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A PROJECT IN ARTIFICIAL INTELLIGENCE

**A NOVEL METHOD FOR HANDWRITTEN  
DIGIT RECOGNITION**

Submitted By,

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# **ABSTRACTION**

Hand writing 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 the 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.

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# **CHAPTER 1**

## **INTRODUCTION**

Handwriting digits and character recognition have become increasingly important in today's digitized world due to their practical applications in various day to day activities. It can be proven by the fact that in recent years, different recognition systems have been developed or proposed to be used in different fields where high classification efficiency is needed. Systems that are used to recognize Handwriting letters, characters, and digits help people to solve more complex tasks that otherwise would be time consuming and costly. A good example is the use of automatic processing systems used in banks to process bank cheque. Without automated bank cheque processing systems, the bank would be required to employ many employees who may not be as efficient as the computerized processing system.

### **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 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**

Hand written character recognition is a translation problem of human writings into machine editable text format. In this paper, Convolutional Neural Networks (CNN) is presented for handwritten character recognition. Handwritten character was transformed into graphs based on its underlying skeleton structure. Edges of the extracted graph were categorized into shape types and vertices were extracted from each of the edges and their layer wise evaluation using deep learning. Matching procedure of the graph was performed in Convolutional Neural Networks (CNN) approach. Performance evaluation of the proposed method was conducted using validated data set which exclude ambiguous and unidentified writing samples. The use of neural network can improve the quality of recognition while achieving good performance and encouraging.

#### **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 margin 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 Reference**

##### **2.2.1 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.

### **2.2.2 An Efficient and Improved Scheme for Handwritten Digit Recognition Based on Convolutional Neural Network (2019)**

*Ali, Saqib and Shaukat, Zeeshan and Azeem, Muhammad and Sakhawat, 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.

### **2.2.3 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.

#### **2.2.4 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. This led them to the conclusion that CNN is the most effective 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.



