A NOVEL METHOD FOR HANDWRITTEN DIGIT RECOGNITION

PROJECT REPORT

Submitted by

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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 PROJECT OVERVIEW

Handwritten digit recognition is the process to provide the ability to machines to recognize human handwritten digits. It is not an easy task for the machine because handwritten digits are not perfect, vary from person-to-person. Papers are replaced by digital documents for various reasons. Machines do not have the ability to understand what has been written on those physical papers.

The MNIST dataset is widely used for this recognition process and it has 70000 handwritten digits. We use artificial neural network 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 the UI. In the Banking Sector, handwritten numbers are involved like account number, figure of cash and checks.

1.2 PURPOSE

The purpose of this project is to use the classification algorithm to identify handwritten digits.

This system recognizes digits from different sources like emails, bank cheque, papers, images and in different real world scenarios.

CHAPTER 2

LITERATURE SURVEY

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 margins since they vary from person to person. Additionally, there would be issues with identifying the numbers because of similarities between numberals like 1 and 7, 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 REFERENCES

Amirreza Fateh , Mansoor Fateh“Multilingual handwritten numeral recognition using a robust deep network joint with transfer learning”Information Sciences 581 (2021) 479–494.

Mohamed Ali Souibgui, Alicia Fornés, Yousri Kessentini , Beáta Megyesi ”A progressive learning approach for low resource handwritten text recognition”Pattern Recognition Letters 160 (2022) 43–49.

Songbin Xu, Yang Xue, Xin Zhang, Lianwen Jin”A Novel Unsupervised domain adaptation method for inertia-Trajectory translation of in-air handwriting”Pattern Recognition 116 (2021) 107939

J. Mukhoti, S. Dutta and R. Sarkar, "Handwritten digit classification in Bangla and Hindi using deep learning", Appl. Artif. Intell., vol. 34, no. 14, pp. 1074-1099, Dec. 2020.

Y. Wen and L. He, "A classifier for Bangla handwritten numeral recognition", Expert Syst. Appl., vol. 39, no. 1, pp. 948-953, Jan. 2012

