PROJECT REPORT

A NOVEL METHOD FOR HANDWRITTEN DIGIT RECOGNITION SYSTEM

submitted by

PNT2022TMID19219

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CHAPTER 1

INTRODUCTION

1.1 PROJECT OVERVIEW

Artificial intelligence and computer technology both heavily rely on machine learning and deep learning. Human effort in identifying, learning, making predictions, and many other areas can be decreased with the application of deep learning and machine learning.

The ability of computer systems to recognize handwritten digits from diverse sources, such as photographs, papers, and other things, is known as handwritten digit recognition. The goal of this project is to enable users to utilize machine learning to eliminate manual digit recognition jobs.

1.2 PURPOSE

Digit recognition software can read numbers from a variety of documents, including emails, bank checks, papers, and images. It can also recognize numbers in a variety of real-world situations, including online handwriting recognition on computer tablets or systems, reading vehicle license plates, processing bank check amounts, and manually filled-out forms.

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. In addition, it would be difficult to distinguish the numbers due to similarities between the numerals, such as 1 and 7, 5 and 6, 3 and 8, 2 and 5, and 2 and 7. Finally, the distinctiveness and variety of each person's handwriting have an impact on the digits' shape and appearance.

2.2 REFERENCES

Improved Handwri┼en Digit Recognition Using Convolutional Neural Networks (CNN) (2020)

Ayush Kumar Agrawal and Vineet Kumar Awasthi

An artificial neural network has one hidden layer between the input and output layers, whereas a deep neural network has numerous hidden layers with input and output layers. Deep neural networks use several hidden layers to increase model performance and achieve higher accuracy compared to accuracy of machine learning models.

Most researchers do their research in the area of pa1ern recognition. In the field of pa1ern recognition, there are many pa1erns that can be used, including handwri1en numbers, characters, pictures, faces, sounds, and speech. This study focuses on the classification and recognition of handwri1en digits.1000 were utilized as test samples and 1000 were training samples.10000 picture samples make up the USPS dataset, of which 7291 serve as training samples and 2007 serve as testing samples. We've used the proposed deep neural network technique in this paper to classify and identify data from the ARDIS and USPS datasets. The

suggested model consists of six layers with sofmax and relu activation functions. Afer model implementation, accuracy for ARDIS samples reached 98.70% testing and 99.76% training, which is greater than accuracy from prior research. Additionally, using the USPS samples dataset, 98.22% training accuracy and 93.01% testing accuracy were a1ained. When compared to earlier methodologies, the data show that deep neural networks perform incredibly well.

Recognition of isolated and simply connected handwri†en numerals, Pa†ern Recognition. (1986)

M. Shridhar and A. Badreldin

In this paper the authors describe the results of their investigation into the development of a recognition algorithm for identifying numerals that may be isolated or connected, broken or continuous. Using a structural classification scheme, the recognition algorithm is derived as a tree classifier. In an extensive test experiment, an accuracy of 99% was realized with isolated numerals. When connected numerals were also included a recognition accuracy of 93% was obtained.

Handwri†en Character Recognition using Neural Network and TensorFlow (2019)

Megha Agarwal, Shalika, Vinam Tomar, Priyanka Gupta

The offline handwri1en character recognition in this study will be carried out using Tensorflow and a convolutional neural network. a process known as using SofMax Regression, one may assign probabilities to one of the many characters in the handwri1en text that offers the range of values from 0 to 1, summed to 1. The objective is to create sofware that is extremely accurate and that has a minimum level of spatial and temporal complexity. It was determined

that strategies for feature extraction like diagonal and direction are significantly be1er at producing high accuracy. Outcomes in comparison to other conventional vertical and horizontal techniques moreover use the best Neural network tried layers provides the benefit of a higher accurate outcome by having a high noise tolerance. The feed forward model in neural networks is the back-propagation algorithm that was primarily used to classify the characters, recognise them, and receive training continually more. In addition to these, normalizing along with feature extraction, the results were be1er and more effective. Character recognition is the outcome of accuracy. The paper will describe the best approach to get more than 90% accuracy in the field of Handwri1en Character Recognition (HCR).

Handwri†en Digit Recognition of MNIST dataset using Deep Learning state-of-the-art Artificial Neural Network (ANN) and Convolutional Neural Network (CNN) (2021)

Drishti Beohar, A. Rasool

Handwri1en digit recognition is an intricate assignment that is vital for developing applications, in computer vision digit recognition is one of the major applications. There has been a copious exploration done in the Handwri1en Character Recognition utilizing different deep learning models. Deep learning is rapidly increasing in demand due to its resemblance to the human brain. The two major Deep learning algorithms Artificial Neural Network and Convolutional Neural Network which have been compared in this paper considering their feature extraction and classification stages of recognition. The models were trained using categorical cross-entropy loss and ADAM optimizer on the MNIST dataset. Backpropagation along with Gradient Descent is being used to train the networks along with reLU activations in the network which do automatic feature extraction. In neural networks, Convolution Neural Network (ConvNets or Convolutional neural networks) is one of the primary classifiers to do image recognition, image

classification tasks in Computer Vision.

