Saqib and Shaukat, Zeeshan and Azeem, Muhammad and Sakawat, Zareen and Mahmood, Tariq and others

This study uses rectified linear units (ReLU) activation and a convolutional neural network (CNN) that incorporates the Deeplearning4j (DL4J) architecture to recognize handwritten digits. The proposed CNN framework has all the necessary parameters for a high level of MNIST digit classification accuracy. The system's training takes into account the time factor as well. The system is also tested by altering the number of CNN layers for additional accuracy verification. It is important to note that the CNN architecture consists of two convolutional layers, the first with 32 filters and a 5x5 window size and the second with 64 filters and a 7x7 window size. In comparison to earlier proposed systems, the experimental findings show that the proposed CNN architecture for the MNIST dataset demonstrates great performance in terms of time and accuracy. As a result, handwritten numbers are detected with a recognition rate of 99.89% and high precision (99.21%) in a short amount of time.

Improved Handwritten Digit Recognition Using Quantum K-Nearest Neighbor Algorithm (2019)

Wang, Yuxiang and Wang, Ruijin and Li, Dongfen and Adu-Gyamfi, Daniel and Tian, Kaibin and Zhu, Yixin

The KNN classical machine learning technique is used in this research to enable quantum parallel computing and superposition. They used the KNN algorithm with quantum acceleration to enhance handwritten digit recognition. When dealing with more complicated and sizable handwritten digital data sets, their suggested method considerably lowered the computational time complexity of the traditional KNN algorithm. The paper offered a theoretical investigation of how quantum concepts can be applied to machine learning. Finally, they established a fundamental operational concept and procedure for machine learning with quantum acceleration.

Handwritten Digit Recognition Using Machine And Deep Learning Algorithms (2021)

Pashine, Samay and Dixit, Ritik and Kushwah, Rishika

In this study, they developed three deep and machine learning-based models for handwritten digit recognition using MNIST datasets. To determine which model was the most accurate, they compared them based on their individual properties. Support vector machines are among the simplest classifiers, making them faster than other algorithms and providing the highest training accuracy rate in this situation. However, due to their simplicity, SVMs cannot categorize complicated and ambiguous images as accurately as MLP and CNN algorithms can. In their research, they discovered that CNN produced the most precise outcomes for handwritten digit recognition.

The solution for all types of prediction issues, including those using picture data. Next, by comparing the execution times of the algorithms, they determined that increasing the number of epochs without changing the configuration of the algorithm is pointless due to the limitation of a certain model, and they discovered that beyond a certain number of epochs, the model begins over-fitting the dataset and provides biased predictions.

2.3 PROBLEM STATEMENT DEFINITION

For years, the traffic department has been combating traffic law violators. These offenders endanger not only their own lives, but also the lives of other individuals. Punishing these offenders is critical to ensuring that others do not become like them. Identification of these offenders is next to impossible because it is impossible for the average individual to write down the license plate of a reckless driver. Therefore, the goal of this project is to help the traffic department identify these offenders and reduce traffic violations as a result.

CHAPTER 3

IDEATION AND PROPOSED SOLUTION

3.1 EMPATHY MAP CANVAS



3.2 IDEATION & BRAINSTORMING

2

Brainstorm

Write down any ideas that come to mind that address your problem statement.

🕒 10 minutes

ROSHINI G

Preprocessing and cleaning has to be done	Remove noises to improve the accuracy
A feature to provide various synonyms for the words recognized	Make application real time

SANJAY S

To create application that detects handwriting	Can recognize different handwriting text
Validate and test with custom input	A feature to export the recognized text

YESHWANTH M

Can implement Fraud Detection	Train the MNIST dataset
Find the best model by experimenting with various models	A feature to check the grammatical error of the recognized text

RISHI KUMAR S

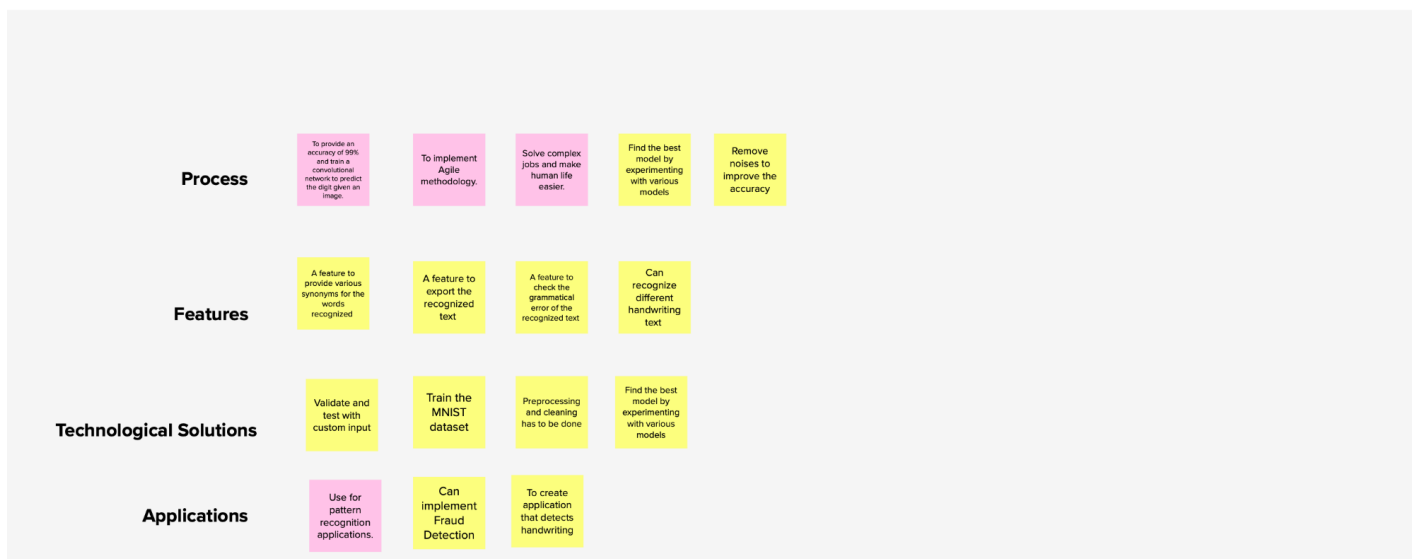
To implement Agile methodology.	Solve complex jobs and make human life easier
Use for pattern recognition applications.	To provide an accuracy of 99% and train a convolutional network to predict the digit given an image.