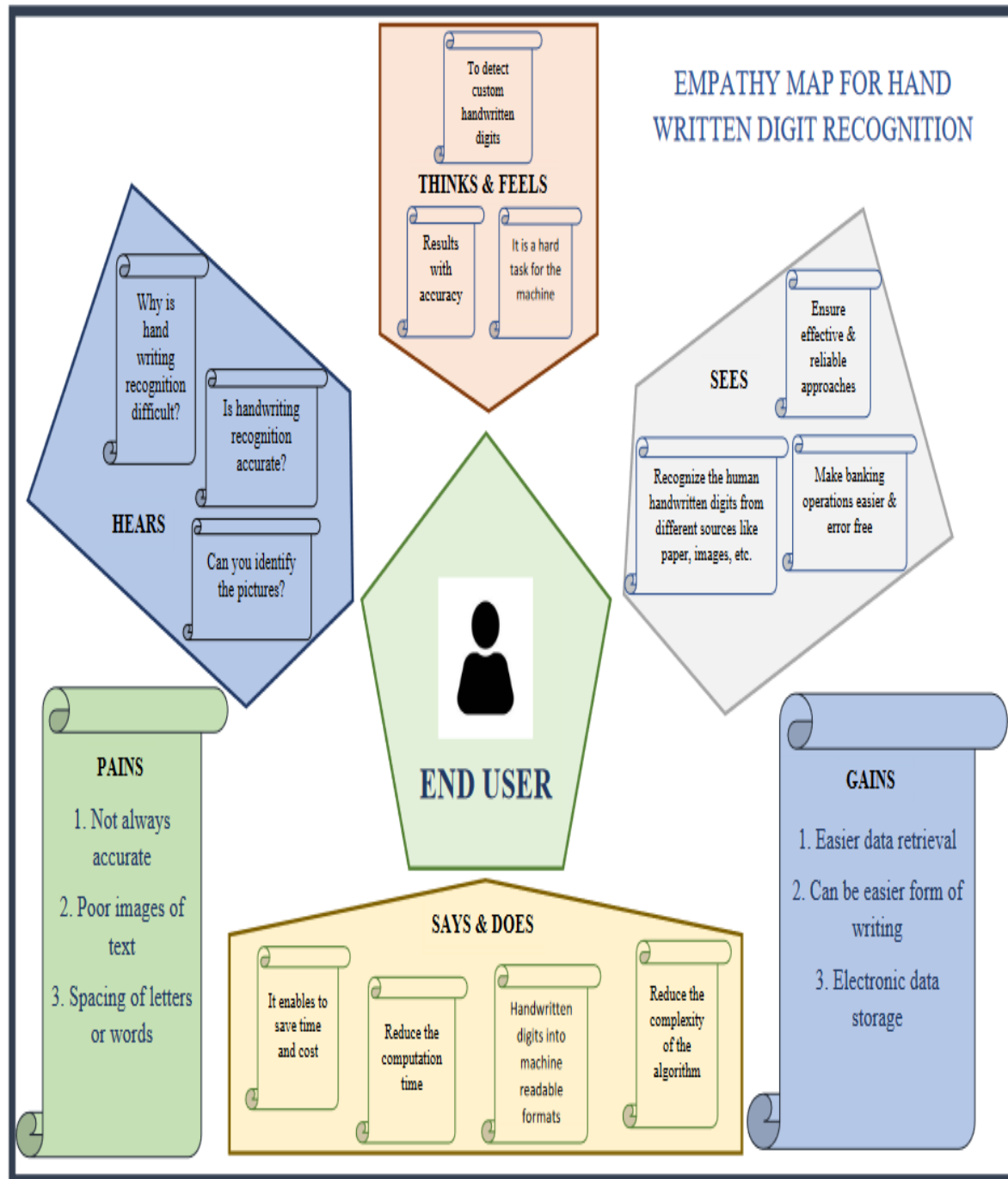
## **2.3 Problem Statement Definition**

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.