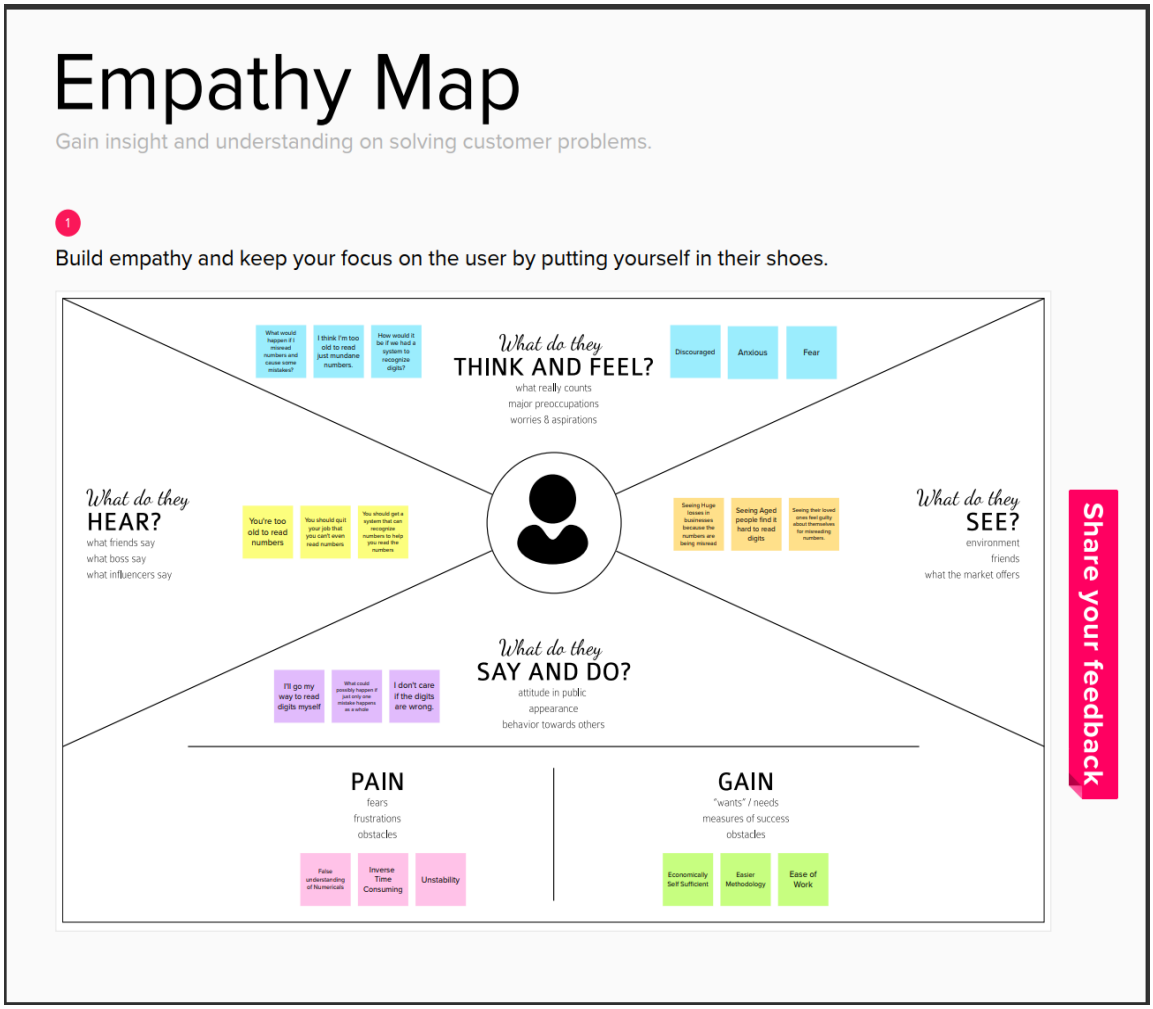
2.3 PROBLEM STATEMENT DEFINITION

Handwritten digit recognition is the ability of computers to recognize human handwritten digits. It is a hard task for the machine because handwritten digits are not perfect and can be made with many different flavors. The handwritten digit recognition is the solution to this problem which uses the image of a digit and recognizes the digit present in the image.

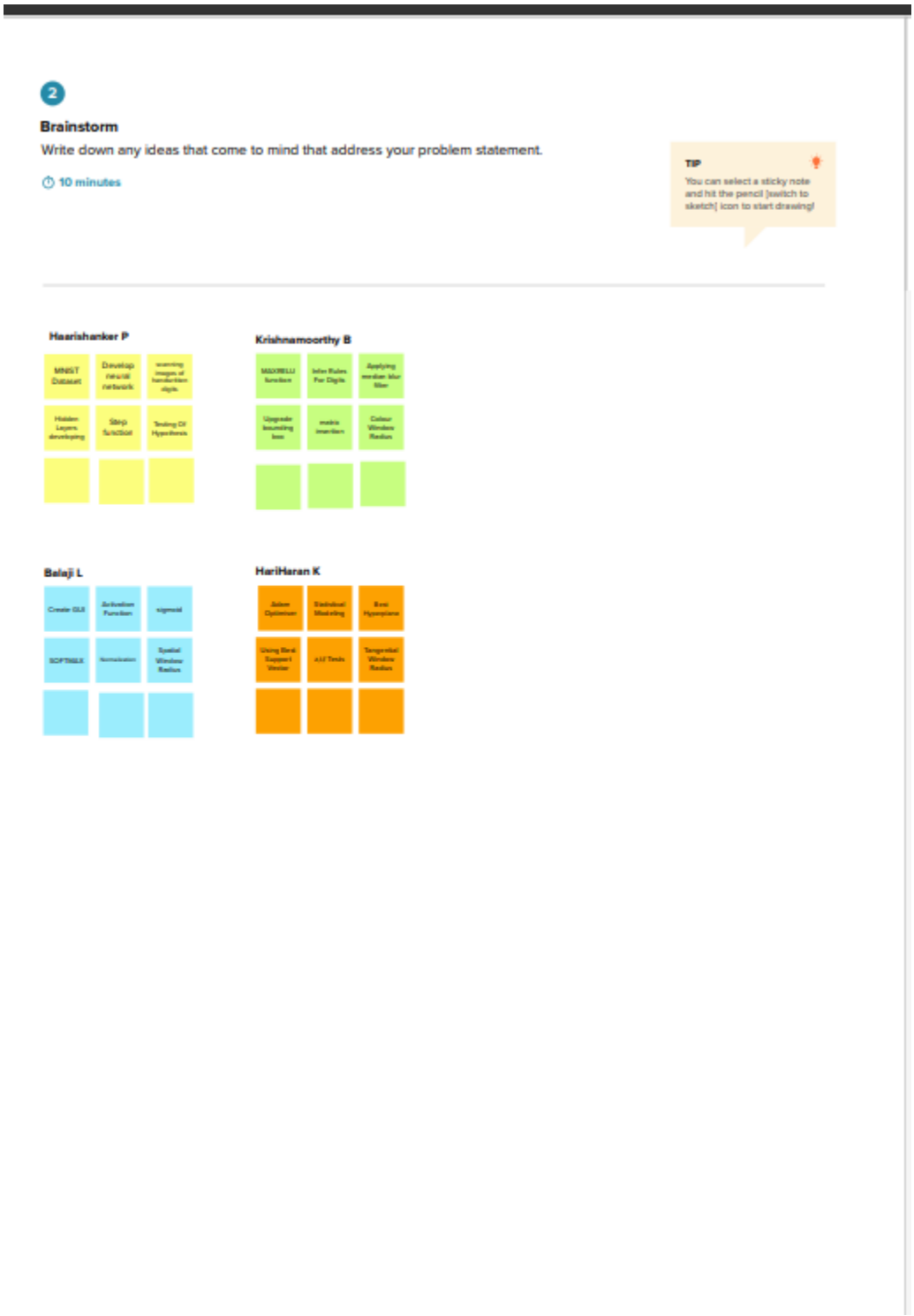
Digit recognition systems are capable of recognizing the digits from different sources like emails, bank cheque, papers, images, etc. and in different real-world scenarios for online handwriting recognition on computer tablets or system, recognize number plates of vehicles, processing bank cheque amounts,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

