

A Novel Method for Handwritten Digit Recognition System

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1. INTRODUCTION

1.1 Project Overview

Handwriting recognition is one of the compelling research works going on because every individual in this world has their own style of writing. It is the capability of the computer to identify and understand handwritten digits or characters automatically. Because of the progress in the field of science and technology, everything is being digitalized to reduce human effort. Hence, there comes a need for handwritten digit recognition in many real-time applications. MNIST data set is widely used for this recognition process and it has 70000 handwritten digits. We use Artificial neural networks to train these images and build a deep learning model. Web application is created where the user can upload an image of a handwritten digit. this image is analyzed by the model and the detected result is returned on to UI

1.2 Purpose

The applications of digit recognition include in **postal mail sorting, bank check processing, form data entry**, etc. The main problem lies within the ability on developing an efficient algorithm that can recognize hand written digits, which is submitted by users by the way of a scanner, tablet, and other digital devices.

2. LITERATURE SURVEY

2.1 Existing problem

The issue is that **there's a wide range of handwriting - good and bad**. This makes it tricky for programmers to provide enough examples of how every character might look. Plus, sometimes, characters look very similar, making it hard for a computer to recognise accurately.

2.2 References

[1] Handwritten Digit Classification Using the **MNIST** Dataset by **M. Wu** and **Z. Zhang**, 2010. [2] Handwritten digit recognition with decoding, A. Dutta and A. Dutta Handwritten digital recognition is utilized in this article. Comprehensive learning techniques have been established. The sam data was used to train and evaluate a number of popular machine learning methods, including

KNN, SVM, RFC, and CNN, to uncover comparisons across divisions. The more deeply you learn using these techniques, the more accurate you will be. In contrast to previous research techniques, this technique focuses on which category helps construct models with separation accuracy of greater than 99%. When CNN is used as the backend and Tensorflow as the software, it can deliver accuracy of roughly 98.72%. CNN provides 98.72% accuracy in the first test.

[2] Handwritten Words and Digits Recognition using Deep Learning Based Bag of Features Framework-February 2020

Najoua Raha, Maroua Tounsi, Tarek M Hamdani, Adel M Alimi

This project is to propose a novel feature extraction model by learning a Bag of Features Framework for handwritten text recognition based on Deep Sparse Auto-Encoder. This method achieves promising recognition on both datasets (IFN/ENIT word images benchmark and **MNIST** handwritten digits.)

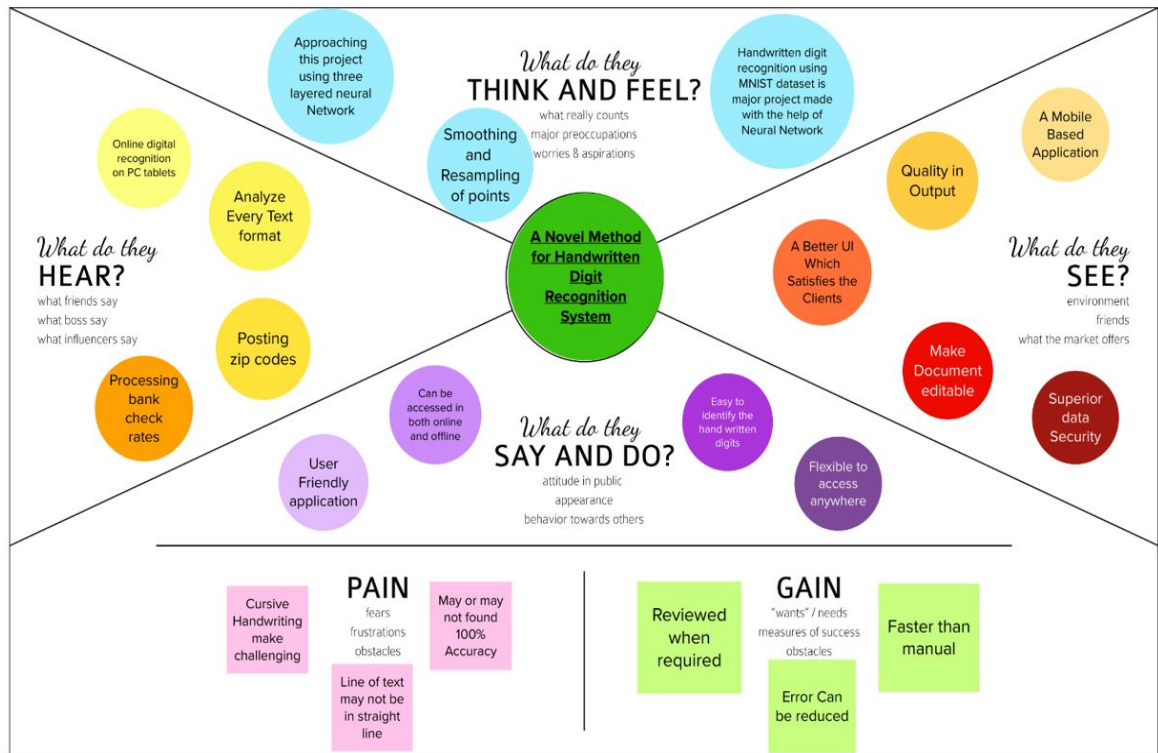
2.3 Problem Statement Definition

The goal of this project is to create a model that will be able to recognize and determine the handwritten digits from its image by using the concepts of Convolution Neural Network. Though the goal is to create a model which can recognize the digits, it can be extended to letters and an individual's handwriting.