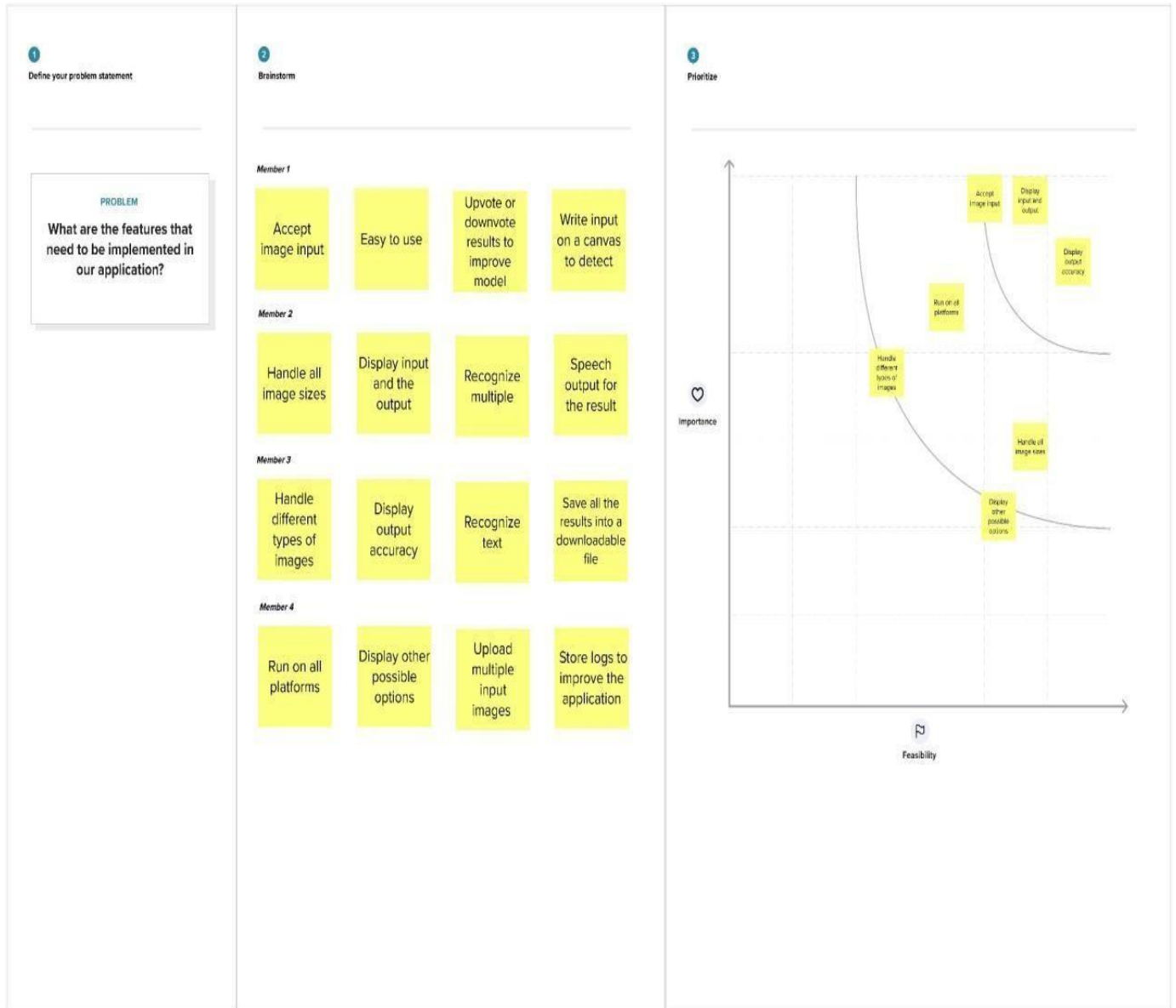
## CHAPTER 3

### IDEATION AND PROPOSED SOLUTION

#### 3.1 Empathy Map Canvas



## 3.2 Ideation & Brainstorming



### 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

<p><b>Define CS, fit into CC</b></p>	<p><b>1. CUSTOMER SEGMENT(S)</b> <span>CS</span></p> <p>Who is your customer? i.e. working parents of young kids</p>	<p><b>6. CUSTOMER CONSTRAINTS</b> <span>CC</span></p> <p>What constraints prevent your customers from taking action or limit their choices of solutions? i.e. spending power, budget, no cash, network connection available, no loss</p>	<p><b>Explore AS, differentiate</b></p>
	<p><b>2. JOBS-TO-BE-DONE / PROBLEMS</b> <span>J&amp;P</span></p> <p>Which jobs-to-be-done (or problems) do you address for your customers? There could be more than one; explore different sides.</p>	<p><b>9. PROBLEM ROOT CAUSE</b> <span>RC</span></p> <p>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</p>	
<p><b>Identify strong TR &amp; EM</b></p>	<p><b>10. YOUR SOLUTION</b> <span>SL</span></p> <p>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.</p>	<p><b>8. CHANNELS of BEHAVIOUR</b> <span>CH</span></p> <p><b>8.1 ONLINE</b> What kind of actions do customers take online? Extract online channels from #7</p> <p><b>8.2 OFFLINE</b> What kind of actions do customers take offline? Extract offline channels from #7 and use them for customer development.</p>	<p><b>Extract online &amp; offline CH of BE</b></p>
	<p><b>3. TRIGGERS</b> <span>TR</span></p> <p>What triggers customers to act? i.e. seeing their neighbour installing solar panels, reading about a more efficient solution in the news.</p> <p><b>4. EMOTIONS: BEFORE / AFTER</b> <span>EM</span></p> <p>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 &amp; design.</p>		

# **CHAPTER 4**

## **REQUIREMENT ANALYSIS**

### **4.1 Functional requirement**

<b>FR.NO</b>	<b>FUNCTIONAL REQUIREMENTS</b>	<b>SUB REQUIREMENTS</b>
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
FR-4	Display Results	Display the result from the model
		Display input image
		Display accuracy the result
		Display other possible predictions with their respective accuracy

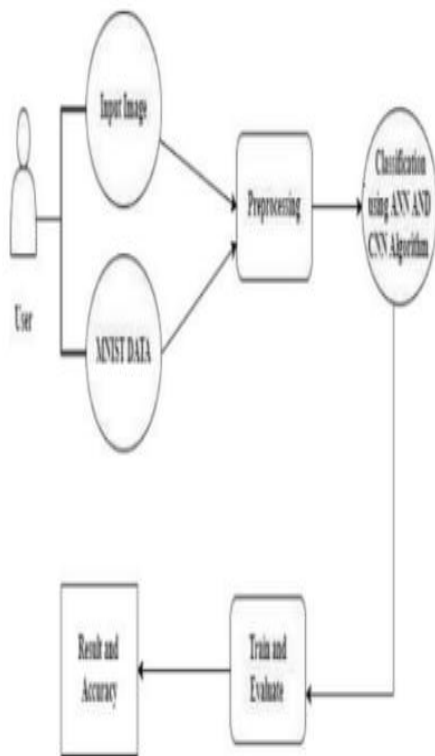
## 4.2 Non-Functional requirements

<b>NFR</b>	<b>NON-FUNCTIONAL REQUIREMENTS</b>	<b>DESCRIPTION</b>
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