3

Group ideas

Take turns sharing your ideas while clustering similar or related notes as you go. In the last 10 minutes, give each cluster a sentence-like label. If a cluster is bigger than six sticky notes, try and see if you can break it up into smaller sub-groups.

🕒 20 minutes



4

Prioritize

Your team should all be on the same page about what's important moving forward. Place your ideas on this grid to determine which ideas are important and which are feasible.

🕒 20 minutes



3.3 PROPOSED SOLUTION

S.NO	PARAMETER	DESCRIPTION
1	Problem Statement	To create an application that recognizes handwritten digits
2	Idea / Solution Description	The application takes an image as the input and accurately detects the digits in it.
3	Novelty / Uniqueness	Instead of recognizing every text, the application accurately recognizes only the digits
4	Social Impact / Customer Satisfaction	This application reduces the manual tasks that need to be performed. This improves productivity in the workplace.
5	Business Model	<p>The application can be integrated with traffic surveillance cameras to recognize vehicle number plates</p> <p>The application can be integrated with Postal systems to recognize the pin codes effectively</p>
6	Scalability of the Solution	The application can easily be scaled to accept multiple inputs and process them parallelly to further increase efficiency

3.4 PROBLEM SOLUTION FIT

Problem-Solution fit *DRS 2.0*

Purpose - To assist in recognizing handwritten digits

Team ID - PNT2022TMID27288

Define CS, fit into CC	1. CUSTOMER SEGMENT(S) CS Bank employees, Postal mail sorters	6. CUSTOMER CONSTRAINTS CC Whether digits are recognized Accurately ? Is this product trustworthy ?	5. AVAILABLE SOLUTIONS AS Designed to recognize only digits, hence much efficient and accurate than OCR	Explore AS, differentiate
Focus on J&P, tap into BE, understand RC	2. JOBS-TO-BE-DONE / PROBLEMS J&P Trustworthy, Fast and accurate recognition of digits.	9. PROBLEM ROOT / CAUSE RC People may think that it may not be accurate to predict the digit and not trustworthy. Inaccurate prediction of digits in postal letters and bank cheque causes lot of issues.	7. BEHAVIOUR BE Finding the right product that recognizes the digits written in all kinds of handwriting accurately and hastily.	Focus on J&P, tap into BE, understand RC
Identify strong TR & EM	3. TRIGGERS TR Seeing the OCR that recognizes the characters, comes up with a mind to use a handwritten digit recognizer.	10. YOUR SOLUTION SL A handwritten digit recognition system using CNN that is trained with several combinations of handwritings.	8. CHANNELS of BEHAVIOUR CH 8.1 ONLINE The system exhibits the similar behavior as in offline	Extract online & offline CH of BE
	4. EMOTIONS: BEFORE / AFTER EM Time consuming,frustrating,saves time,no manual effort,less stress		8.2 OFFLINE Predicts the digits accurately even in offline	

REQUIREMENT ANALYSIS

4.1 FUNCTIONAL REQUIREMENTS

FR.NO	FUNCTIONAL REQUIREMENTS	SUB REQUIREMENTS
FR-1	Model Creation	Get access the MNIST dataset
		Analyze the dataset
		Define a CNN model
		Train and Test the Model
FR-2	Application Development	Create a website to let the user recognize handwritten digits.
		Create a home page to upload images
		Create a result page to display the results
		Host the website to let the users use it from anywhere
FR-3	Input Image Upload	Let users upload images of various formats.
		Let users upload images of various size
		Prevent users from uploading unsupported image formats
		Pre-Process the image to use it on the model

		Create a database to store all the input images
		Display the result from the model
		Display input image
FR-4	Display Results	Display accuracy the result