3. IDEATION & PROPOSED SOLUTION

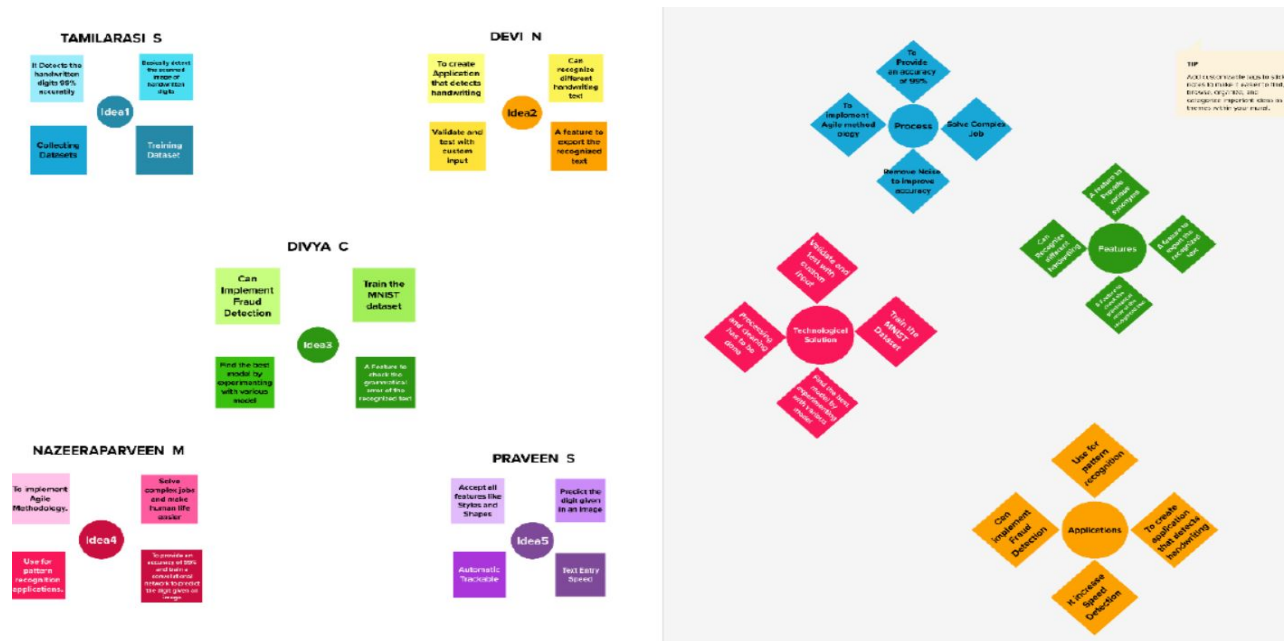
3.1 Empathy Map Canvas

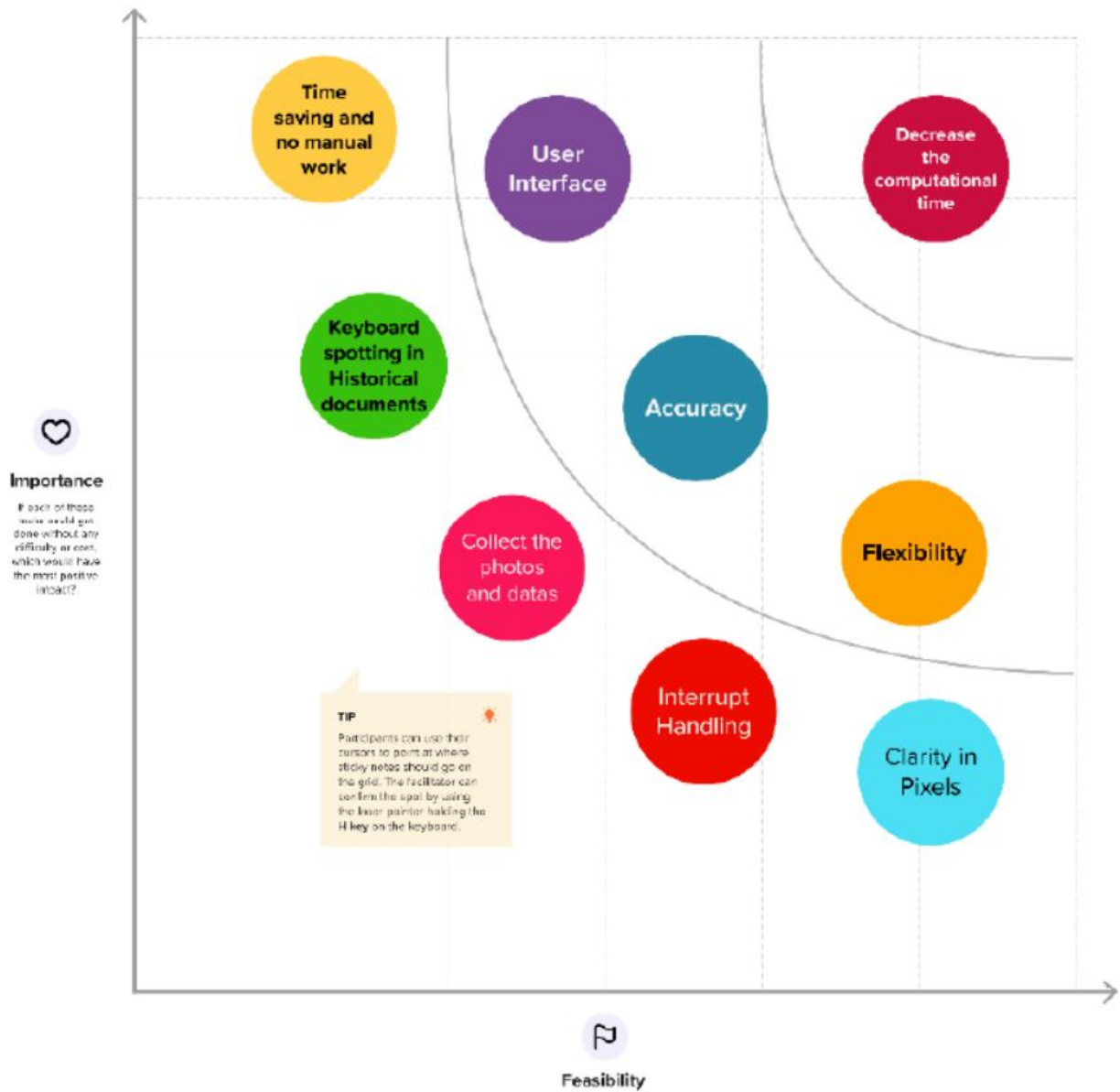
An empathy map is a collaborative tool teams can use to gain a deeper insight into their customers. Much like a user persona, an empathy map can represent a group of users, such as a customer segment. The empathy map was originally created by Dave Gray and has gained much popularity within the agile community.