CHAPTER 3
IDEATION AND PROPOSED SOLUTION

3.1 EMPATHY MAP CANVAS



3.2 IDEATION & BRAINSTORMING



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 and 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 (Problem to be solved)	Recognition of handwritten illegible numerical digits by people.
2	Idea / Solution description	To develop a web application that recognizes handwritten digits using machine learning algorithms.
3	Novelty / Uniqueness	There are ten classes to predict. Results are reported using prediction error, which is nothing more than the inverted classification accuracy.
4	Social Impact / Customer Satisfaction	Make the customers feel satisfied by the service provided as there will be no more human interference needed.
5	Business Model (Revenue Model)	Create a customer base by providing trial versions, and make them pay for the product by creating subscription plans.
6	Scalability of the Solution	Product can be scaled as per the increase in number of the customers.

3.4 PROBLEM SOLUTION FIT

Project Title: A Novel Method For Handwritten Digit Recognition System

Project Design Phase-I - Problem Solution Fit

Team ID: PNT2022TMID19219

Define CS, fit into CC

1. CUSTOMER SEGMENT(S) CS

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

Aged people, People with disabilities in their eyes.

6. CUSTOMER CONSTRAINTS CC

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

Scarcity of resources to identify individual digits.

5. AVAILABLE SOLUTIONS AS

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

Using a magnifying lens to identify the structure of the digits.

Explore AS, differentiate

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

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

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

Recognises digits from 0 to 9 in a series parallel or written digits by comparing them with inbuilt digit images

9. PROBLEM ROOT CAUSE RC

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

People writing digits that are illegible.

7. BEHAVIOUR BE

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

Requesting other people to recognize the digits.

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

Identify strong TR & EM

3. TRIGGERS TR

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

Customers know that there can be a better solution to recognize digits using computer systems.

4. EMOTIONS: BEFORE / AFTER EM

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

Fear, unsure -> confident, strong

10. YOUR SOLUTION SL

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

Developing a web application to recognize handwritten digits using machine learning algorithms.

8. CHANNELS of BEHAVIOUR CH

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

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

Online -> Find if they can obtain a better solution to recognize digits.

Offline -> Request other people to help them with recognizing handwritten digits.

Identify strong TR & EM

CHAPTER 4
REQUIREMENT ANALYSIS

4.1 FUNCTIONAL REQUIREMENTS

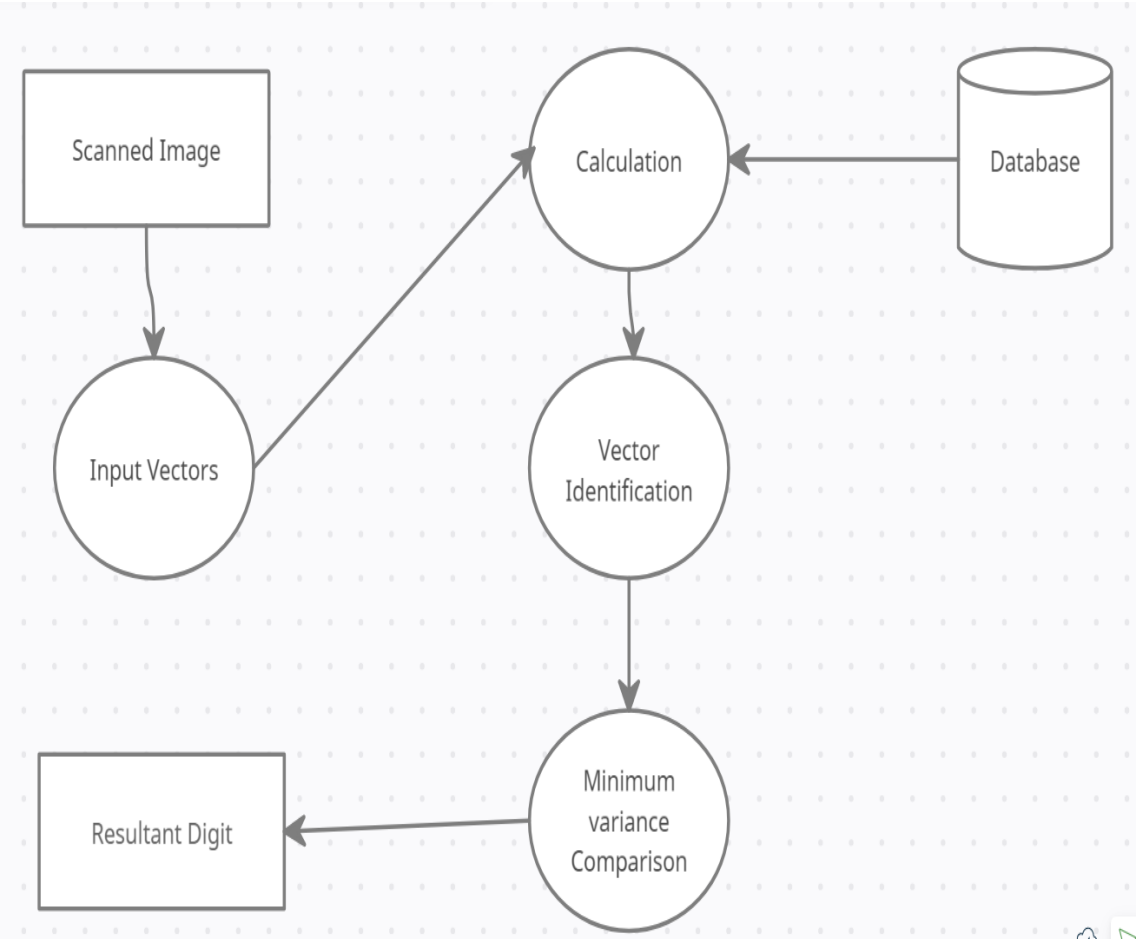
FR No.	Functional Requirement (Epi.)	Sub Requirement (Story / Sub-Task)
FR-1	Image Data	Handwritten digit recognition refers to a computer's capacity to identify human handwritten digits from a variety of sources, such as photographs, documents, touch screens, etc., and categorise them into ten established classifications (0-9).
FR-2	Website	Web hosting makes the ode, graphics, and other items that make up a website accessible online. A server hosts every website you've ever visited. The type of hosting determines how much space is allotted to a website on a server.
FR-3	Digit Classifier Model	To train a convolutional network to predict the digit form an image, use the MNIST database of handwritten digits. Get the training and validation data first.
FR-4	Cloud	The cloud offers a range of IT services, including virtual storage, networking, servers, databases, and applications. In plain English, cloud computing is described as a virtual platform that enables unlimited storage and access to your data over the internet.
FR-5	MNIST Dataset	The abbreviation of MNIST stands for Modified National Institute of Standards and Technology dataset. It is a collection of 60,000 tiny square grayscale photographs, each easuring 28 by 28, comprising handwritten single digits between 0 and 9.