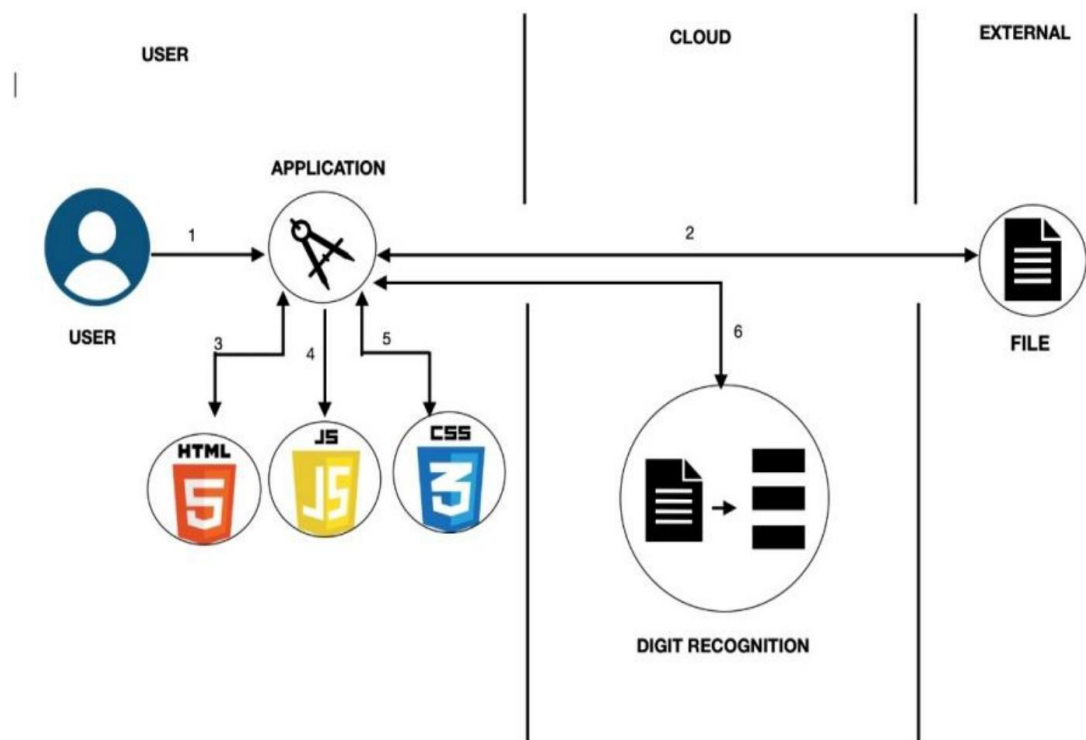
4.2 NON FUNCTIONAL REQUIREMENTS

NFR	NON-FUNCTIONAL REQUIREMENTS	DESCRIPTION
NFR-1	Usability	The application must be usable in all devices
NFR-2	Security	The application must protect user uploaded image
NFR-3	Reliability	The application must give an accurate result as much as possible
NFR-4	Performance	The application must be fast and quick to load up
NFR-5	Availability	The application must be available to use all the time
NFR-6	Scalability	The application must scale along with the user base