3.2 Ideation & Brainstorming

Ideation refers to the whole creative process of coming up with and communicating new ideas. It can take many different forms, from coming up with a totally new idea to combining multiple existing ideas to create a new process or organizational system. Ideation is similar to a practice known as brainstorming.





3.3 Proposed Solution

Proposed Solution means **the technical solution to be provided by the Implementation agency in response to the requirements and the objectives of the Project.**

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	<ul style="list-style-type: none">✓ An optimized way to recognize and predict the handwritten digit with increased accuracy (expecting to achieve results more than 97% accuracy), low run time and low memory requirements.
2.	Idea / Solution description	<ul style="list-style-type: none">✓ The idea is to calculate features that make it possible to distinguish between different numbers.✓ Some example features for this dataset might include the number of colour pixels, or maybe the width and the height of the digits and use the SVMs algorithm to optimize the prediction.✓ However, generally just the algorithm is not enough to get optimal classification rates.✓ Another important aspect to improve scores is feature extraction.✓ Although the other algorithms might not be what you are looking for, it is possible that adding more features can improve the performance of the algorithm you are currently using as well.
3.	Novelty / Uniqueness	<ul style="list-style-type: none">✓ Precisely recognise and predict the uploaded document and canvas drawn digits using the SVMs algorithm and the feature extraction aspect.

4.	Social Impact / Customer Satisfaction	<ul style="list-style-type: none"> ✓ It helps the postal department, banking sector and traffic department. ✓ It also helps the old age humans with less eye sight
5.	Business Model (Revenue Model)	<ul style="list-style-type: none"> ✓ We can generate revenue by advertisement part of our website and application play store revenue. ✓ We are aiming to collaborate with banking sectors, postal sectors and traffic control department to use our project in recognising cheque digits, zip code and number plate digit. ✓ We share the profit by group driveways.
6.	Scalability of the Solution	<ul style="list-style-type: none"> ✓ The scalability of our solution is to get accuracy of around 97% or more and also to grow exponentially in revenue.

3.4 Problem Solution fit

The Problem-Solution Fit simply means that you have found a problem with your customer and that the solution you have realized for it actually solves the customer's problem.

Define CS, fit into CC	<div>1. CUSTOMER SEGMENT(S)<div>CS</div><div><div>😊</div>Used in Banking and Post Office</div><div>😊</div>Register Office</div> <div>😊</div> Passport and visa Office <div>😊</div> Government Document Verification Office <div>😊</div> Aadhar Sector <div>😊</div> Medical Department <div>😊</div> Old Age People	<div>6. CUSTOMER CONSTRAINTS<div>CC</div><div><div>⌚</div>Time</div><div>⚖️</div>Accuracy</div> <div>👉</div> Ease to access <div>👉</div> Imperfect findings	<div>5. AVAILABLE SOLUTIONS<div>AS</div><div><div>1.</div>In past they get trouble in finding handwritten digits</div><div>2.</div>Using this system, they can resolve this type of problems</div> <div>3.</div> Pros of this system is quick recognition and Accurate prediction <div>4.</div> Cons are using this system Knowledge about the system is required	Explore AS, differentiate
	<div>2. JOBS-TO-BE-DONE / PROBLEMS<div>J&P</div><div>There are different types of handwriting are in world. Each and every handwriting has its own characteristics and uniqueness. Its difficult to understand the different people's handwriting digit.</div></div>	<div>9. PROBLEM ROOT CAUSE<div>RC</div><div><div>⚡</div>Not everyone can understand everyone's handwriting</div><div>👉</div>The handwriting is differed from person to person</div> <div>⚡</div> So, it is difficult to recognize the digit. <div>👉</div> To solve this problem this system has developed	<div>7. BEHAVIOUR<div>BE</div><div><div>⚡</div>Designing the best software that more quickly and accurately identifies the handwritten digits.</div><div>👉</div>To address the problem, they can take scan copy of the handwritten digit and upload it in the software</div>	
Focus on J&P, tap into BE, understand RC				
Identify strong TR & EM	<div>3. TRIGGERS<div>TR</div><div>When provide Accurate output</div><div>Anyone can use it.</div><div>Good user experience</div></div>	<div>10. YOUR SOLUTION<div>SL</div><div><div>⚡</div>A novel method for handwritten digit recognition system helps in recognizing the handwritten digits that uses MNIST dataset for training the model.</div><div>⚡</div>The model gets the image of the handwritten digits and recognizes the handwritten digits.</div> <div>⚡</div> CNN algorithm is used over the MNIST dataset to recognize the handwritten digits.	<div>8. CHANNELS of BEHAVIOUR<div>CH</div><div>ONLINE</div><div>In online they can upload the handwritten picture and yield output</div><div>OFFLINE</div><div>In offline they can ask their neighbours to scribble the digits to find them</div></div>	Identify strong TR & EM
	<div>4. EMOTIONS: BEFORE / AFTER<div>EM</div><div><div>⚡</div>It is a quite irritating and frustrating while manually convert the handwritten digits.</div><div>👉</div>By using our system, user can save the time and reduce the error occur on recognition.</div>			