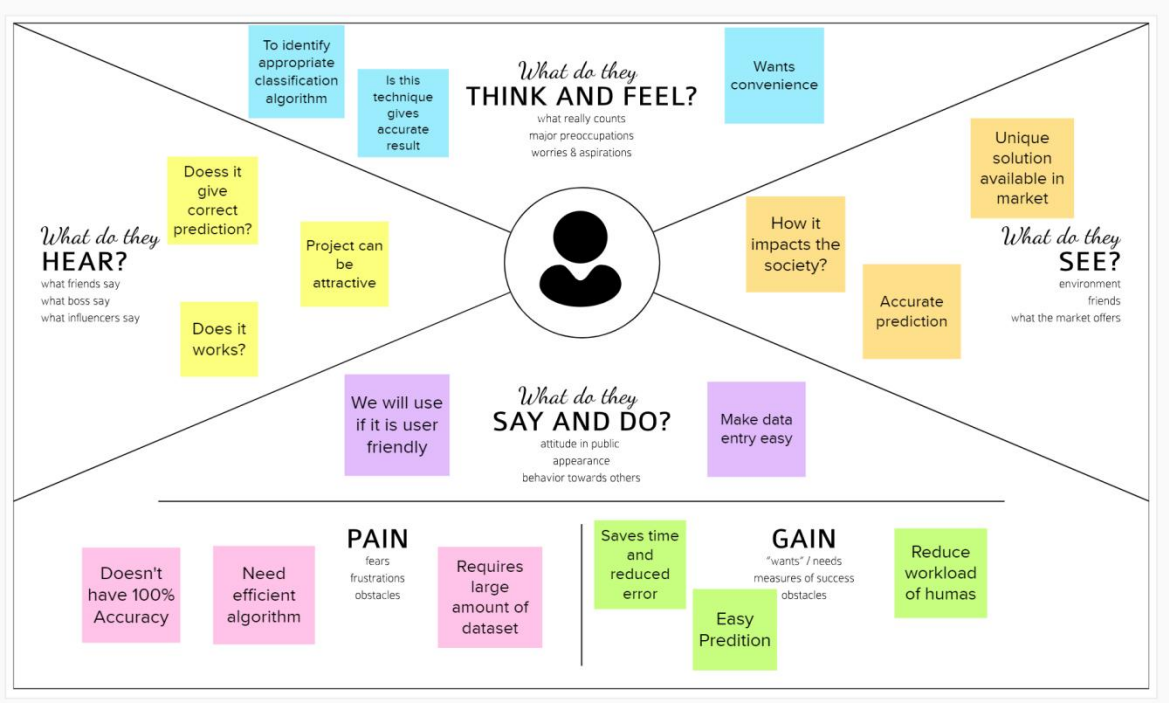
2.3 PROBLEM STATEMENT DEFINITION

Handwritten digit recognition is the process to provide the ability to machines to recognize human handwritten digits. It is not an easy task for the machine because handwritten digits are not perfect, vary from person-to-person. Papers are replaced by digital documents for various reasons. Machines do not have the ability to understand what has been written on those physical papers. The purpose of this project is to use the classification algorithm to identify handwritten digits.