4.2 NON FUNCTIONAL REQUIREMENTS

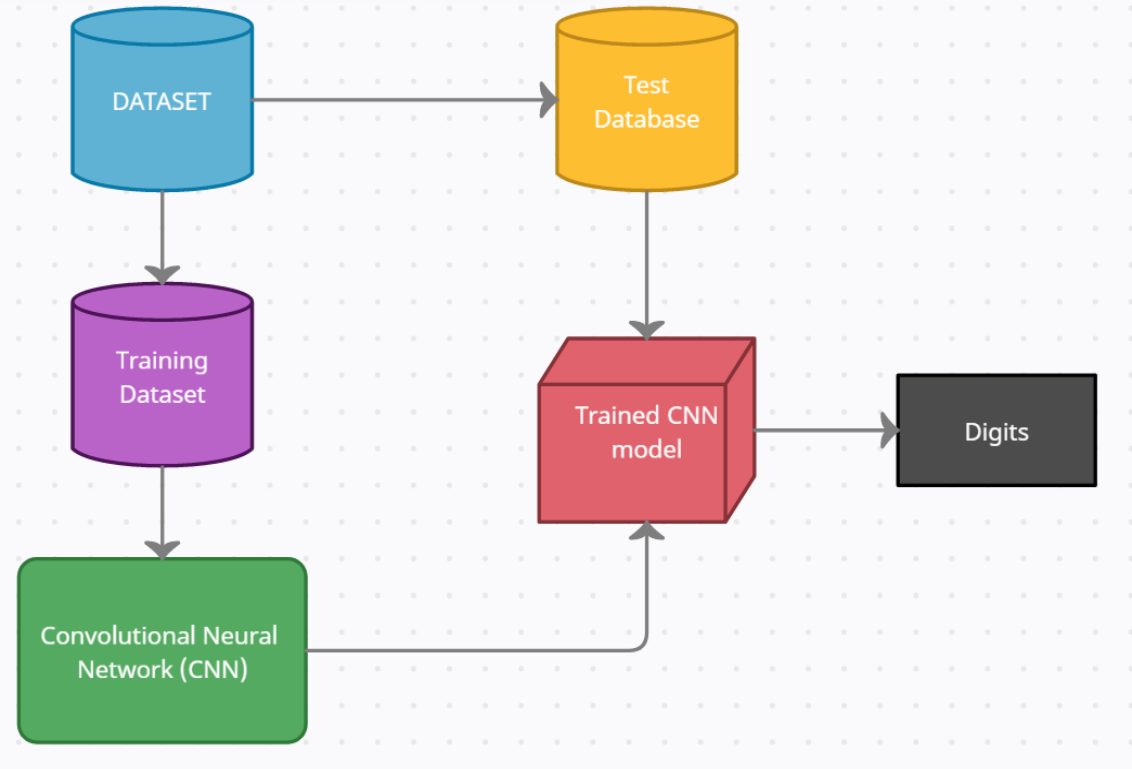
FR No.	Non-Functional Requirement	Description
NFR-1	**Usability**	One of the very significant problems in pattern recognition applications is the recognition of handwritten characters. Applications for digit recognition include filling out forms, processing bank checks, and sorting mail.
NFR-2	**Security**	The system generates a thorough description of the instantiation parameters, which might reveal information like the writing style, in addition to a categorization of the digit. The generative models are capable of segmentation driven by recognition. The procedure uses a relatively.
NFR-3	**Reliability**	The samples are used by the neural network to automatically deduce rules for reading handwritten digits. Furthermore, the network may learn more about handwriting and hence enhance its accuracy by increasing the quantity of training instances.
NFR-4	**Performance**	The application is expected of having response which is derived in a quick manner.
NFR-5	**Availability**	Since the application is hosted in the cloud, we can expect the application to be available all over the world where people can have access to the internet.
NFR-6	**Scalability**	The application is expected to handle huge chunks of data without having the need to compromise on performance and accuracy of the end result.