4. REQUIREMENT ANALYSIS

4.1 Functional requirement

Functional requirements are **product features or functions that developers must implement to enable users to accomplish their tasks.**

FR No.	Functional Requirement	Sub Requirement
FR-1	Input	<ul style="list-style-type: none"> Must be able to take the handwritten inputs in the form of the images. (JPG, PNG)
FR-2	Error	<ul style="list-style-type: none"> System shall show the error message to the user when the input given is not in the required format.
FR-3	Detect Target	<ul style="list-style-type: none"> System should detect characters present in the image. Must be able to perform classification and identification algorithms and should recognize the handwritten input
FR-4	Output	<ul style="list-style-type: none"> System should retrieve characters present in the image and display them to the user. Must be able to display the accurate output in text format.

4.2 Non-Functional requirements

Nonfunctional Requirements (NFRs) define system attributes such as security, reliability, performance, maintainability, scalability, and usability.

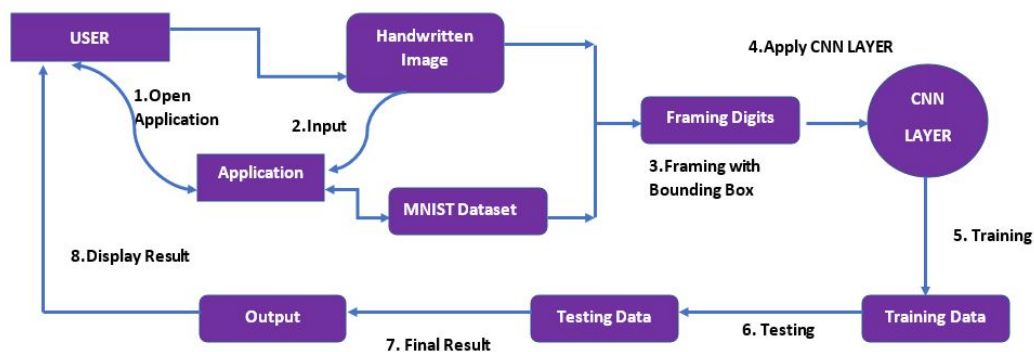
FR No.	Non-Functional Requirement	Description
NFR-1	Usability	<ul style="list-style-type: none">✓ Applications for digit recognition include filling out forms, processing bank checks, and sorting mail.✓ It can also used for blind-people by using sound input.
NFR-2	Security	<ul style="list-style-type: none">✓ Banking sector where it can be used to maintain the security pin number safely.
NFR-3	Reliability	<ul style="list-style-type: none">✓ This software will work reliably for low resolution image and not for graphical images✓ The standard implementations of neural networks achieve an accuracy of approximately
NFR-4	Performance	<ul style="list-style-type: none">✓ Software will perform its intended function for a large period of sufficient time and also it will operate in a secured environment without any failures.
NFR-5	Availability	<ul style="list-style-type: none">✓ This system will retrieve the handwritten text regions only if the image contains written text in it.
NFR-6	Scalability	<ul style="list-style-type: none">✓ System can work normally under any amount of inputted handwritten data.