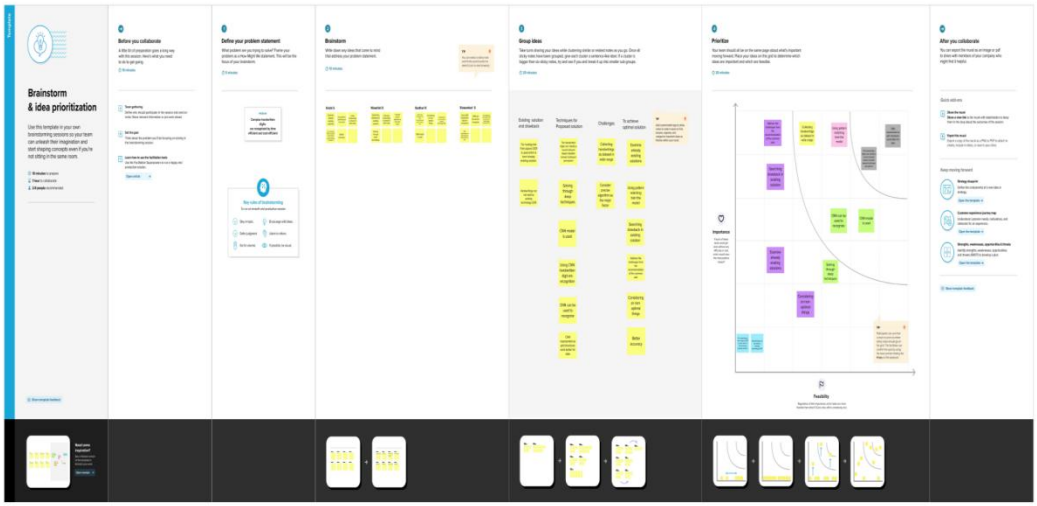
CHAPTER 3

IDEATION AND PROPOSED SOLUTION

3.1 EMPATHUY MAP CANVAS



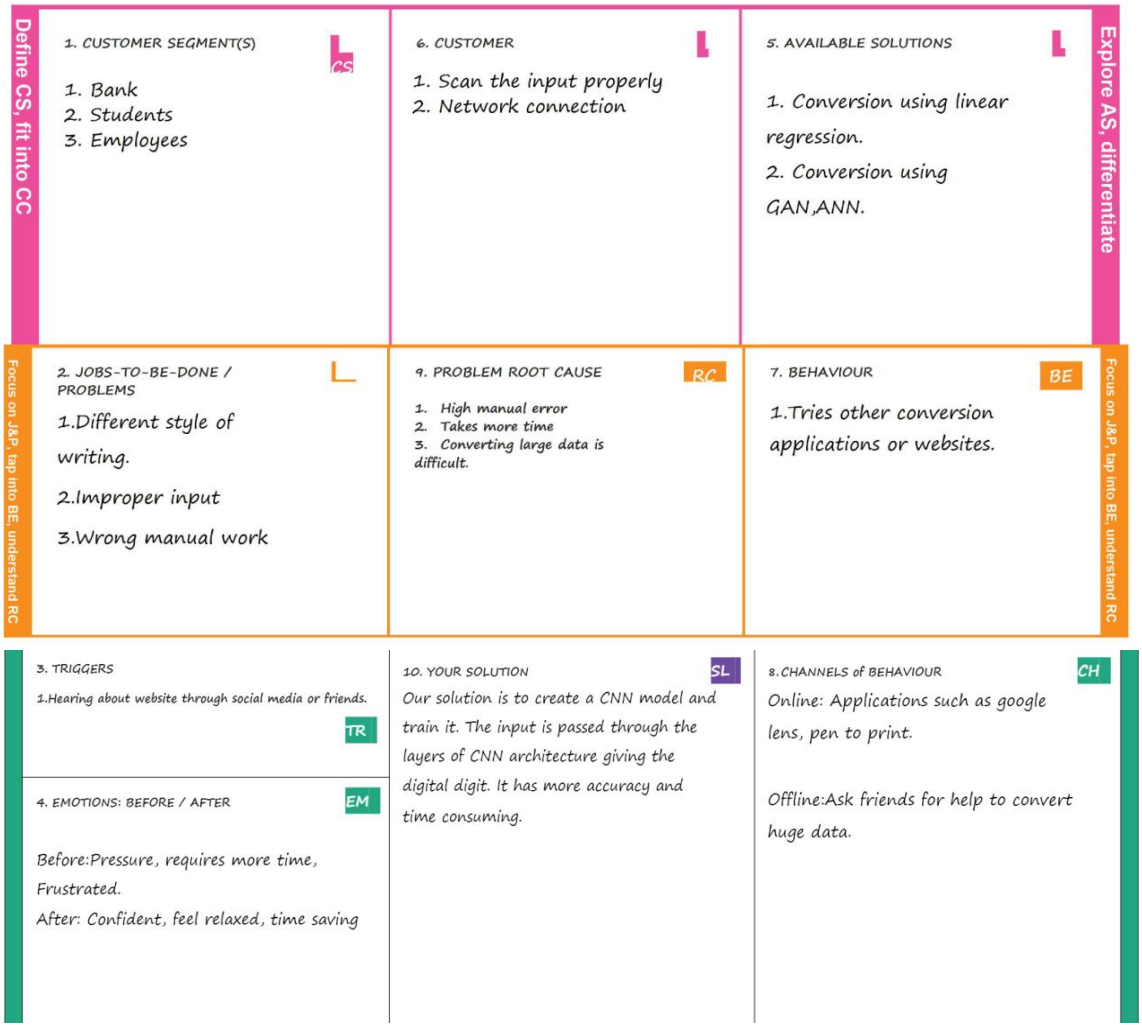
3.2 IDEATION & BRAINSTORMING



3.3 PROPOSED SOLUTION

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	Handwritten digit recognition is the process to provide the ability to machines to recognize human handwritten digits. It is not an easy task for the machine because handwritten digits are not perfect, vary from person-to-person. Papers are replaced by digital documents for various reasons. Machines do not have the ability to understand what has been written on those physical papers. The purpose of this project is to use the classification algorithm to identify handwritten digits.
2.	Idea / Solution description	CNN architecture in AI is used to recognise the handwritten digits. The input is passed through the CNN layers to classify the handwritten digits. The MNIST dataset contains 60,000 plus training images of handwritten digits from zero to nine and more than 10,000 images for testing are present in the MNIST dataset.
3.	Novelty / Uniqueness	GAN layers can be used for better accuracy in the handwritten digit recognition system. Normalisation can be used for better efficiency.
4.	Social Impact / Customer Satisfaction	Old people having eye sight problems with handwritten digits can be helped. Postal department and courier services can easily find the handwritten digits.
5.	Business Model (Revenue Model)	In banking sectors handwritten numbers are involved like account number, figure of cash and checks. By this system we can avoid human mistakes.
6.	Scalability of the Solution	AI is used for the development of this system. So it can be used in any devices.

3.4 PROBLEM SOLUTION FIT



CHAPTER 4

REQUIREMENT ANALYSIS

4.1 FUNTIONAL REQUIREMENTS

Functional Requirements:

Following are the functional requirements of the proposed solution.