CHAPTER 5

PROJECT DESIGN

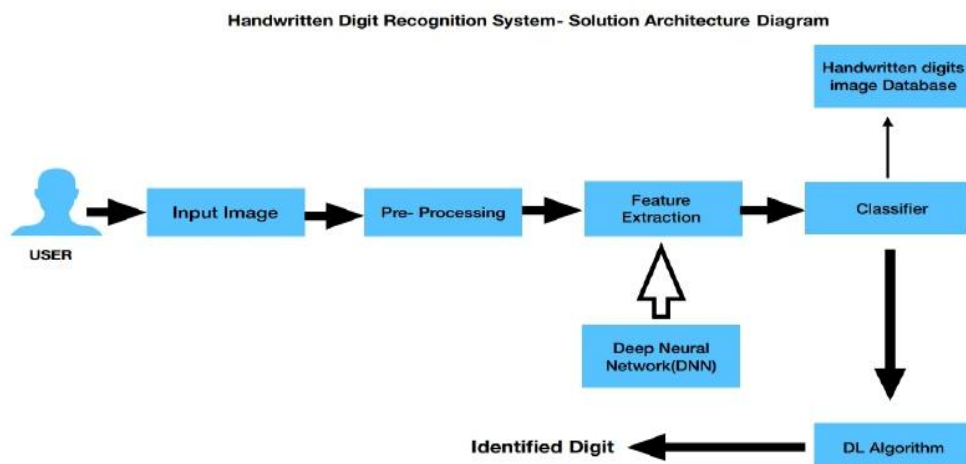
5.1 DATA FLOW DIAGRAM

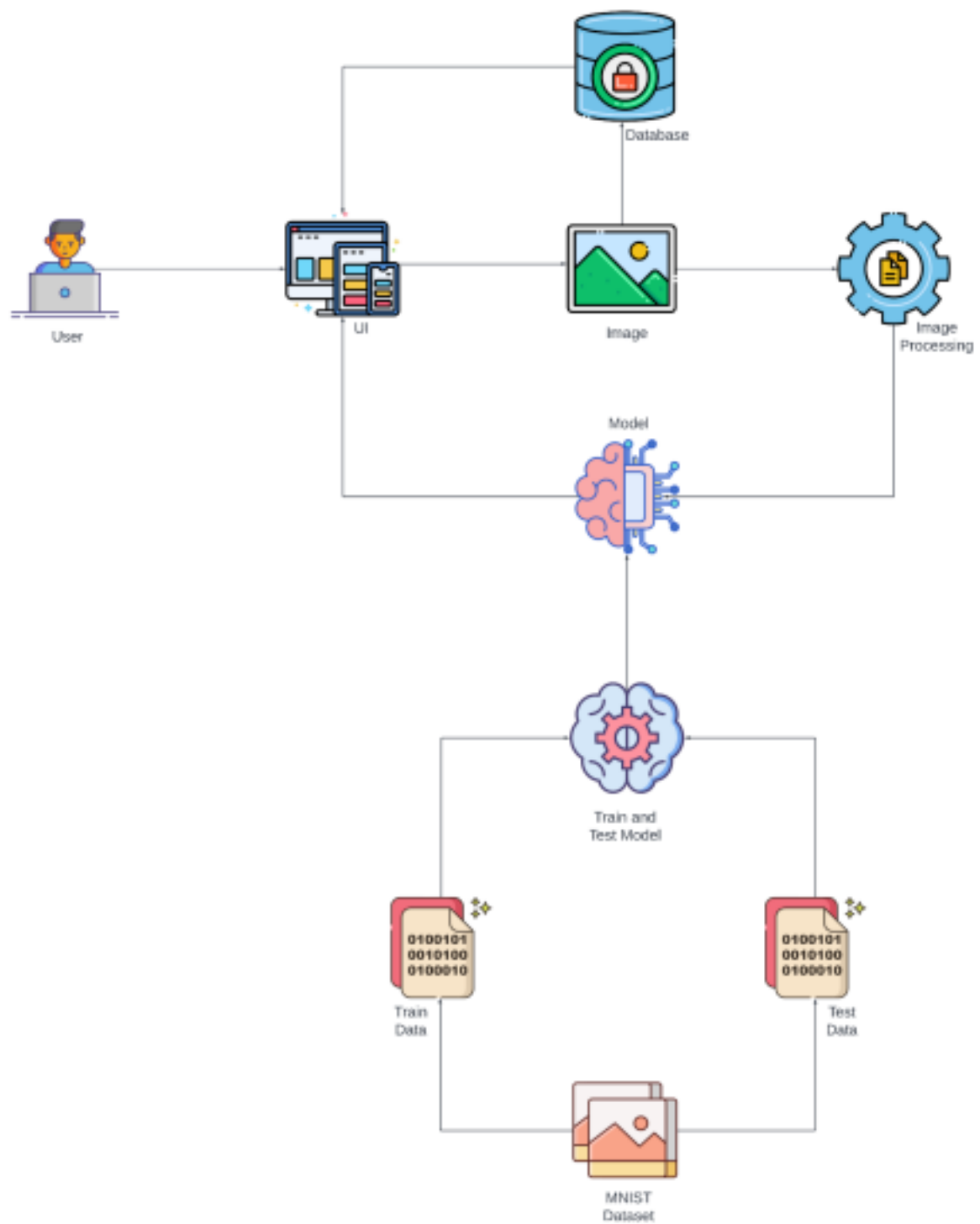


5.2 SOLUTION & TECHNICAL ARCHITECTURE

Project Design Phase-I Solution Architecture

Date	19 September 2022
Team ID	PNT2022TMID27288
Project Name	Project - DRS 2.0
Maximum Marks	4 Marks





5.3 USER STORIES

User Type	Functional Requirements	User Story Number	User Story / Task	Acceptance Criteria	Priority	Release
Customer	Accessing the Application	USN-1	As a user, I should be able to access the application from anywhere and use on any devices	User can access the application using the browser on any device	High	Sprint-4
	Uploading Image	USN-2	As a user, I should be able to upload images to predict the digits	User can upload images	High	Sprint-3
	Viewing the Results	USN-3	As a user, I should be able to view the results	The result of the prediction is displayed	High	Sprint-3
	Viewing Other Prediction	USN-4	As a user, I should be able to see other close predictions	The accuracy of other values must be displayed	Medium	Sprint-4
	Usage Instruction	USN-5	As a user, I should have a usage instruction to know how to use the application	The usage instruction is displayed on the home page	Medium	Sprint-4

CHAPTER 6

PROJECT PLANNING AND SCHEDULING

6.1 SPRINT PLANNING AND ESTIMATION

Sprint	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Get the dataset	3	High	Sanjay S Roshini G
	Explore the data	2	Medium	Sanjay S Roshini G Rishi Kumar S Yeshwanth M
	Data Pre-Processing	3	High	Sanjay S Roshini G Rishi Kumar S Yeshwanth M
	Prepare training and testing data	3	High	Sanjay S Roshini G Rishi Kumar S Yeshwanth M
Sprint- 2	Create the model	3	High	Sanjay S Roshini G Rishi Kumar S Yeshwanth M
	Train the model	3	High	Sanjay S Roshini G Rishi Kumar S Yeshwanth M
	Test the model	3	High	Sanjay S Roshini G Rishi Kumar S Yeshwanth M
Sprint- 3	Improve the model	2	Medium	Sanjay S Roshini G
	Save the model	3	High	Sanjay S Roshini G Rishi Kumar S Yeshwanth M

Sprint	User Story / Task	Story Points	Priority	Team Members
	Build the Home Page	3	High	Roshini G
	Setup a database to store input images	2	Medium	Sanjay S
Sprint- 4	Build the results page	3	High	Sanjay S Roshini G Rishi Kumar S Yeshwanth M
	Integrate the model with the application	3	High	Sanjay S Roshini G
	Test the application	3	High	Sanjay S Roshini G Rishi Kumar S Yeshwanth M

6.2 SPRINT DELIVERY SCHEDULE

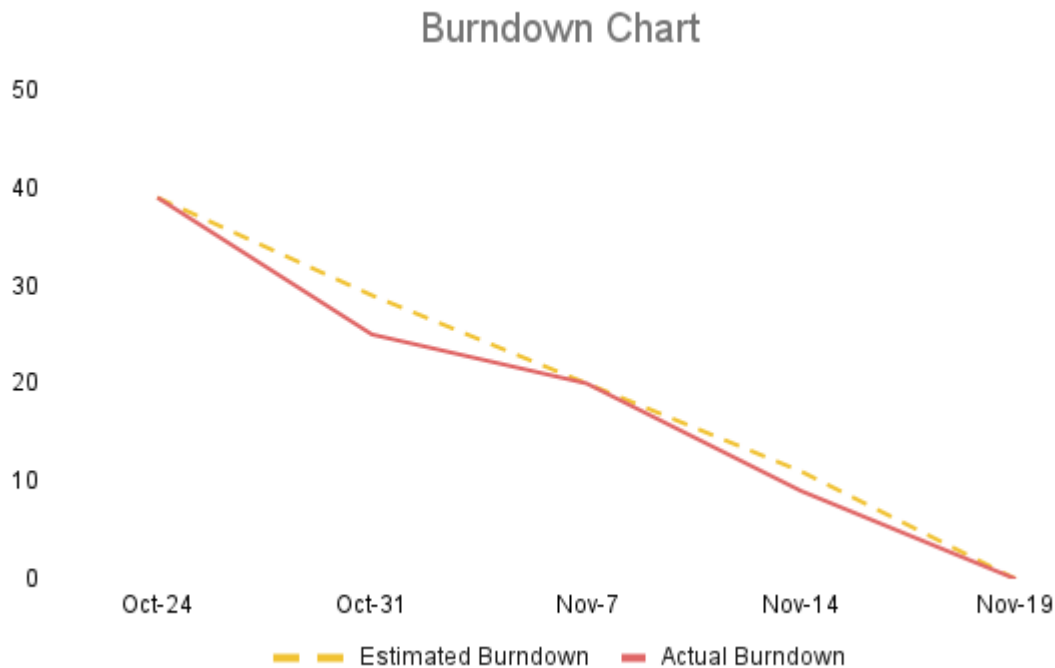
Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	11	6 Days	24 Oct 2022	29 Oct 2022	11	29 Oct 2022
Sprint-2	9	6 Days	31 Oct 2022	05 Nov 2022	9	05 Nov 2022
Sprint-3	10	6 Days	07 Nov 2022	12 Nov 2022	10	12 Nov 2022
Sprint-4	9	6 Days	14 Nov 2022	19 Nov 2022	9	19 Nov 2022