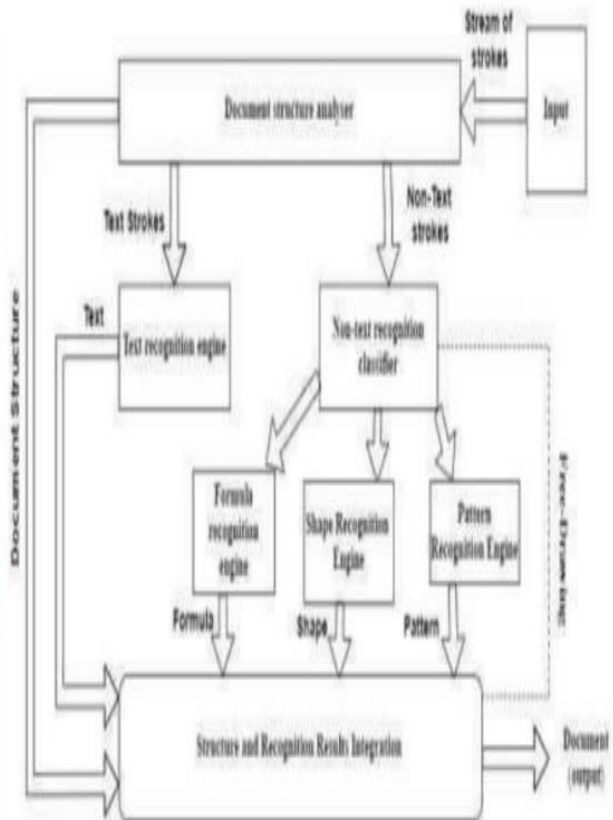
# **CHAPTER 5**

## **PROJECT DESIGN**

### **5.1 Data Flow Diagrams**

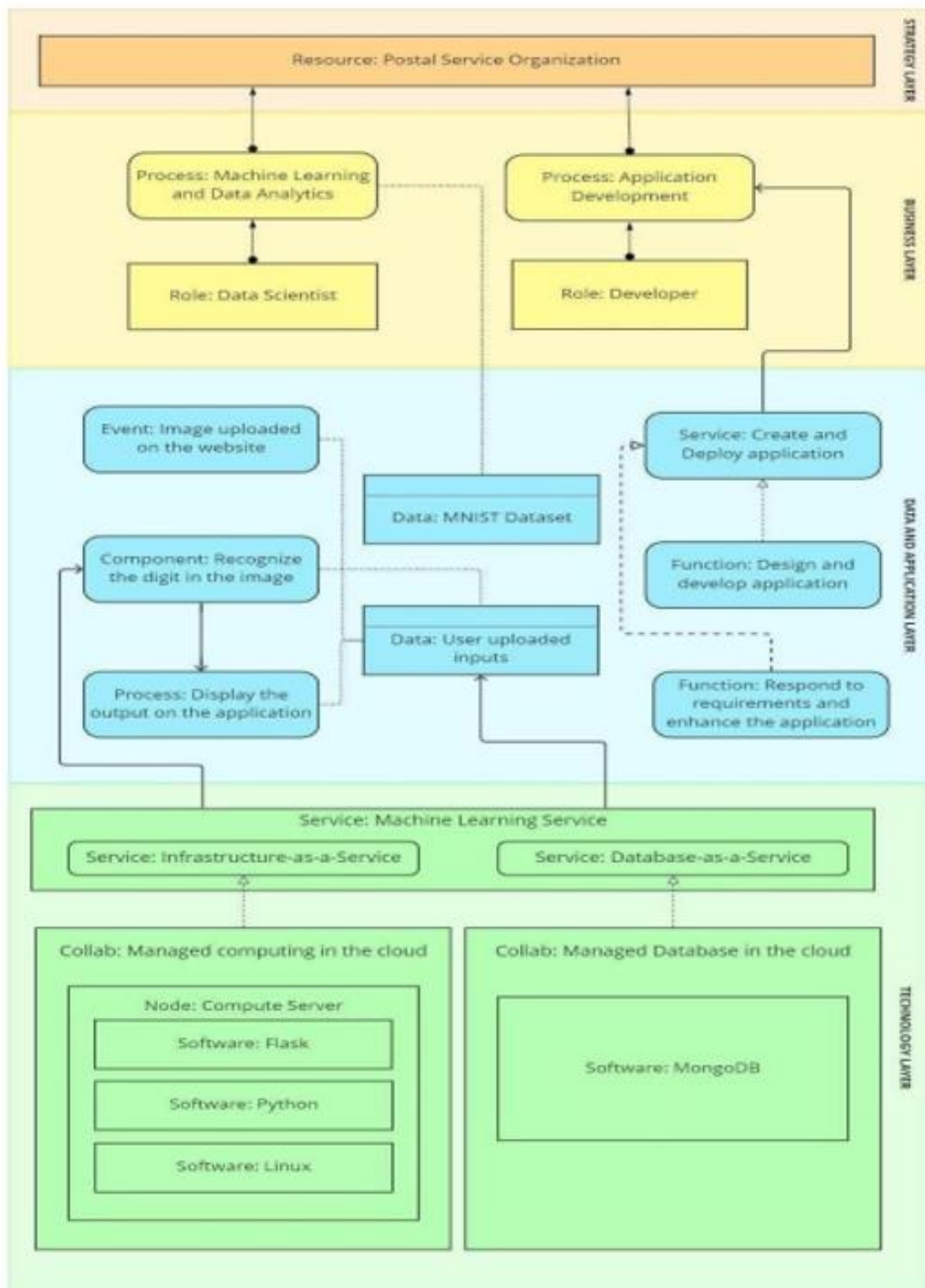


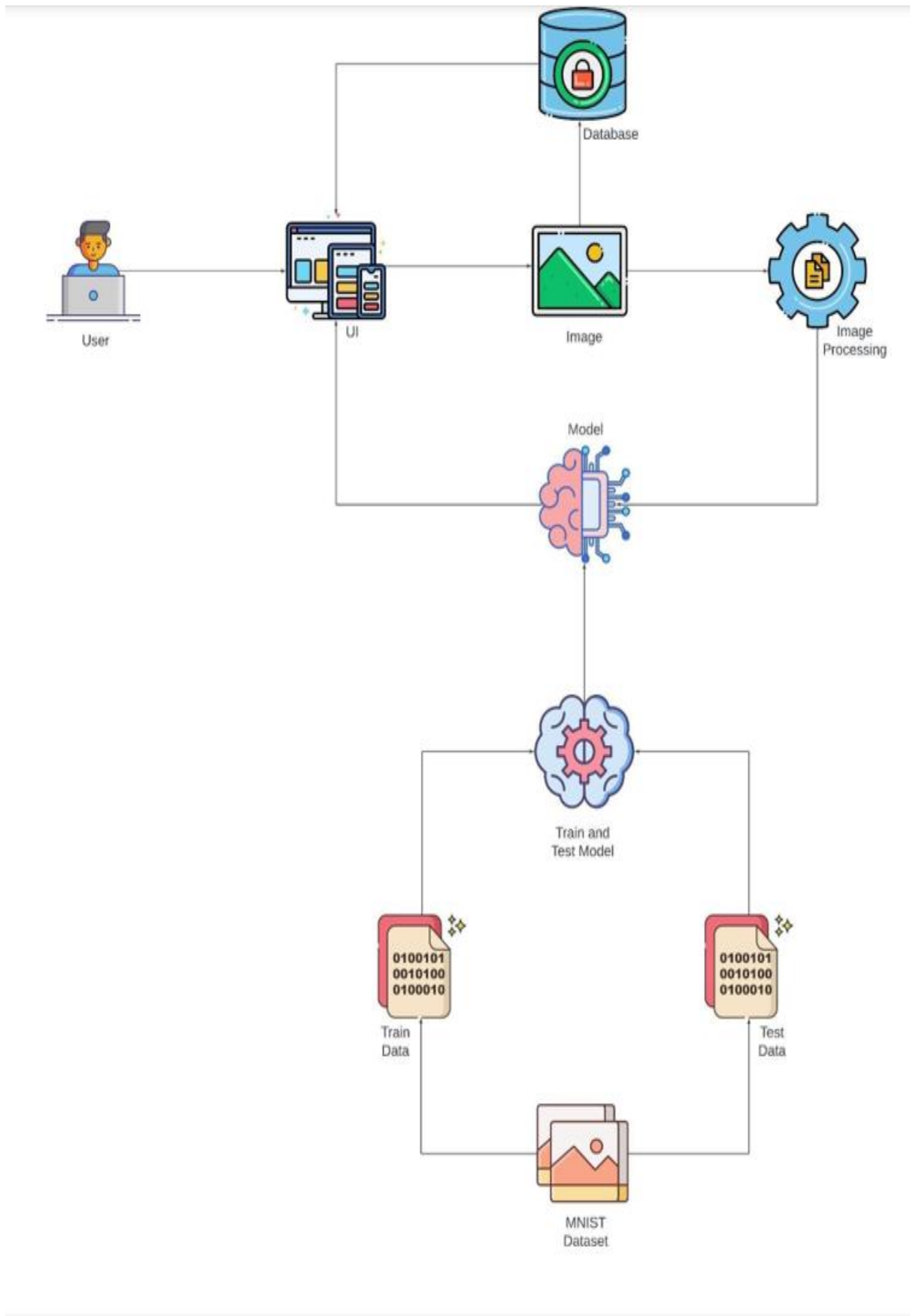
Example: DFD Level 0 (Industry Standard)





## 5.2 Solution & Technical Architecture





## 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 & Estimation**

<b>SPRINT</b>	<b>USER STORY / TASK</b>	<b>STORY POINTS</b>	<b>PRIORITY</b>	<b>TEAM MEMBERS</b>
Sprint - I	Get the dataset	3	High	PAVITHRAN P
	Explore the data	2	Medium	PAVITHRAN P LAVANESH S
	Data Pre-Processing	3	High	NAVEEN M KRISHNA A T
	Prepare training and testing data	3	High	PAVITHRAN P NAVEEN M
Sprint - II	Create the model	3	High	PAVITHRAN P
	Train the model	3	High	LAVANESH S
	Test the model	3	High	KRISHNA A T
Sprint - III	Improve the model	2	Medium	LAVANESH S NAVEEN M
	Save the model	3	High	PAVITHRAN P
	Build the Home Page	3	High	KRISHNA A T PAVITHRAN P
	Setup a database to store input images	2	Medium	LAVANESH S
Sprint - IV	Build the results page	3	High	LAVANESH S PAVITHRAN P
	Integrate the model with the application	3	High	LAVANESH S PAVITHRAN P
	Test the application	3	High	KRISHNA A T NAVEEN M