5. PROJECT DESIGN

5.1 Data Flow Diagrams

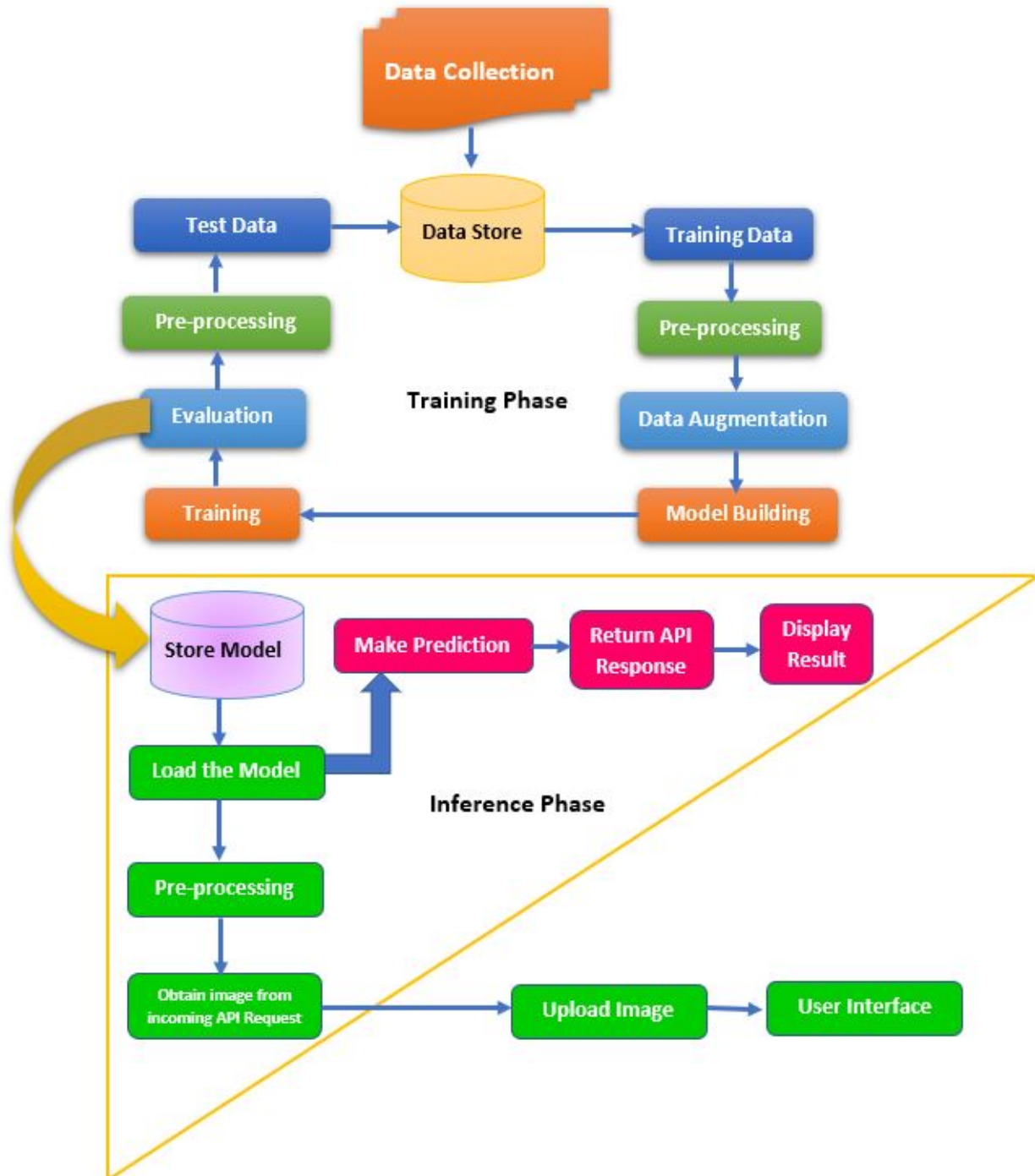
A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.

Data Flow Diagrams:



5.2 Solution & Technical Architecture

A technical solutions architect is **somebody who helps companies design and delivers a range of solutions to their problems**. Technical solutions architects need to have the skills and the knowledge to create solutions that fit in with company strategy.



5.3 User Stories

A user story is an **informal, general explanation of a software feature written from the perspective of the end user or customer**. The purpose of a user story is to articulate how a piece of work will deliver a particular value back to the customer.

User Stories

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Customer (Mobile user)	Home page	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'm 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 the instructions to use this application.	I can read instructions also to use it in a user-friendly method.	Low	Sprint-2
	Recognize	USN-4	As a user, <u>in</u> this prediction page I get to choose the image.	I can choose the image from our local system and predict the output.	Medium	Sprint-1
		USN-5	As a user need to choose mentioned format image as per the guided	I can choose the image correct format	High	Sprint-1
	Predict	USN-6	As a user, I'm 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-7	As a user, I will train and test the input to get the maximum accuracy of output.	I can able to train and test the application until it gets maximum accuracy of the result.	High	Sprint-4
		USN-8	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-9	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
	Recognize	USN-10	As a user, I can use the web application virtually anywhere.	I can use the application portably anywhere.	High	Sprint-1
		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
		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
	Predict	USN-13	As a user, I'm 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

6. PROJECT PLANNING & SCHEDULING

6.1 Sprint Planning & Estimation

Sprint planning is an **event in Scrum that kicks off the Sprint**. It's the first event that happens during a Sprint. The main agenda of Sprint planning is to define the scope of delivery and how to accomplish that work. It sets up a common goal for the team, and everyone's focus is to achieve that goal during the Sprint.

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Data Collection	USN-1	As a user, I can collect the dataset from various resources with different handwritings.	10	Low	Devi.N Divya.C
Sprint-1	Data Pre-processing	USN-2	As a user, I can load the dataset ,handling the missing data, scaling and split data into train and test.	10	Medium	Tamilarasi.S Nazeeraparveen.M
Sprint-2	Model Building	USN-3	As a user, I will get an application with ML model which provides high accuracy of recognized handwritten digit.	5	High	Tamilarasi.S Divay.C Praveen.S
Sprint-2	Add CNN layers	USN-4	Creating the model and adding the input, hidden, and output layers to it.	5	High	Praveen.S
Sprint-2	Compiling the model	USN-5	With both the training data defined and model defined, it's time to configure the learning process.	2	Medium	Tamilarasi.S
Sprint-2	Train & test the model	USN-6	As a user, let us train our model with our image dataset.	6	Medium	Devi.N