Velocity:

$$Team\ Velocity = \frac{\sum sprint1 + \dots + sprint4}{4} = \frac{11+9+10+9}{4} = 9.75$$

$$AV = \frac{team\ velocity}{duration} = 1.625$$

Burndown Chart:



CHAPTER 7

CODING & SOLUTIONING

```
# Import necessary packages
import os
import random
import string
from pathlib import Path
import numpy as np
from tensorflow.keras.models import load_model
from PIL import Image, ImageOps
```

```
def random_name_generator(n: int) -> str:
    """
    Generates a random file name.

    Args:
        n (int): Length the of the file name.

    Returns:
        str: The file name.
    """
    return ''.join(random.choices(string.ascii_uppercase + string.digits, k=n))
```

```

def recognize(image: bytes) -> tuple:
    """
    Predicts the digit in the image.

    Args:
        image (bytes): The image data.

    Returns:
        tuple: The best prediction, other predictions and file name
    """

    model=load_model(Path("./model/model.h5"))

    img = Image.open(image).convert("L")

    # Generate a random name to save the image file.
    img_name = random_name_generator(10) + '.jpg'
    if not os.path.exists(f"./static/data/"):
        os.mkdir(os.path.join('./static/', 'data'))
    img.save(Path(f"./static/data/{img_name}"))

    # Convert the Image to Grayscale, Invert it and Resize to get better prediction.
    img = ImageOps.grayscale(img)
    img = ImageOps.invert(img)
    img = img.resize((28, 28))

    # Convert the image to an array and reshape the data to make prediction.
    img2arr = np.array(img)
    img2arr = img2arr / 255.0
    img2arr = img2arr.reshape(1, 28, 28, 1)

    results = model.predict(img2arr)
    best = np.argmax(results,axis = 1)[0]

    # Get all the predictions and it's respective accuracy.
    pred = list(map(lambda x: round(x*100, 2), results[0]))

    values = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
    others = list(zip(values, pred))

    # Get the value with the highest accuracy
    best = others.pop(best)

    return best, others, img_name

```


CHAPTER 8

TESTING

8.1 TEST CASES

Test case ID	Feature Type	Component	Test Scenario	Expected Result	Actual Result	Status
HP_TC_001	UI	Home Page	Verify UI elements in the Home Page	The Home page must be displayed properly	Working as expected	PASS
HP_TC_002	UI	Home Page	Check if the UI elements are displayed properly in different screen sizes	The Home page must be displayed properly in all sizes	The UI is not displayed properly in screen size 2560 x 1801 and 768 x 630	FAIL
HP_TC_003	Functional	Home Page	Check if user can upload their file	The input image should be uploaded to the application successfully	Working as expected	PASS
HP_TC_004	Functional	Home Page	Check if user cannot upload unsupported files	The application should not allow user to select a non image file	User is able to upload any file	FAIL
HP_TC_005	Functional	Home Page	Check if the page redirects to the result page once the input is given	The page should redirect to the results page	Working as expected	PASS

BE_TC_001	Functional	Backend	Check if all the routes are working properly	All the routes should properly work	Working as expected	PASS
M_TC_001	Functional	Model	Check if the model can handle various image sizes	The model should rescale the image and predict the results	Working as expected	PASS
M_TC_002	Functional	Model	Check if the model predicts the digit	The model should predict the number	Working as expected	PASS
M_TC_003	Functional	Model	Check if the model can handle complex input image	The model should predict the number in the complex image	The model fails to identify the digit since the model is not built to handle such data	FAIL
RP_TC_001	UI	Result Page	Verify UI elements in the Result Page	The Result page must be displayed properly	Working as expected	PASS
RP_TC_002	UI	Result Page	Check if the input image is displayed properly	The input image should be displayed properly	The size of the input image exceeds the display container	FAIL
RP_TC_003	UI	Result Page	Check if the result is displayed properly	The result should be displayed properly	Working as expected	PASS
RP_TC_004	UI	Result Page	Check if the other predictions are displayed properly	The other predictions should be displayed properly	Working as expected	PASS

8.1 USER ACCEPTANCE TESTING

8.1.1 DEFECT ANALYSIS

Resolution	Severity 1	Severity 2	Severity 3	Severity 4	Total
By Design	1	0	1	0	2
Duplicate	0	0	0	0	0
External	0	0	2	0	2
Fixed	4	1	0	1	6
Not Reproduced	0	0	0	1	1
Skipped	0	0	0	1	1
Won't Fix	1	0	1	0	2
Total	6	1	4	3	14

8.1.2 TEST CASE ANALYSIS

Section	Total Cases	Not Tested	Fail	Pass
Client Application	10	0	3	7
Security	2	0	1	1
Performance	3	0	1	2
Exception Reporting	2	0	0	2