## 6.2 Sprint Delivery Schedule

SPRINT	TOTAL STORY POINTS	DURATION	SPRINT START DATE	SPRINT END DATE (PLANNED)	STORY POINTS COMPLETED (AS ON PLANNED DATE)	SPRINT RELEASE DATE (ACTUAL )
Sprint - I	11	6 Days	24 Oct 2022	29 Oct 2022	11	29 Oct 2022
Sprint - II	9	6 Days	31 Oct 2022	05 Nov 2022	9	05 Nov 2022
Sprint - III	10	6 Days	07 Oct 2022	12 Nov 2022	10	12 Nov 2022
Sprint - IV	9	6 Days	14 Nov 2022	19 Nov 2022	9	19 Nov 2022

## 6.3 Reports from JIRA

The screenshot displays the JIRA 'Your work' dashboard. At the top, there's a navigation bar with 'Your work - Jira' and a search bar. Below this, the 'Your work' section is visible, featuring a 'Recent projects' card for 'A Novel Method for Handwritten Digit Recognition System'. This card includes quick links for 'My open issues' (0), 'Done issues', and '1 board'. Below the projects, there's a filter bar with 'Worked on', 'Viewed', 'Assigned to me', and 'Starred'. The main content area shows a list of tasks under the 'Worked on' filter, all with a status of 'Created'. The tasks are:

- Test the application (ANMFHDS-14)
- Integrate the model with the application (ANMFHDS-13)
- Build the results page (ANMFHDS-12)
- Setup a database to store input images (ANMFHDS-11)
- Build the Home Page

Each task has an orange 'PP' icon to its right. The bottom of the screenshot shows a Windows taskbar with the date and time as 12:09 AM on 19-11-2022.

# **CHAPTER 7**

## **CODING AND 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 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
    """
    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 no 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



## 8.2 User Acceptance Testing

### 8.2.1 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

### 8.2.2 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

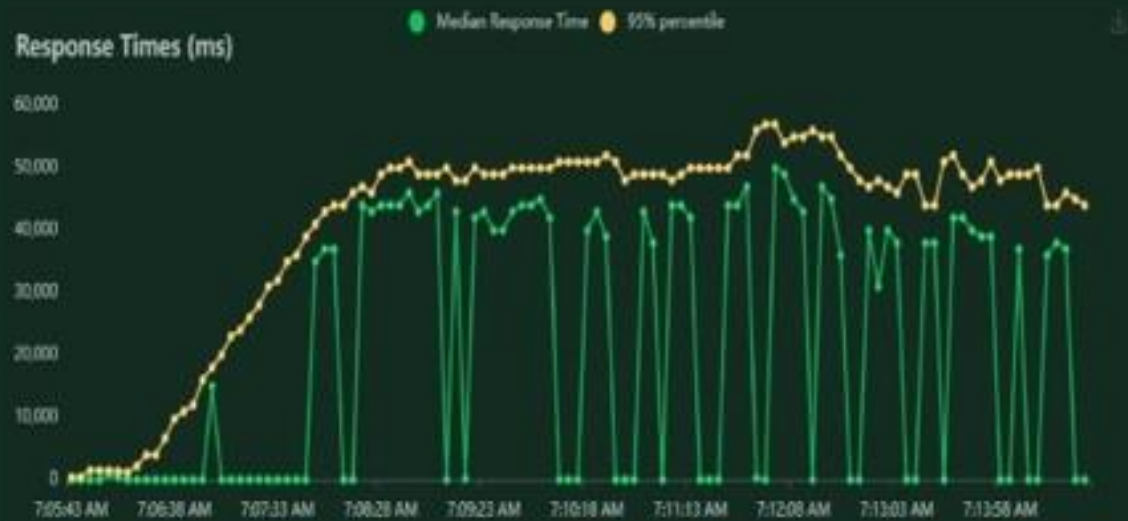
Method	Name	50%ile (ms)	60%ile (ms)	70%ile (ms)	80%ile (ms)	90%ile (ms)	95%ile (ms)	99%ile (ms)	100%ile (ms)
GET	/	10	11	13	15	19	22	62	290
GET	/predict	44000	46000	47000	48000	50000	52000	55000	60000
Aggregated		36	36000	43000	45000	48000	50000	54000	60000