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-2	Save the model	USN-7	As a user, the model is saved & integrated with an android application or web application in order to predict something.	2	Low	Praveen . S
Sprint-3	Building UI Application	USN-8	As a user, I will upload the handwritten digit image to the application by clicking a upload button.	5	High	Devi. N Divya. C Tamilarasi.S
Sprint-3		USN-9	As a user, I can know the details of the fundamental usage of the application.	5	Low	Divya.C
Sprint-3		USN-10	As a user, I can see the predicted / recognized digits in the application.	5	Medium	Tamilarasi.S Devi.N
Sprint-4	Train the model on IBM	USN-11	As a user ,I train the model on IBM and integrate flask/ Django with scoring end point.	10	High	Devi.N Divya .C Nazeeraparveen.M
Sprint-4	Cloud Deployment	USN-12	As a user, I can access the web application and make the use of the product from anywhere.	10	High	Tamilarasi.S Divya.C Praveen .S

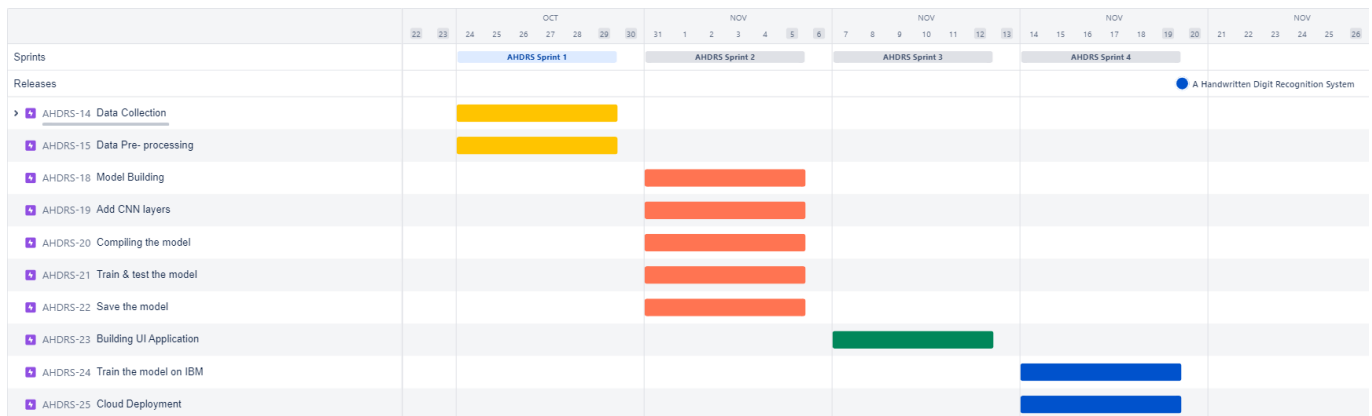
6.2 Sprint Delivery Schedule

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

Velocity:

$$AV = \frac{\text{Sprint duration}}{\text{Velocity}} = \frac{20}{6} = 3.33$$

6.3 Reports from JIRA



7. CODING & SOLUTIONING (Explain the features added in the project along with code)

7.1 File Name : app.py

```
from flask import Flask, request, render_template, flash
from PIL import ImageOps
import numpy as np
from tensorflow.keras.models import load_model
from tensorflow.keras.preprocessing import image
```

```
app = Flask(__name__, template_folder='template')
model = load_model("./models/mnistCNN.h5")
@app.route('/')
def batch():
    return render_template("index.html")
```

```

@app.route('/web')
def batch2():
    return render_template("web.html")

@app.route('/web',methods=['GET','POST'])
def web():
    imagefile = request.files['imagefile']
    image_path = "./uploads/"+imagefile.filename
    imagefile.save(image_path)
    img = image.load_img(image_path).convert("L")
    img = ImageOps.grayscale(img)
    img = ImageOps.invert(img)
    img = img.resize((28, 28))
    im2arr = np.array(img)
    im2arr= im2arr/255.0
    im2arr = im2arr.reshape(1, 28, 28, 1)
    result = model.predict(im2arr)
    best = np.argmax(result, axis=1)[0]
    pred = list(map(lambda x: round(x * 100, 2), result[0]))
    values = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
    pred_val = list(zip(values,pred))
    best = pred_val.pop(best)
    return render_template('web.html',prediction=best)

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

```

7.2 File Name : index.html

```

<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
        <meta name="viewport" content="width=device-width, initial-scale=1">
        <link rel="stylesheet"
href="https://maxcdn.bootstrapcdn.com/bootstrap/3.3.7/css/bootstrap.min.css">
        <title>Handwritten Digit Recognition System</title>
        <script

```



```

src="https://ajax.googleapis.com/ajax/libs/jquery/3.2.1/jquery.min.js"></script>
<script
src="https://maxcdn.bootstrapcdn.com/bootstrap/3.3.7/js/bootstrap.min.js"></script>
<link rel="stylesheet" type="text/css" href="/static/css/style.css">
<style>
    body{
        background-image:
url("https://static.vecteezy.com/system/resources/previews/004/585/397/large_2x/fo
lder-data-management-low-poly-wireframe-illustration-isolated-background-vector.jpg");
        background-size: cover;
    }
</style>
</head>
<body>
<div id="home">
    <div class = "landing-text">
        <h2>Team ID : PNT2022TMID38424</h2>
        <h1>A Novel Method For Handwritten Digit Recognition System</h1>
        <h3>Predict Digits Click Here !</h3><br>
        <a href="/web" class="btn btn-default btn-lg">Predict</a>
    </div>
</div>
</body>
</html>