CHAPTER 5
PROJECT DESIGN

5.1 DATA FLOW DIAGRAM



5.2 SOLUTION & 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 awareness to use this application and its limitations.	Low	Sprint-1
		USN-2	As a user, I am allowed to view the guided video to use the interface of this application.	I can gain knowledge to use this application by a practical method.	Low	Sprint-1
		USN-3	As a user, I can read instructions to use this application.	I can read instructions to use the application the most correct possible way.	Low	Sprint-2
	Recognize	USN-4	As a user, in this prediction page I get to choose the image.	I can choose the image from our local system and predict the output.	High	Sprint-2
	Predict	USN-5	As a user, I am allowed to upload and choose the image to be uploaded.	I can upload and choose the image from the system storage and also in any virtual storage.	Medium	Sprint-3
		USN-6	As a user, I will train and test the input to get the maximum accuracy of output.	I can also to train and test the application until it gets maximum accuracy of the accurate result.	High	Sprint-4
		USN-7	As a user, I can access the MNIST data set.	I can access the MNIST data 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 the web app.	I can view the awareness of this application and its limitations.	Low	Sprint-1
Customer (Mobile user)	Home	USN-1	As a user, I can view the guide and awareness to use this application.	I can view the awareness to use this application and its limitations.	Low	Sprint-1
		USN-2	As a user, I am allowed to view the guided video to use the interface of this application.	I can gain knowledge to use this application by a practical method.	Low	Sprint-1
		USN-3	As a user, I can read instructions to use this application.	I can read instructions to use the application the most correct possible way.	Low	Sprint-2
	Recognize	USN-10	As a user, I can use the web application virtually anywhere.	I can use the application portably anywhere.	High	Sprint-1

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
		USN-11	As it is an open source, can use it cost freely	I can use it without any payment to be paid for it to access.	Medium	Sprint-2
	Predict	USN-12	As it is a web application, it is installation free	I can use it without the installation of the application or any software.	Medium	Sprint-4
		USN-13	As a user, I am allowed to upload and choose the image to be uploaded.	I can upload and choose the image from the system storage and also in any virtual storage.	Medium	Sprint-3

CHAPTER 6
PROJECT PLANNING AND SCHEDULING

6.1 SPRINT PLANNING AND ESTIMATION

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Home	USN-1	As a user, I can view the guide and awareness to use this application.	4	Low	Haarishanker Krishna Balaji Hariharan
Sprint-1		USN-2	As a user, I am allowed to view the guided video to use the interface of this application.	4	Low	Haarishanker Krishna Balaji Hariharan
Sprint-2		USN-3	As a user, I can read instructions to use this application.	7	Low	Haarishanker Krishna Balaji Hariharan
Sprint-2	Recognize	USN-4	As a user, in this prediction page I get to choose the image.	7	High	Haarishanker Krishna Balaji Hariharan
Sprint-3	Predict	USN-5	As a user, I am allowed to upload and choose the image to be uploaded.	7	Medium	Haarishanker Krishna Balaji Hariharan
Sprint-4	Dashboard	USN-6	As a user, I will train and test the input to get the maximum accuracy of output.	10	High	Haarishanker Krishna Balaji Hariharan
Sprint-3		USN-7	As a user, I can access the MNIST data set.	7	Medium	Haarishanker Krishna Balaji Hariharan
Sprint-1	Home	USN-8	As a user, I can view the guide to use the web app.	4	Low	Haarishanker Krishna Balaji Hariharan
Sprint-1	Home	USN-1	As a user, I can view the guide and awareness to use this application.	4	Low	Haarishanker Krishna Balaji Hariharan
Sprint-1		USN-2	As a user, I am allowed to view the guided video to use the interface of this application.	4	Low	Haarishanker Krishna Balaji Hariharan

Sprint-2		USN-3	As a user, I can read instructions to use this application.	7	Low	Haarishanker Krishna Balaji Hariharan

6.2 SPRINT DELIVERY SCHEDULE

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

CHAPTER 7

CODING & SOLUTIONING

Import Required Librauries

In [52]:
```
import numpy as np
import tensorflow as tf
import matplotlib.pyplot as plt
from keras.utils import np_utils
import tensorflow as tf
from tensorflow.keras.layers import Conv2D, Dense, Flatten
```

In [2]:
```
print(tf.__version__)
```

```
2.9.2
```

In [3]:
```
mnist_ds = tf.keras.datasets.mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
11490434/11490434 [==============================] - 0s 0us/step
```

In [4]:
```
mnist_ds
```

Building The Model

In [53]:
```
model = tf.keras.models.Sequential([tf.keras.layers.Conv2D(64, (3, 3), input_shape=(28, 28, 1), activation="relu"),
                                    tf.keras.layers.Conv2D(32, (3, 3), activation="relu"),
                                    tf.keras.layers.Flatten(),
                                    tf.keras.layers.Dense(10, activation=tf.nn.softmax)])
```

In [54]:
```
model.compile(loss='categorical_crossentropy', optimizer="Adam", metrics=["accuracy"])
```

In [55]:
```
model.summary()
```

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

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

 flatten (Flatten)           (None, 18432)             0

 dense (Dense)               (None, 10)                184330

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

Training The Model

In [56]:
```
model.fit(training_images, training_labels, batch_size=32, epochs=5, validation_data=(test_images,test_labels))
```

```
Epoch 1/5
1875/1875 [==============================] - 16s 4ms/step - loss: 0.1254 - accuracy: 0.9625 - val_loss: 0.0519 - val_accuracy: 0.9831
Epoch 2/5
1875/1875 [==============================] - 7s 4ms/step - loss: 0.0464 - accuracy: 0.9861 - val_loss: 0.0385 - val_accuracy: 0.9868
Epoch 3/5
1875/1875 [==============================] - 7s 4ms/step - loss: 0.0296 - accuracy: 0.9907 - val_loss: 0.0409 - val_accuracy: 0.9872
Epoch 4/5
1875/1875 [==============================] - 7s 4ms/step - loss: 0.0201 - accuracy: 0.9937 - val_loss: 0.0403 - val_accuracy: 0.9878
Epoch 5/5
1875/1875 [==============================] - 7s 4ms/step - loss: 0.0139 - accuracy: 0.9957 - val_loss: 0.0457 - val_accuracy: 0.9872
```

Out[56]:

Test The Model

In [58]:
```
metrics = model.evaluate(test_images, test_labels, verbose=0)

print("Test Loss -> {}  \nTest Accuracy -> {}".format(metrics[0],metrics[1]))
```

```
Test Loss -> 0.04573516175150871
Test Accuracy -> 0.9872000217437744
```