## Charts

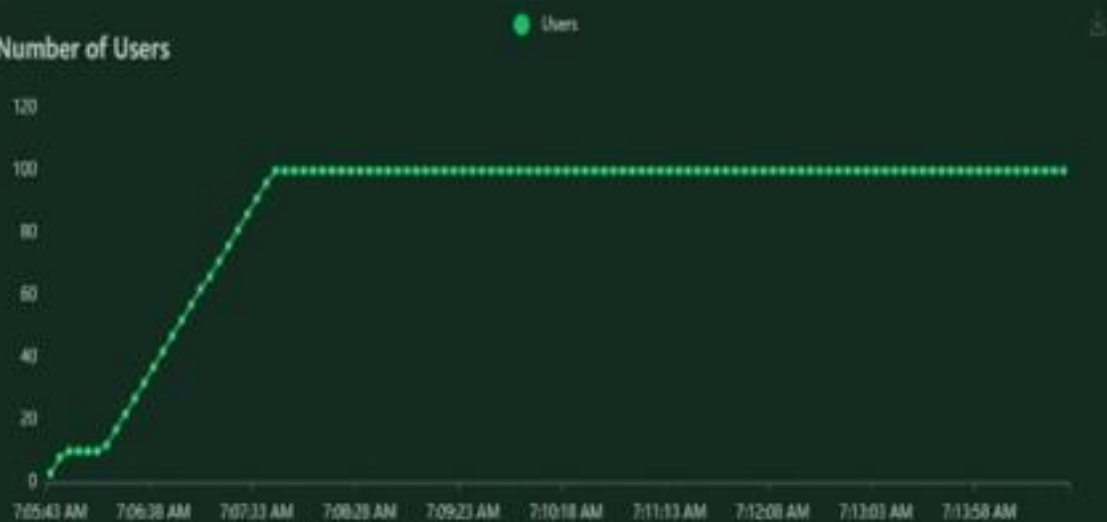
### Total Requests per Second



### Response Times (ms)



### Number of Users



# **CHAPTER 10**

## **ADVANTAGES AND DISADVANTAGES**

### **10.1 Advantages**

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

### **10.2 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 numberplates 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.

# **CHAPTER 13**

## **APPENDIX**

### **13.1 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()

print(X_train.shape)
print(X_test.shape)

X_train[0]

y_train[0]

# 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)

Y_train[0]

# 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)

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

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

#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

```

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

```

#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 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
    """
    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

```

## HOME PAGE (HTML)

```

<html>

  <head>

    <meta name="viewport" content="width=device-width, initial-scale=1.0" />

    <title>Handwritten Digit Recognition</title>

    <link rel="icon" type="image/svg" sizes="32x32"
href="{{ url_for('static',filename='images/icon.svg') }}" />

    <link rel="stylesheet" href="{{ url_for('static',filename='css/main.css') }}" />

    <script src="https://unpkg.com/feather-icons"></script>

    <script defer src="{{ url_for('static',filename='js/script.js') }}"></script>

  </head>

  <body>

    <div class="container">

      <div class="heading">

        <h1 class="heading__main">Handwritten Digit Recognizer</h1>

        <h2 class="heading__sub">Easily analyze and detect handwritten digits</h2>

      </div>

      <div class="upload-container">

        <div class="form-wrapper">

          <form class="upload" action="/predict" method="post"
enctype="multipart/form-data">

            <label id="label" for="upload-image"><i data-feather="file-plus"></i>Select
File</label>

            <input type="file" name="photo" id="upload-image" hidden />

            <button type="submit" id="up_btn"></button>

          </form>

        </div>

      </div>

    </div>

```

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

## HOME PAGE (CSS)

```
@import
url("https://fonts.googleapis.com/css2?family=Overpass:wght@200;300;400;500;600;700;900&display=swap");
```

```
* {
    padding: 0;
    margin: 0;
}
```

```
body {
    color: black;
    font-family: "Overpass", sans-serif;
}
```

```
.container {
    width: 100%;
    height: 100%;
    display: flex;
    flex-direction: column;
    justify-content: center;
    align-items: center;
    background-color: white;
}
```

```
.heading {
```

```
        margin-top: -2rem;
        padding-bottom: 2rem;
        width: fit-content;
        text-align: center;
    }
```

```
.heading .heading__main {
    font-size: 3rem;
    font-weight: 550;
}
```

```
.heading .heading__sub {
    font-size: 1rem;
    color: rgb(90, 88, 88);
}
```

```
.upload-container {
    box-shadow: 0 0 20px rgb(172, 170, 170);
    width: 40rem;
    height: 25rem;
    padding: 1.5rem;
}
```

```
.form-wrapper {
    background-color: rgba(190, 190, 190, 0.5);
    width: 100%;
    height: 100%;
    display: flex;
    border: 1px dashed black;
    justify-content: center;
```

```
        align-items: center;
    }
```

```
.form-wrapper #loading {
    display: none;
    position: absolute;
}
```

```
.form-wrapper .upload {
    display: flex;
    justify-content: center;
    align-items: center;
    width: 8rem;
    height: -webkit-fit-content;
    height: -moz-fit-content;
    height: fit-content;
    border-radius: 6px;
    color: white;
    background-color: rgb(114, 96, 182);
    box-shadow: 0 5px 10px rgb(146, 135, 247);
}
```

```
.form-wrapper .upload #up_btn {
    display: none;
}
```

```
.form-wrapper .upload label {
    font-size: 1rem;
    font-weight: 600;
    color: white;
```

```
        height: 100%;  
        width: 100%;  
        padding: 10px;  
        display: block;  
    }  
}
```

```
.form-wrapper .upload svg {  
    height: 15px;  
    width: auto;  
    padding-right: 8px;  
    margin-bottom: -2px;  
}
```