```

File Name : web.html

```

<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1">
    <link rel="stylesheet"
href="https://maxcdn.bootstrapcdn.com/bootstrap/3.3.7/css/bootstrap.min.css">
    <title>Handwritten Digit Recognition System</title>
    <script
src="https://ajax.googleapis.com/ajax/libs/jquery/3.2.1/jquery.min.js"></script>

```

```

        <script
src="https://maxcdn.bootstrapcdn.com/bootstrap/3.3.7/js/bootstrap.min.js"></script>

</head>
<style>
    body{
        background-image: url("https://www.icapitalkkrpmfund.com/wp-
content/uploads/2021/06/media-0321-03.png");
        background-size: cover;
    }
    .fit-image{
        width: 100%;
        object-fit: cover;
        height: 200px; /* only if you want fixed height */
    }
    .img{
        height: 200px;
        width: 200px;
    }
</style>
<body>
<div class="head">
    <div class="container">
        <h1 style="color: #ffffff;text-align: center">Vi Institute of Technology</h1>
    </div>
</div>
<div class="container">
    <div id="content" style="...">
        <div class="container">
            <div class="row">

                <div class="col">
                    <div class="text-center"></div>
                </div>

```


8. TESTING

8.1 Test Cases

A test case is a set of actions performed on a system to determine if it satisfies software requirements and functions correctly.

Test case	Feature Type	Component	Test Scenario	Pre-Requisite	Steps To Execute	Test Data	Expected Result	Actual Result	Status	Comments	TC for Autom	BUG ID	Executed By
HWD RS_TC_OO1	Functional	Home Page	Verify user is able to see the Home page	Not required	1.Click on Predict Button 2.Check It Moves on prediction page 3.Verify prdctc button is displayed or not	https://127.0.0.1:5000/	Should display the Webpage	Working as expected	Pass	Steps are clear to follow	N	NA	Devi N
HWD RS_TC_OO2	UI	Home Page	Verify the UI elements is Responsive	Not required	1.Click Predict Button 2.Check it moves on prediction page 3.Verify page to response different Views	https://127.0.0.1:5000/	Webpage should be responsive	Working as expected	Pass	Steps are clear to follow	N	NA	Divya C
HWD RS_TC_OO3	Functional	Prediction page	Verify whether the uploading Image is a valid data	Not required	1.Click on Choose file Button 2.Upload the image 3.Verify Predict button is displayed or not	https://127.0.0.1:5000/	User should able to access the Webpage	Working as expected	Pass	Steps are clear to follow	N	NA	Tamilarasi S
HWD RS_TC_OO4	Functional	Prediction page	Verify user is able to see the predict result	Not required	1.Check the input image is valid data or not. 2.Verify whether the result is displayed of not. 3.Again Click Choose file button to predict next digit.	7	Webpage should be responsive	Working as expected	Pass	Steps are clear to follow	N	NA	Nazeeraparveen M
HWD RS_TC_OO4	Functional	Prediction page	Testing the website with various Images	Not required	1.Check the input image is valid data or not. 2.Verify whether the result is displayed of not. 3.Again Click Choose file button to predict next digit.	2	User should able to see the resultWorking	Working as expected	Pass	Steps are clear to follow	N	NA	Praveen S

8.2 User Acceptance Testing

Defect Analysis

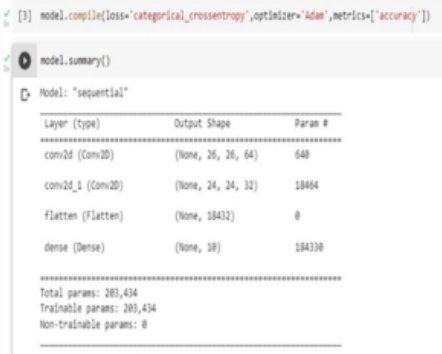
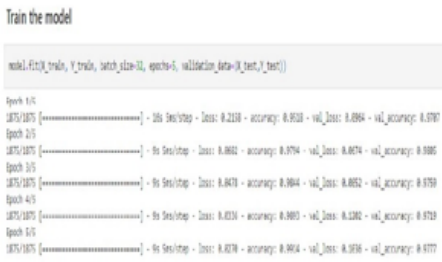
This report shows the number of resolved or closed bugs at each severity level, and how they were resolved

Resolution	Severity 1	Severity 2	Severity 3	Severity 4	Subtotal
By Design	10	4	2	3	20
Duplicate	1	0	3	0	4
External	2	3	0	1	6
Fixed	12	3	4	18	37
Not Reproduced	0	0	1	0	1
Skipped	0	0	1	1	2
Won't Fix	0	5	2	1	8
Totals	25	15	13	24	77