In [67]:
```
model.predict(test_images[2:8])
```

```
1/1 [==============================] - 0s 15ms/step
```

Out[67]:
```
array([[2.32068427e-08, 9.99983430e-01, 8.10439190e-07, 1.28179977e-07,
        9.64922492e-06, 1.83879649e-06, 1.62838049e-07, 1.56461965e-06,
        2.34936374e-06, 3.22469944e-08],
       [9.99998927e-01, 1.04071238e-13, 7.69856399e-07, 1.84226245e-09,
        3.37900985e-13, 4.71777106e-09, 8.84182239e-09, 2.02508791e-11,
        3.22932721e-07, 9.56373647e-09],
       [8.73478698e-13, 4.26847549e-13, 1.15858136e-10, 3.97662771e-11,
        9.99999881e-01, 2.68545906e-12, 8.56604648e-11, 7.41609482e-11,
        4.87753553e-08, 1.05269102e-07],
       [2.15423035e-09, 9.99581635e-01, 2.15949945e-06, 1.08863398e-08,
        2.10376020e-05, 2.63231090e-08, 3.26978977e-08, 3.81208694e-04,
        1.27898356e-05, 1.17525337e-06],
       [2.41032138e-18, 9.36788008e-11, 3.97475330e-10, 3.54850779e-13,
        9.99299288e-01, 6.94019908e-09, 6.61158953e-14, 4.28452246e-10,
        7.00477336e-04, 2.29253416e-07],
       [1.89875802e-16, 2.21634187e-11, 1.76986703e-09, 2.65193867e-09,
        2.56875592e-06, 2.88839956e-08, 1.60236594e-14, 2.67538752e-11,
        5.46009005e-06, 9.99991894e-01]], dtype=float32)
```

In [74]:
```
history=model.predict(np.array([test_images[7]]))
history
```

```
1/1 [==============================] - 0s 17ms/step
```

Out[74]:
```
array([[1.8987580e-16, 2.2163419e-11, 1.7698670e-09, 2.6519387e-09,
        2.5687532e-06, 2.8883996e-08, 1.6023692e-14, 2.6753875e-11,
        5.4600901e-06, 9.9999189e-01]], dtype=float32)
```

In [75]:
```
np.argmax(history, axis=1)
```

Out[75]:
```
array([9])
```

In [73]:
```
#It predicted as 9
```

Let us see , It is correct or not?

In [78]:
```
tl=test_labels[7]
tl
```

Out[78]:
```
array([0., 0., 0., 0., 0., 0., 0., 0., 0., 1.], dtype=float32)
```

In [81]:
```
np.argmax(tl)
```

Out[81]:
```
9
```

It Predicted Correctly!!!

CHAPTER 8
TESTING

8.1 TEST CASES

Testcase 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 2560x1801 and 768x630	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 ifthe 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

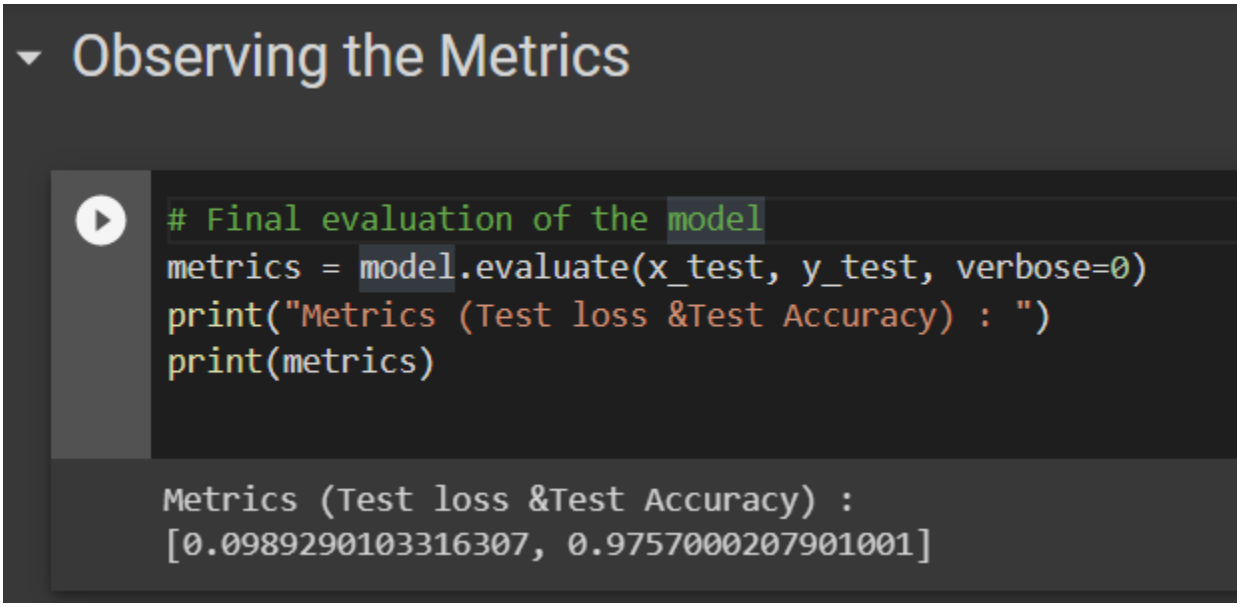
Resolution	Severity 1	Severity 2	Severity 3	Severity 4	Total
By Design	1	0	1	0	2
Duplicate	0	0	0	0	0
External	0	0	2	0	2
Fixed	4	1	0	1	6
Not Reproduced	0	0	0	1	1
Skipped	0	0	0	1	1
Won’t Fix	1	0	1	0	2
Total	6	1	4	3	14