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	Collecting MNIST data	Image dataset undergoes preprocessing
FR-2	Text identification	Text is identified using CNN model
FR-3	Detect handwritten	Handwritten is detected through CNN model
FR-4	Digit recognition	Number in the image is identified

4.2 NON FUMTIONAL REQUIREMENTS

Non-functional Requirements:

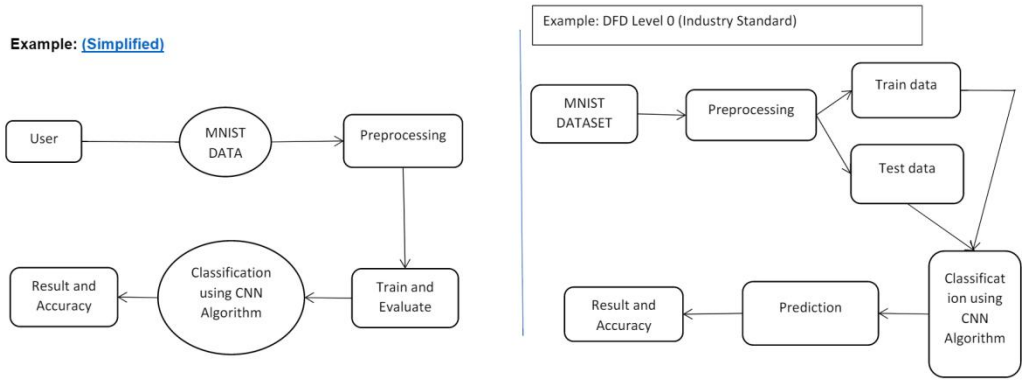
Following are the non-functional requirements of the proposed solution.

FR No.	Non-Functional Requirement	Description
NFR-1	**Usability**	Model is safe to install
NFR-2	**Security**	Highly secured
NFR-3	**Performance**	Model will reach greater accuracy
NFR-4	**Availability**	Model is available at all time

CHAPTER 5

PROJECT DESIGN

5.1 Data Flow Diagrams



5.2 Solution & Technical Architecture

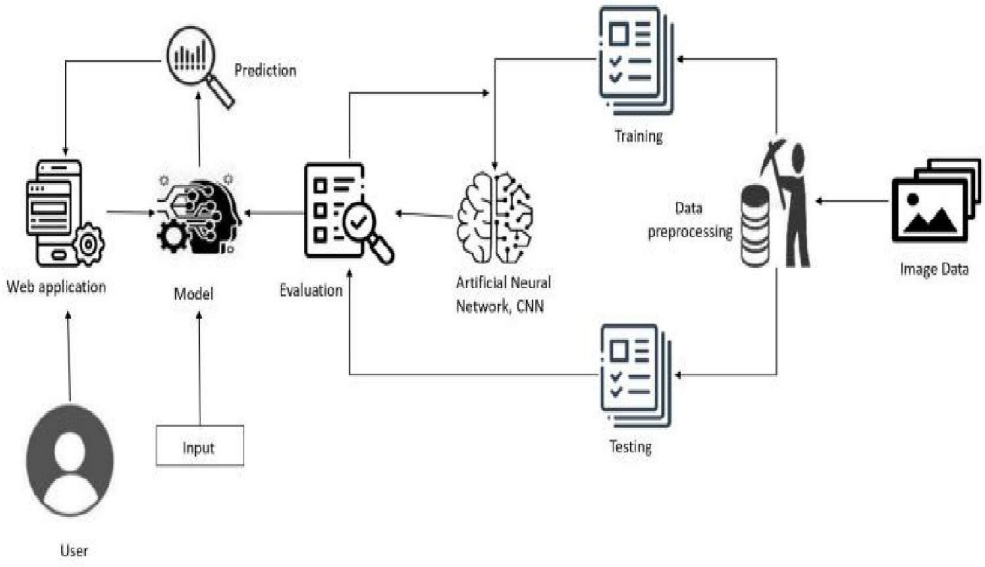


Table-1 : Components & Technologies:

S.No	Component	Description	Technology
1.	User Interface	How user interacts with web application	HTML, CSS, JavaScript / React JS etc.
2.	Application Logic-1 Image processing	User uploads or process the data in our application	Python
3.	Application Logic-2 Create and train model	CNN model is created and trained.	Tensorflow, Keras
4.	Application Logic-3 Prediction	The image is predicted as digits by using CNN model.	Tensorflow, Keras, openCV (computer vision)
5.	Database	Digits dataset will be stored for training and testing the data to predict the output	MNIST dataset
6.	Cloud Database	Database service on cloud	IBM Watson cloud
7.	File Storage	User requirements will be processed through the file	IBM Block Storage or Other Storage Service or Local Filesystem
8.	Machine Learning Model	To predict the given processed image	Image Classification Model CNN
9.	Infrastructure (Server / Cloud)	Cloud based web application	Cloud application

Table-2: Application Characteristics:

S.No	Characteristics	Description	Technology
1.	Open-Source Frameworks	It is made freely available code for application notification and redistribution	Google colab
2.	Scalable Architecture	The behaviour of the application must be correct and predictable	HTML, CSS, JS, PYTHON, FLASK, IBM Cloud
3.	Availability	This app can be available to everyone through the cloud.	IBM cloud
4.	Performance	The application must be scalable enough to support 10,000 visits at the same time while maintaining optimal performance	IBM Cloud balancing

5.3 User Stories

User Stories

Use the below template to list all the user stories for the product.

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 aware to use this application and view the guide.	I can aware to use this application and it's limitation.	Low	Sprint-1
		USN-2	As a user, I can use the interface of the application which is allowed to view the guided image.	I can gain knowledge by practical method to use this application.	Low	Sprint-1
		USN-3	As a user, I can use this application by reading the instructions.	I can used in a user-friendly method by reading instructions.	Low	Sprint-2
	Recognize	USN-4	As a user, I can choose the image in this prediction page.	I can predict the output by choosing the image from our local system.	High	Sprint-2
	predict	USN-5	As a user, I'm Allowed to upload the image.	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 can get the maximum accuracy of the output by training and testing the input.	I can able to train and test application to get accurate	High	Sprint-4

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
				result.		
		USN-7	As a user, I can access the MNIST data set.	I can access MNIST data set it will produce accurate result.	Medium	Sprint-3
Customer (Web user)	Home	USN-8	As a user, I can use the web app by viewing the guide.	I can view the limitation of this application.	Low	Sprint-1
Customer (Mobile user)		USN-1	As a user, I can aware to use this application and view the guide.	I can aware to use this application and it's limitation.	Low	Sprint-1
		USN-2	As a user, I can use the interface of the application which is allowed to view the guided image.	I can gain knowledge by practical method to use this application.	Low	Sprint-1
		USN-3	As a user, I can use this application by reading the instructions.	I can used in a user-friendly method by reading instructions.	Low	Sprint-2
	Recognize	USN-9	As a user, I can use the web application virtually anywhere.	I can use the application Anywhere portably.	High	Sprint-1
		USN-10	As it is an op[en source, I can use it cost freely.	I can use it without any payment to access.	Medium	Sprint-2
		USN-11	As it is a web application, it is installation free.	I can use it without the installation of the Application.	Medium	Sprint-4
	Predict	USN-12	As a user, I'm Allowed to upload and choose the image.	I can upload and choose the image from the system storage and also in any virtual storage.	Medium	Sprint-3

CHAPTER 6

PROJECT PLANNING & SCHEDULING4

6.1 Sprint Planning & Estimation

Product Backlog, Sprint Schedule, and Estimation (4 Marks)