CHAPTER 9

RESULTS

9.1 PERFORMANCE METRICS

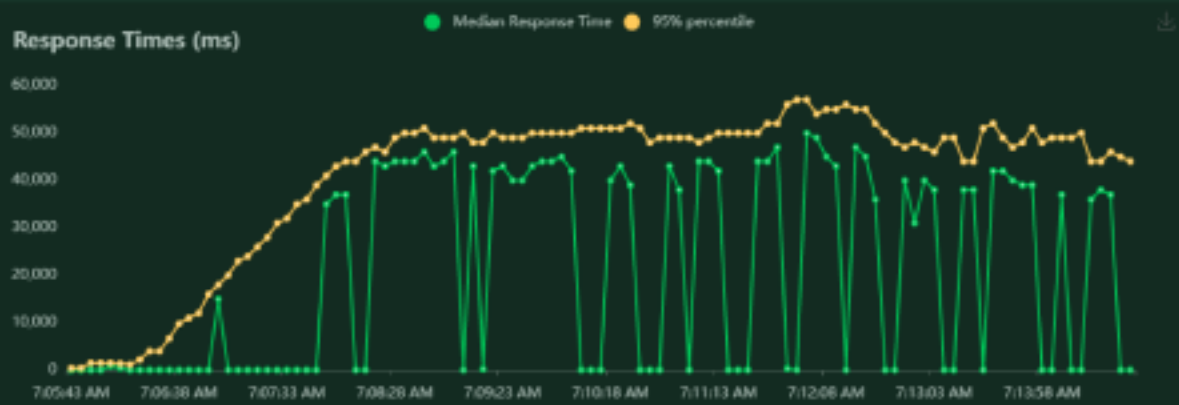
Locust Test Report									
During: 11/12/2022, 7:05:40 AM - 11/12/2022, 7:14:47 AM									
Target Host: http://127.0.0.1:5000/									
Script: locust.py									
Request Statistics									
Method	Name	# Requests	# Fails	Average (ms)	Min (ms)	Max (ms)	Average size (bytes)	RPS	Failures/s
GET	/	1043	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	46000	50000	54000	60000

Charts

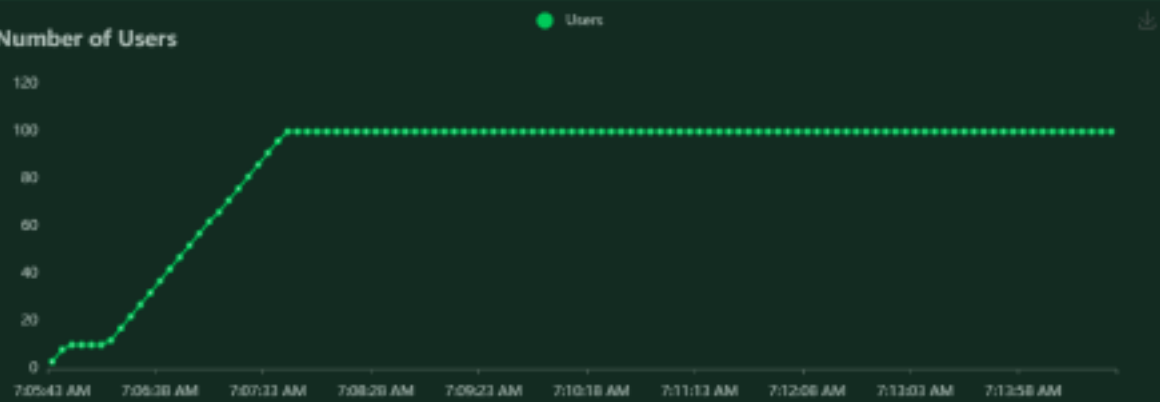
Total Requests per Second



Response Times (ms)



Number of Users



CHAPTER 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

CHAPTER 11

CONCLUSION

This project demonstrated a web application that uses machine learning to recognise 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 99.61% 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.

CHAPTER 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 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.

APPENDIX

SOURCE CODE

MODEL CREATION

```
# Load the necessary packages
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

# Load the data
(X_train, y_train), (X_test, y_test) = mnist.load_data()

# Data pre-processing
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)

# Create the model
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"])

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

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

# Save the model
model.save("model.h5")
```

```

# Test the saved model
model=load_model("model.h5")

img = Image.open("sample.png").convert("L")
img = img.resize((28, 28))
img2arr = np.array(img)
img2arr = img2arr.reshape(1, 28, 28, 1)
results = model.predict(img2arr)
results = np.argmax(results,axis = 1)
results = pd.Series(results,name="Label")
print(results)

```

FLASK APP

```

File View Navigate Code Refactor Run Tools VCS Window Help APP - app.py
app.py
recognizer.py x
from flask import Flask,render_template,request
from recognizer import recognize

app=Flask(__name__)

@app.route('/')
def main():
    return render_template("home.html")

@app.route('/predict',methods=['POST'])
def predict():
    if request.method=='POST':
        image = request.files.get('photo', '')
        best, others, img_name = recognize(image)
        return render_template("predict.html", best=best, others=others, img_name=img_name)

if __name__=="__main__":
    app.run()

```

RECOGNIZER

```

File Edit View Navigate Code Refactor Run Tools VCS Window Help APP - recognizer.py
APP > recognizer.py
recognizer.py x
1 import os
2 import random
3 import string
4 from pathlib import Path
5 import numpy as np
6 from tensorflow.keras.models import load_model
7 from PIL import Image, ImageOps
8
9
10 def random_name_generator(n: int) -> str:
11     """
12     Generates a random file name.
13
14     Args:
15         n (int): Length the of the file name.
16
17     Returns:
18         str: The file name.
19     """
20     return ''.join(random.choices(string.ascii_uppercase + string.digits, k=n))