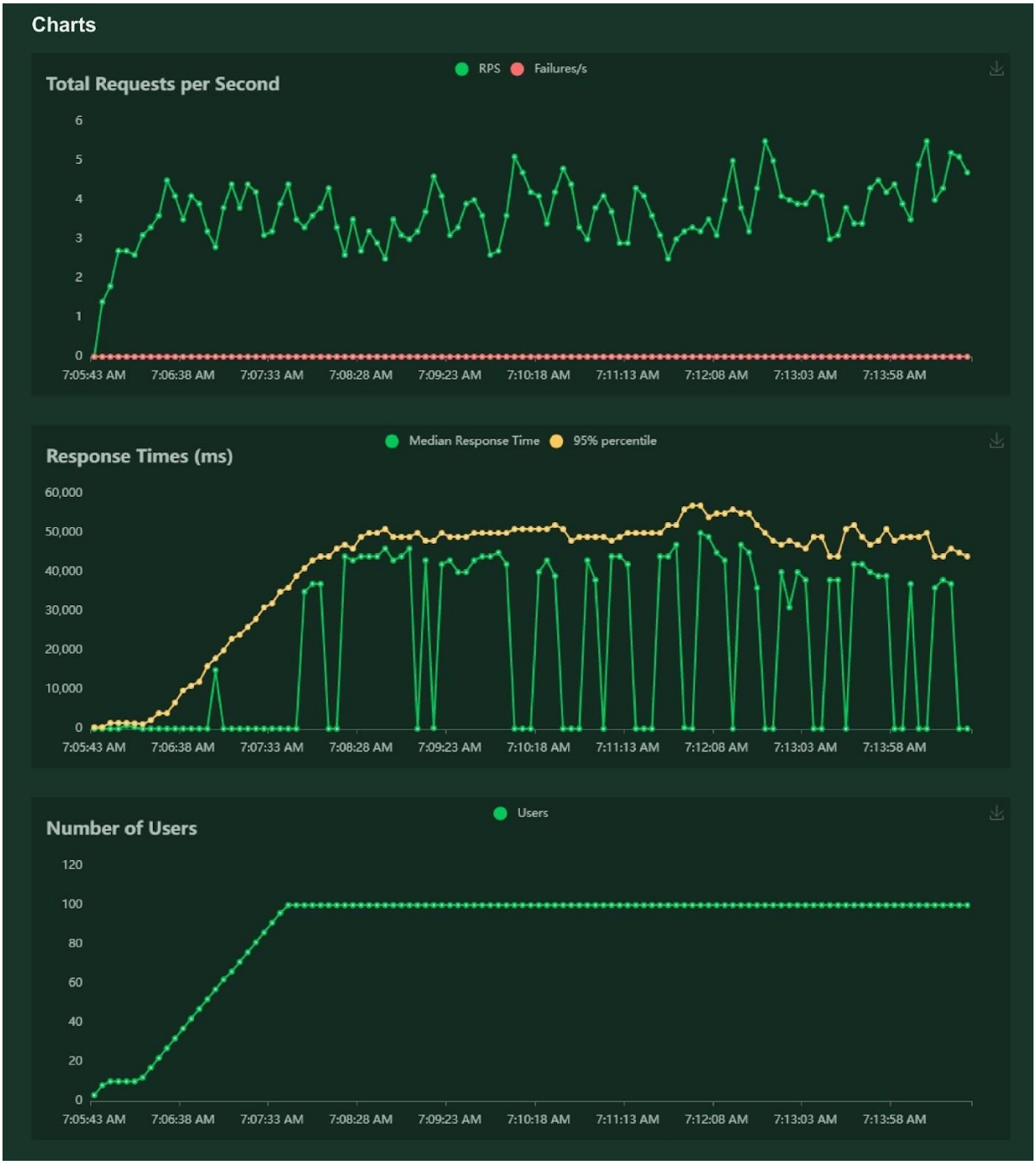
8.2.2 TEST CASE ANALYSIS

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




Charts
Total Requests per Second
RPS
Failures/s
6
5
4
3
2
1
0
7:05:43 AM
7:06:38 AM
7:07:33 AM
7:08:28 AM
7:09:23 AM
7:10:18 AM
7:11:13 AM
7:12:08 AM
7:13:03 AM
7:13:58 AM
Response Times (ms)
Median Response Time
95% percentile
60,000
50,000
40,000
30,000
20,000
10,000
0
7:05:43 AM
7:06:38 AM
7:07:33 AM
7:08:28 AM
7:09:23 AM
7:10:18 AM
7:11:13 AM
7:12:08 AM
7:13:03 AM
7:13:58 AM
Number of Users
Users
120
100
80
60
40
20
0
7:05:43 AM
7:06:38 AM
7:07:33 AM
7:08:28 AM
7:09:23 AM
7:10:18 AM
7:11:13 AM
7:12:08 AM
7:13:03 AM
7:13:58 AM

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

Building The Model

In [53]:
```
model = tf.keras.models.Sequential([tf.keras.layers.Conv2D(64, (3, 3), input_shape=(28, 28, 1), activation="relu"),
                                    tf.keras.layers.Conv2D(32, (3, 3), activation="relu"),
                                    tf.keras.layers.Flatten(),
                                    tf.keras.layers.Dense(10, activation=tf.nn.softmax)])
```

In [54]:
```
model.compile(loss='categorical_crossentropy', optimizer="Adam", metrics=["accuracy"])
```

In [55]:
```
model.summary()
```

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

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

 flatten (Flatten)           (None, 18432)             0

 dense (Dense)               (None, 10)                184330

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

Training The Model

In [56]:
```
model.fit(training_images, training_labels, batch_size=32, epochs=5, validation_data=(test_images,test_labels))
```

```
Epoch 1/5
1875/1875 [==============================] - 16s 4ms/step - loss: 0.1254 - accuracy: 0.9625 - val_loss: 0.0519 - val_accuracy: 0.9831
Epoch 2/5
1875/1875 [==============================] - 7s 4ms/step - loss: 0.0464 - accuracy: 0.9861 - val_loss: 0.0385 - val_accuracy: 0.9868
Epoch 3/5
1875/1875 [==============================] - 7s 4ms/step - loss: 0.0296 - accuracy: 0.9907 - val_loss: 0.0409 - val_accuracy: 0.9872
Epoch 4/5
1875/1875 [==============================] - 7s 4ms/step - loss: 0.0201 - accuracy: 0.9937 - val_loss: 0.0403 - val_accuracy: 0.9878
Epoch 5/5
1875/1875 [==============================] - 7s 4ms/step - loss: 0.0139 - accuracy: 0.9957 - val_loss: 0.0457 - val_accuracy: 0.9872
```