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Data Collection & pre processing	USN-1	As a user,the image that I uploaded is preprocessed.	10	High	Krishi,Kasthuri,Nivasini, Sivasankari
Sprint-1		USN-2	As a user, I can upload variety of handwritten digits.	10	High	Krishi,Kasthuri,Nivasini, Sivasankari
Sprint-2	Building the Machine learning model	USN-3	As a user, I will get a application with high accuracy ML model which recognizes handwritten digit.	4	Medium	Krishi,Kasthuri,Nivasini, Sivasankari
Sprint-2		USN-4	As a user, I can upload the handwritten digit image for recognizing the digit with higher accuracy.	2	Medium	Krishi,Kasthuri,Nivasini, Sivasankari
Sprint-2		USN-5	As a user, I receive the digital digit for the given handwritten digit.	3	High	Krishi,Kasthuri,Nivasini, Sivasankari
Sprint-3	Building User Interface Application	USN-6	As a user, I will upload the handwritten digit image to the application by clicking a upload button.	8	Medium	Krishi,Kasthuri,Nivasini, Sivasankari
Sprint-3		USN-7	As a user, I know the details of the basic usage of the application.	3	Medium	Krishi,Kasthuri,Nivasini, Sivasankari
Sprint-3		USN-8	As a user, I can view the predicted digits in the application	9	High	Krishi,Kasthuri,Nivasini, Sivasankari
Sprint-4	Train, deployment of model in IBM Cloud	USN-9	As a user, I can access the application and make the use of the product from anywhere.	20	High	Krishi,Kasthuri,Nivasini, Sivasankari

6.2 Sprint Delivery Schedule

Project Tracker, Velocity & Burndown Chart: (4 Marks)

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

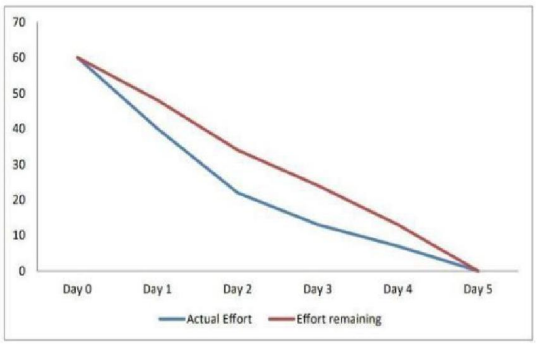
Velocity:
Imagine we have a 6-day sprint duration, and the velocity of the team is 20 (points per sprint). Let's calculate the team's average velocity (AV) per iteration unit (story points per day)