```

```
APP > recognizer.py
def recognize(image: bytes) -> tuple:
    """
    Predicts the digit in the image.

    Args:
        image (bytes): The image data.

    Returns:
        tuple: The best prediction, other predictions and file name
    """
    model = load_model(Path("./model/modelCNN.h5"))

    img = Image.open(image).convert("L")

    # Generate a random name to save the image file.
    img_name = random_name_generator(10) + '.jpg'
    if not os.path.exists(f"./static/data/"):
        os.mkdir(os.path.join('./static/', 'data'))
    img.save(Path(f"./static/data/{img_name}"))
```

```
APP > recognizer.py
# Convert the Image to Grayscale, Invert it and Resize to get better prediction.
img = ImageOps.grayscale(img)
img = ImageOps.invert(img)
img = img.resize((28, 28))

# Convert the image to an array and reshape the data to make prediction.
img2arr = np.array(img)
img2arr = img2arr / 255.0
img2arr = img2arr.reshape(1, 28, 28, 1)

results = model.predict(img2arr)
best = np.argmax(results, axis=-1)[0]

# Get all the predictions and it's respective accuracy.
pred = list(map(lambda x: round(x*100, 2), results[0]))

values = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
others = list(zip(values, pred))

# Get the value with the highest accuracy
```

```
APP > recognizer.py
File Edit View Navigate Code Refactor Run Tools VCS Window Help APP - recognizer.py
app.py x recognizer.py x
52
53     results = model.predict(img2arr)
54     best = np.argmax(results,axis=-1)[0]
55
56     # Get all the predictions and it's respective accuracy.
57     pred = list(map(lambda x: round(x*100, 2), results[0]))
58
59     values = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
60     others = list(zip(values, pred))
61
62     # Get the value with the highest accuracy
63     best = others.pop(best)
64
65     return best, others, img_name
66
```

HOME PAGE (HTML)

```
1 <html>
2
3 <head>
4     <meta name="viewport" content="width=device-width, initial-scale=1.0" />
5     <title>Handwritten Digit Recognition</title>
6     <link rel="icon" type="image/svg" sizes="32x32" href="{{url_for('static',filename='images/icon.svg')}}" />
7     <link rel="stylesheet" href="{{url_for('static',filename='css/main.css')}}" />
8     <script src="https://unpkg.com/feather-icons"></script>
9     <script defer src="{{url_for('static',filename='js/script.js')}}"></script>
10 </head>
11
12 <body>
13     <div class="container">
14         <div class="heading">
15             <h1 class="heading_main" data-shadow="Handwritten Digit Recognizer">Handwritten Digit Recognizer</h1>
16             <h2 class="heading_sub">Analyze and detect handwritten digits with ease</h2>
17         </div>
18         <div class="upload-container">
19             <div class="form-wrapper">
20                 <form class="upload" action="/predict" method="post" enctype="multipart/form-data">
21                     <label id="label" for="upload-image"><i data-feather="file-plus"></i>Upload File</label>
22                     <input type="file" name="photo" id="upload-image" hidden />
23                     <button type="submit" id="up_btn"></button>
24                 </form>
25                 
26             </div>
27         </div>
28     </div>
29 </body>
30
```

HOME PAGE (CSS)

```
1 @import url('https://fonts.googleapis.com/css2?family=Open+Sans:wght@400;500;600&family=Righteous&family=Song:wght@400;500;600;700;800&display=swap');
2
3 * {
4     padding: 0;
5     margin: 0;
6 }
7
8 body {
9     color: #f1faee;
10    font-family: "Righteous", Open Sans;
11 }
12
13 @keyframes gradient {
14     0% {
15         background-position: 0% 50%;
16     }
17     50% {
18         background-position: 100% 50%;
19     }
20     100% {
21         background-position: 0% 50%;
22     }
23 }
24
25 .container {
```

```
31 .container {
32   width: 100%;
33   height: 100%;
34   display: flex;
35   flex-direction: column;
36   justify-content: center;
37   align-items: center;
38   background: linear-gradient(-45deg, #ee7752, #e73c7e, #23a6d5, #23d5ab);
39   background-size: 400% 400%;
40   animation: gradient 15s ease infinite;
41 }
42 }
43 }
44 .heading {
45   margin-top: -2rem;
46   padding-bottom: 2rem;
47   width: fit-content;
48   text-align: center;
49 }
50 }
51 .heading .heading__main {
52   font-size: 3rem;
53   font-weight: 550;
54 }
55 }
56 .heading .heading__sub {
57   font-size: 1rem;
58   color: #f0ead2;
59   font-family: "Balooa", Open Sans;
60 }
61 }
```

```
63 .upload-container {
64   box-shadow: 0 0 20px rgb(27, 183, 255);
65   width: 40rem;
66   height: 25rem;
67   padding: 1.5rem;
68 }
69 }
70 .form-wrapper {
71   background-color: rgba(190, 190, 190, 0.5);
72   width: 100%;
73   height: 100%;
74   display: flex;
75   border: 1px dashed black;
76   justify-content: center;
77   align-items: center;
78 }
79 }
80 .form-wrapper #loading {
81   display: none;
82   position: absolute;
83 }
84 }
85 .form-wrapper .upload {
86   display: flex;
87   justify-content: center;
88   align-items: center;
89   width: 8rem;
90   height: -webkit-fit-content;
91   height: -moz-fit-content;
92   height: fit-content;
93   border-radius: 6px;
94 }
```

```
94   color: white;
95   background-color: rgb(114, 96, 182);
96   box-shadow: 0 5px 10px rgb(146, 135, 247);
97 }
98 }
99 .form-wrapper .upload #up_btn {
100   display: none;
101 }
102 }
103 .form-wrapper .upload label {
104   font-size: 1rem;
105   font-weight: 600;
106   color: white;
107   height: 100%;
108   width: 100%;
109   padding: 10px;
110   display: block;
111 }
112 }
113 .form-wrapper .upload svg {
114   height: 15px;
115   width: auto;
116   padding-right: 8px;
117   margin-bottom: -2px;
118 }
119 }
120 .buttons {
121   margin: 10%;
122   text-align: center;
123 }
124 }
```

```
124
125
126
127
128 @media screen and (max-width: 700px) {
129   .upload-container {
130     height: 20rem;
131     width: 18rem;
132     margin-top: 3.5rem;
133     margin-bottom: -8rem;
134   }
135
136   .heading .heading__main {
137     margin-top: -6rem;
138     font-size: 2rem;
139     padding-bottom: 1rem;
140   }
141 }
```