Out[56]:

Test The Model

In [58]:
```
metrics = model.evaluate(test_images, test_labels, verbose=0)

print("Test Loss -> {}  \nTest Accuracy -> {}".format(metrics[0],metrics[1]))
```

```
Test Loss -> 0.04573516175150871
Test Accuracy -> 0.9872000217437744
```

FLASK APP

```python
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

```python
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

```

```python
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/digitRecog.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))
```

```python
    # 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">
            <h1 class="heading__main">Handwritten Digit Recognizer</h1>
                <h2 class="heading__sub">Web Application to detect Handwritten digits</h2>

                <div class="form-wrapper">
                    <marquee width="100%" direction="left" height="60px">
                        <b><-----Provide an image for which you want to get the clear identity-------></b>
                        </marquee><br>
                    <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>
                    <img id="loading" src="{{url_for('static',filename='images/loading.gif')}}">

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

HOME PAGE (CSS)

```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;
        background-image: url('https://www.zastavki.com/pictures/1600x900/2015/Backgrounds_Orange_gradient_background_096901_25.jpg');

}

.container {
        width: 100%;
        height: 100%;
        display: flex;
        flex-direction: column;
        justify-content: center;
        align-items: center;
        background-color: rgba(102, 100, 100, 0.79);
}

.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(239, 12, 12, 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;
        width: 700px;
        height: 500px;
        border: 1px solid rgb(255, 98, 0);
}

.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: rgb(255, 255, 255);
        background-color: rgb(34, 14, 213);
        box-shadow: 0 5px 10px rgb(249, 127, 51);
}
```

```
80
81  .form-wrapper .upload #up_btn {
82          display: none;
83
84  }
85
86  .form-wrapper .upload label {
87          font-size: 1rem;
88          font-weight: 600;
89          color: rgb(255, 255, 255);
90          height: 100%;
91          width: 100%;
92          padding: 10px;
93          display: block;
94          background-color: blueviolet;
95          text-align: left;
96
97  }
98
99  .form-wrapper .upload svg {
100         height: 15px;
101         width: auto;
102         padding-right: 8px;
103         margin-bottom: -2px;
104 }
105
106 @media screen and (max-width: 700px) {
107         .upload-container {
108                 height: 20rem;
109                 width: 18rem;
110                 margin-top: 3.5rem;
111                 margin-bottom: -8rem;
112         }
113
114         .heading .heading__main {
115                 margin-top: -6rem;
116                 font-size: 2rem;
117                 padding-bottom: 1rem;
118         }
119 }
```

PREDICT PAGE (HTML)

```
<html>
        <head>
                <style>
                        .bt{
        background-color: gray;
        color: rgb(14, 13, 13);
        border: 1px solid #eee;
        border-radius: 20px;
        box-shadow: 5px 5px 5px #eee;
        text-shadow: none;
        text-align: center;
}
.button {
  border-radius: 4px;
  background-color: #043217;
  border: none;
  color: #FFFFFF;
  text-align: center;
  font-size: 22px;
  padding: 10px;
  width: 200px;
  transition: all 0.5s;
  cursor: pointer;
  margin: 5px;
}

```

```
.button span {
  cursor: pointer;
  display: inline-block;
  position: relative;
  transition: 0.5s;
}

.button span:after {
  content: ' \00AB';
  position: absolute;
  opacity: 0;
  top: 0;
  left: -20px;
  transition: 0.5s;
}

.button:hover span {
  padding-left: 25px;
}

.button:hover span:after {
  opacity: 1;
  left: 0;
}
                </style>
                <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')}}" />

        <link href="https://cdn.jsdelivr.net/npm/bootstrap@5.2.2/dist/css/bootstrap.min.css" rel="stylesheet" integrity="sha384-Zenh87qX5JnK2Jl0vWa8Ck2rdkQ2Bzep5ID
                <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">
                                        <img src="{{url_for('static',filename='data/')}}{{img_name}}" /><br>


                                </div>
                                <img src="https://media3.giphy.com/media/XwcRf1O9HD0Sk6RaRM/giphy.gif" height="250">
                                <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>

                <form action="/" >
                        <div class="bt">
                                <button type="submit" class="button"><span>Choose another pic !  </span></button>
                </div>
                  </form>


        </body>
</html>
```

PREDICT PAGE (CSS)

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

body {
        color: rgb(255, 255, 255);
        font-family: "Overpass", sans-serif;
        background-image: url('https://wallpaperaccess.com/full/1092567.png');
}

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(124, 189, 245);
        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(129, 175, 231);
}

.result-wrapper .input-image-container img {
        width: 60%;
        height: 60%;
        background-color: aqua;
        background-size: contain;
}
```

```
54
55  .result-wrapper .result-container .value {
56          font-size: 6rem;
57  }
58
59  .result-wrapper .result-container .accuracy {
60          margin-top: -1rem;
61  }
62
63  .other_predictions {
64          display: flex;
65          justify-content: center;
66          align-items: center;
67          flex-wrap: wrap;
68          column-gap: 1rem;
69          row-gap: 1rem;
70          font-weight: 700;
71          border: 2px dotted black;
72  }
73
74  .other_predictions .value {
75          display: flex;
76          justify-content: center;
77          align-items: center;
78          flex-direction: column;
79          width: 5rem;
80          height: 5rem;
81          box-shadow: 0 0 7px rgb(158, 157, 157);
82          border: 2px dotted black;
83  }
84
85  .other_predictions .value div {
86          margin-top: -1.2rem;
87          border: 2px dotted black;
88
89  }
90
91  @media screen and (max-width: 700px) {
92          h1 {
93                  font-size: 2.3rem;
94          }
95
96          .result-wrapper .input-image-container,
97          .result-wrapper .result-container {
98                  width: 7rem;
99                  height: 7rem;
100         }
101
102         .result-wrapper .result-container .value {
103                 font-size: 4rem;
104         }
105 }
```

JavaScript

```
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';
});
```

GITHUB

https://github.com/IBM-EPBL/IBM-Project-7332-1658852917

PROJECT DEMO

https://drive.google.com/file/d/1uM7KK3d0J8w6xJ2SASNfuqD-UkB8-X87/view?usp=share_link