```
@media screen and (max-width: 700px) {  
    .upload-container {  
        height: 20rem;  
        width: 18rem;  
        margin-top: 3.5rem;  
        margin-bottom: -8rem;  
    }  
}
```

```
.heading .heading__main {  
    margin-top: -6rem;  
    font-size: 2rem;  
    padding-bottom: 1rem;  
}  
}
```

## HOME PAGE (JS)

```
feather.replace(); // Load feather icons
```

```
form = document.querySelector('.upload')

loading = document.querySelector("#loading")

select = document.querySelector("#upload-image");

select.addEventListener("change", (e) => {

    e.preventDefault();

    form.submit()

    form.style.visibility = "hidden";

    loading.style.display = 'flex';

});
```

## PREDICT PAGE (HTML)

```
<html>

    <head>

        <title>Prediction | Handwritten Digit Recognition</title>

        <link rel="stylesheet" href="{{ url_for('static',filename='css/predict.css') }}" />

        <link rel="icon" type="image/svg" sizes="32x32"

href="{{ url_for('static',filename='images/icon.svg') }}" />

        <meta name="viewport" content="width=device-width, initial-scale=1.0" />

    </head>

    <body>

        <div class="container">

            <h1>Prediction</h1>
```

```

<div class="result-wrapper">

    <div class="input-image-container">

        </div>

        <div class="result-container">

            <div class="value">{{ best.0 }}</div>

            <div class="accuracy">{{ best.1 }}%</div>

        </div>

    </div>

<h1>Other Predictions</h1>

<div class="other_predictions">

    {% for x in others %}

        <div class="value">

            <h2>{{ x.0 }}</h2>

            <div class="accuracy">{{ x.1 }}%</div>

        </div>

        {% endfor %}

    </div>

</div>

</body>

</html>

```

## PREDICT PAGE (CSS)



```
@import
```

```
url("https://fonts.googleapis.com/css2?family=Overpass:wght@200;300;400;500;600;700;900&display=swap");
```

```
body {
```

```
    color: black;
```

```
    font-family: "Overpass", sans-serif;
```

```
}
```

```
h1 {
```

```
    padding-top: 2rem;
```

```
}
```

```
.container {
```

```
    display: flex;
```

```
    justify-content: center;
```

```
    align-items: center;
```

```
    flex-direction: column;
```

```
}
```

```
.result-wrapper {
```

```
    width: -webkit-fit-content;
```

```
    width: -moz-fit-content;
```

```
    width: fit-content;
```

```
    height: -webkit-fit-content;
```

```
    height: -moz-fit-content;

    height: fit-content;

    box-shadow: 0 0 10px rgb(126, 125, 125);

    padding: 1.5rem;

    display: flex;

    justify-content: center;

    align-items: center;

    -moz-column-gap: 1rem;

    column-gap: 1rem;

}
```

```
.result-wrapper .input-image-container,

.result-wrapper .result-container {

    width: 15rem;

    height: 15rem;

    border: 1px dashed black;

    justify-content: center;

    display: flex;

    align-items: center;

    flex-direction: column;

    background-color: rgb(209, 206, 206);

}
```

```
.result-wrapper .input-image-container img {

    width: 60%;

}
```

```
    height: 60%;  
  
    background-color: aqua;  
  
    background-size: contain;  
}
```

```
.result-wrapper .result-container .value {  
  
    font-size: 6rem;  
}
```

```
.result-wrapper .result-container .accuracy {  
  
    margin-top: -1rem;  
}
```

```
.other_predictions {  
  
    display: flex;  
  
    justify-content: center;  
  
    align-items: center;  
  
    flex-wrap: wrap;  
  
    column-gap: 1rem;  
  
    row-gap: 1rem;  
  
    font-weight: 700;  
}
```

```
.other_predictions .value {  
  
    display: flex;
```

```
    justify-content: center;

    align-items: center;

    flex-direction: column;

    width: 5rem;

    height: 5rem;

    box-shadow: 0 0 7px rgb(158, 157, 157);
}
```

```
.other_predictions .value div {

    margin-top: -1.2rem;

}
```

```
@media screen and (max-width: 700px) {

    h1 {

        font-size: 2.3rem;

    }

}
```

```
.result-wrapper .input-image-container,

.result-wrapper .result-container {

    width: 7rem;

    height: 7rem;

}
```

```
.result-wrapper .result-container .value {

    font-size: 4rem;

}
```

```
}  
  
}
```

## **13.2 GitHub**

<https://github.com/IBM-EPBL/IBM-Project-40041-1660621871>

## **13.3 Project Demo Link**

[https://drive.google.com/drive/folders/1ayVtYX57MWq9hVUy01MVfliG8Mz6bUVM?usp=share\\_link](https://drive.google.com/drive/folders/1ayVtYX57MWq9hVUy01MVfliG8Mz6bUVM?usp=share_link)