HOME PAGE (JS)

```
1 feather.replace(); // Load feather icons
2
3 form = document.querySelector('.upload')
4 loading = document.querySelector("#loading")
5 select = document.querySelector("#upload-image");
6
7 select.addEventListener("change", (e) => {
8   e.preventDefault();
9
10   form.submit()
11   form.style.visibility = "hidden";
12   loading.style.display = 'flex';
13 });
14
```

PREDICT PAGE (HTML)

```
1 <html>
2
3 <head>
4   <title>Prediction | Handwritten Digit Recognition</title>
5   <link rel="stylesheet" href="{{url_for('static', filename='css/predict.css')}}" />
6   <link rel="icon" type="image/svg" sizes="32x32" href="{{url_for('static', filename='images/icon.svg')}}" />
7   <meta name="viewport" content="width=device-width, initial-scale=1.0" />
8 </head>
9
10 <body>
11   <div class="container">
12     <h1>PREDICTIONS</h1>
13     <div class="result-wrapper">
14       <div class="input-image-container">
15         
16       </div>
17       <div class="result-container">
18         <div class="value">{{best.0}}</div>
19         <div class="accuracy">{{best.1}}%</div>
20       </div>
21     </div>
22     <h1>OTHER PREDICTIONS</h1>
23     <div class="other_predictions">
24       {% for x in others %}
25       <div class="value">
26         <h2>{{x.0}}</h2>
27         <div class="accuracy">{{x.1}}%</div>
28       </div>
29       {% endfor %}
30     </div>
```

PREDICT PAGE (CSS)

```
1  @import url('https://fonts.googleapis.com/css2?family=Open+Sans:wght@400;500;600&family=Righteous&family=Song:wght@400;500;600;700;800&display=swap');
2
3  body {
4    background: linear-gradient(-45deg, #ee7752, #e73c7e, #23a6d5, #23d5ab);
5    background-size: 400% 400%;
6    animation: gradient 15s ease infinite;
7    font-family: "Righteous", Open Sans;
8  }
9
10 @keyframes gradient {
11   0% {
12     background-position: 0% 50%;
13   }
14
15   50% {
16     background-position: 100% 50%;
17   }
18
19   100% {
20     background-position: 0% 50%;
21   }
22 }
23
24 h1 {
25   padding-top: 2rem;
26   color: #c1d8ff;
27 }
28
29 .container {
30   display: flex;
31   justify-content: center;
32
33   justify-content: center;
34   align-items: center;
35   flex-direction: column;
36 }
37
38 .result-wrapper {
39   width: -webkit-fit-content;
40   width: -moz-fit-content;
41   width: fit-content;
42   height: -webkit-fit-content;
43   height: -moz-fit-content;
44   height: fit-content;
45   box-shadow: 0 0 10px rgb(126, 125, 125);
46   padding: 1.5rem;
47   display: flex;
48   justify-content: center;
49   align-items: center;
50   -moz-column-gap: 1rem;
51   column-gap: 1rem;
52 }
53
54 .result-wrapper .input-image-container,
55 .result-wrapper .result-container {
56   width: 15rem;
57   height: 15rem;
58   border: 1px dashed black;
59   justify-content: center;
60   display: flex;
61   align-items: center;
62   flex-direction: column;
63   background-color: rgb(289, 286, 286);
64 }
```

```
61     background-color: rgb(209, 206, 206);
62     box-shadow: 0 0 20px rgb(17, 211, 255);
63 }
64
65 .result-wrapper .input-image-container img {
66     width: 60%;
67     height: 60%;
68     background-color: aqua;
69     background-size: contain;
70 }
71
72 .result-wrapper .result-container .value {
73     font-size: 6rem;
74 }
75
76 .result-wrapper .result-container .accuracy {
77     margin-top: -1rem;
78 }
79
80 .other_predictions {
81     display: flex;
82     justify-content: center;
83     align-items: center;
84     flex-wrap: wrap;
85     column-gap: 1rem;
86     row-gap: 1rem;
87     font-weight: 700;
88 }
89
90
91 .other_predictions .value {
92     display: flex;
93     justify-content: center;
94     align-items: center;
95     flex-direction: column;
96     width: 5rem;
97     height: 5rem;
98     background-color: #666666;
99     box-shadow: 0 0 7px rgb(23, 236, 255);
100 }
101
102 .other_predictions .value div {
103     margin-top: -1.2rem;
104 }
105
106 @media screen and (max-width: 700px) {
107     h1 {
108         font-size: 2.3rem;
109     }
110
111     .result-wrapper .input-image-container,
112     .result-wrapper .result-container {
113         width: 7rem;
114         height: 7rem;
115     }
116
117     .result-wrapper .result-container .value {
118         font-size: 4rem;
119     }
120 }
```

GITHUB

<https://github.com/IBM-EPBL/IBM-Project-21788-1659791535>

PROJECT DEMO

<https://youtu.be/NMPbRoFWzoQ>

<https://drive.google.com/file/d/1wVn3LmFhl1djRsZbJOBvX6IOPEBe8wA/view?usp=sharing>