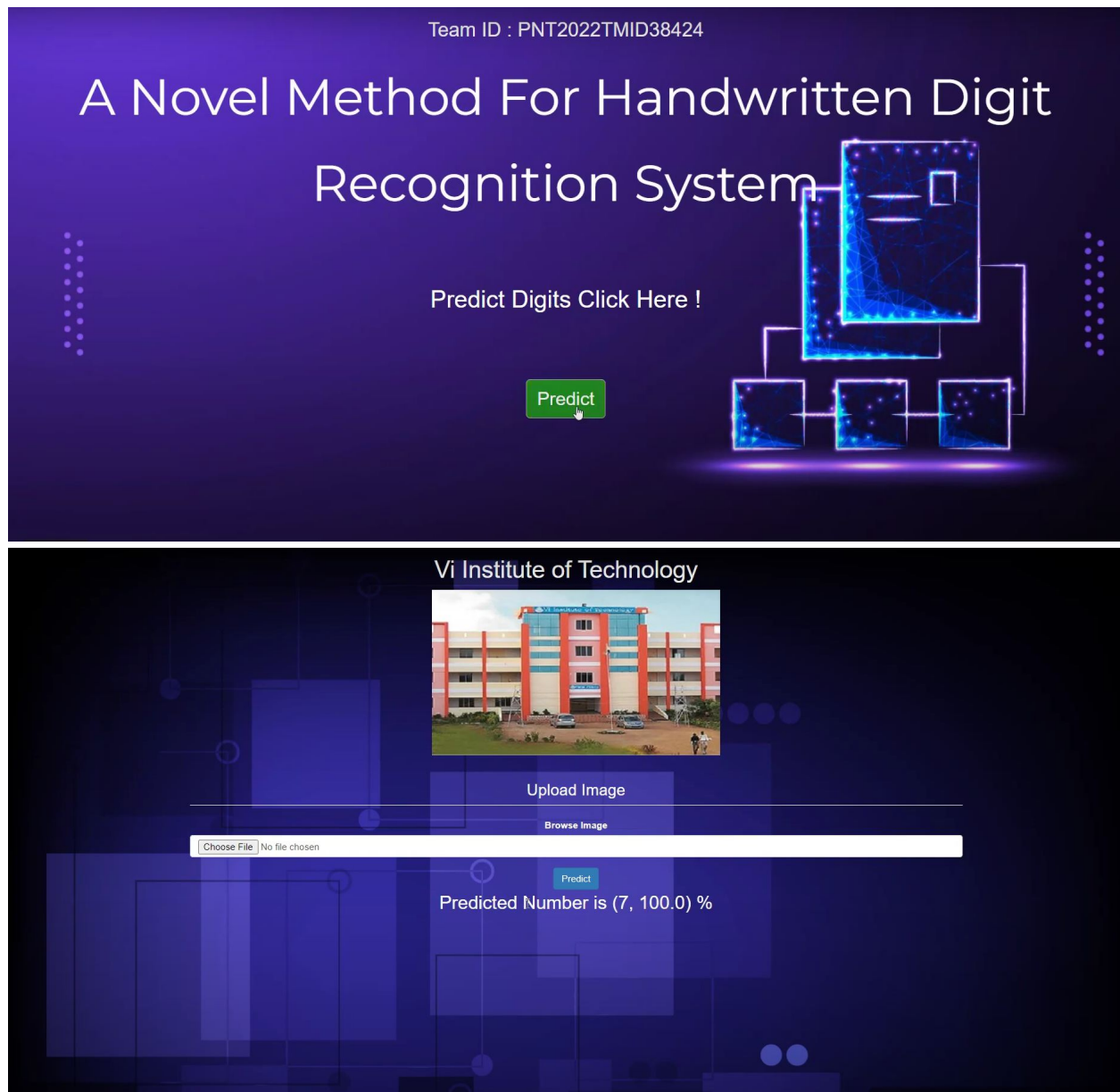
Section	Total Cases	Not Tested	Fail	Pass
Print Engine	7	0	0	7
Client Application	51	0	0	51
Security	2	0	0	2
Outsource Shipping	3	0	0	3
Exception Reporting	9	0	0	9
Final Report Output	4	0	0	4
Version Control	2	0	0	2

9. RESULTS

9.1 Performance Metrics

S.No.	Parameter	Values	Screenshot
1.	Model Summary	Total params: 203,434 Trainable params: 203,434 Non-trainable params: 0	 <pre> [1] model.compile(loss='categorical_crossentropy',optimizer='Adam',metrics=['accuracy']) 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 </pre>
2.	Accuracy	Training Accuracy – 0.9914 Validation Accuracy – 0.9777	 <pre> Train the model model.fit(x_train, y_train, batch_size=32, epochs=5, validation_data=(x_test, y_test)) Epoch 1/5 1875/1875 [=====] - 50s 5es/step - loss: 0.2218 - accuracy: 0.9538 - val_loss: 0.0964 - val_accuracy: 0.9797 Epoch 2/5 1875/1875 [=====] - 4s 5es/step - loss: 0.0862 - accuracy: 0.9794 - val_loss: 0.0674 - val_accuracy: 0.9885 Epoch 3/5 1875/1875 [=====] - 4s 5es/step - loss: 0.0473 - accuracy: 0.9864 - val_loss: 0.0652 - val_accuracy: 0.9759 Epoch 4/5 1875/1875 [=====] - 4s 5es/step - loss: 0.0093 - accuracy: 0.9923 - val_loss: 0.1282 - val_accuracy: 0.9724 Epoch 5/5 1875/1875 [=====] - 4s 5es/step - loss: 0.0078 - accuracy: 0.9924 - val_loss: 0.3036 - val_accuracy: 0.9777 </pre>

9.2. Result



10. ADVANTAGES & DISADVANTAGES

ADVANTAGES

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

DISADVANTAGES

- Cannot handle complex data
- All the data must be in digital format

- Requires a high performance server for faster predictions
- Prone to occasional errors

11. CONCLUSION

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

12. FUTURE SCOPE

The task of handwritten digit recognition, using a classifier, has great importance and use such as – online handwriting recognition on computer tablets, recognize zip codes on mail for postal mail sorting, processing bank check amounts, numeric entries in forms filled up by hand (for example - tax forms) and so on.

Github Link - <https://github.com/IBM-EPBL/IBM-Project-46525-1660748845>