$$AV = \frac{sprint\ duration}{velocity}$$

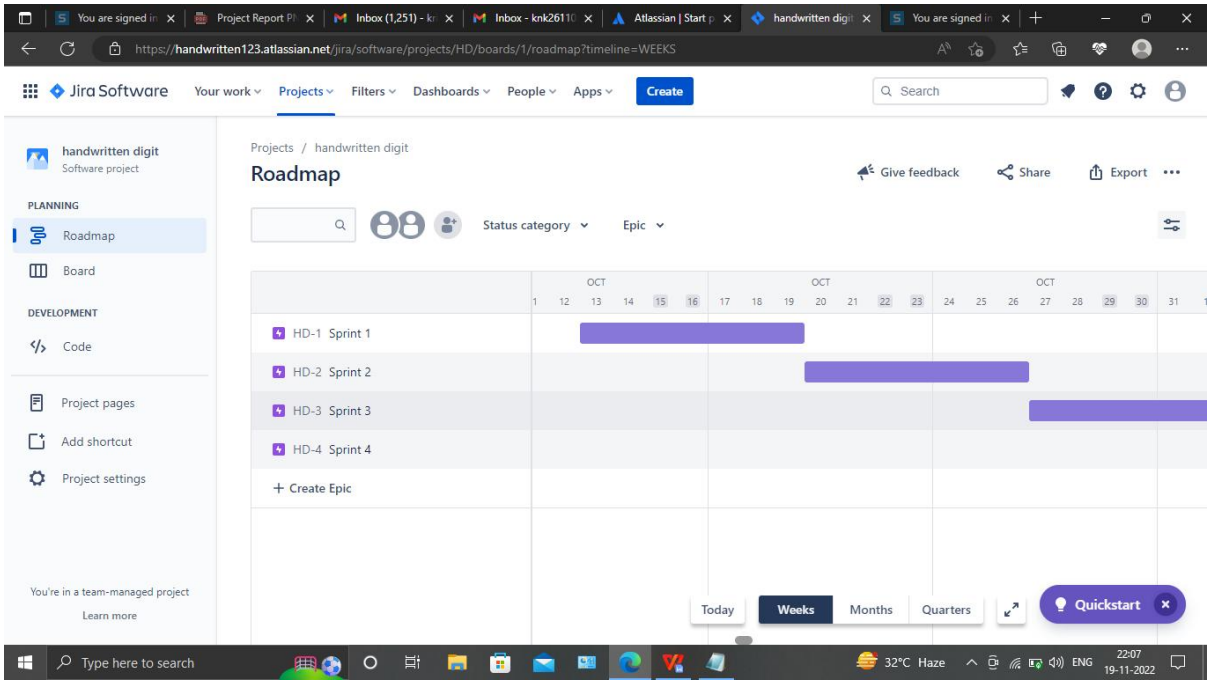
=20/6 =3.33

Burndown Chart:

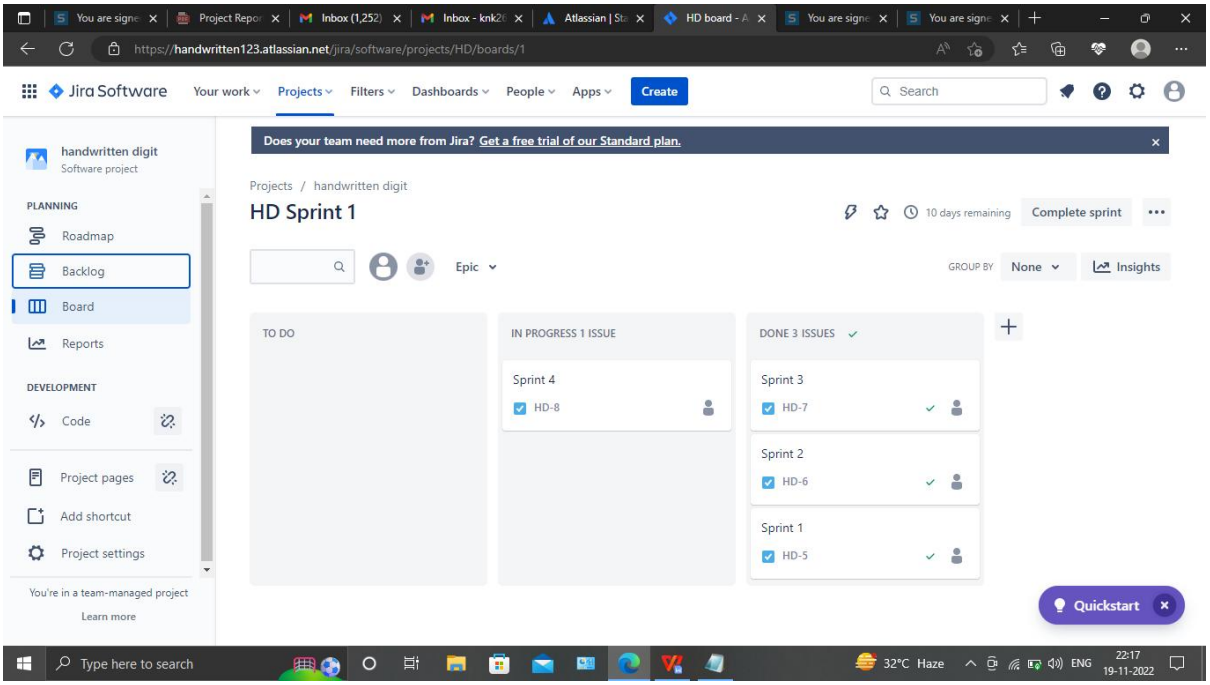
A burn down chart is a graphical representation of work left to do versus time. It is often used in agile software development methodologies such as Scrum. However, burn down charts can be applied to any project containing measurable progress over time.



6.3 Reports from JIRA



BORAD


https://handwritten123.atlassian.net/jira/software/projects/HD/boards/1
Jira Software
Your work
Projects
Filters
Dashboards
People
Apps
Create
Search
handwritten digit
Software project
PLANNING
Roadmap
Backlog
Board
Reports
DEVELOPMENT
Code
Project pages
Add shortcut
Project settings
You're in a team-managed project
Learn more
Does your team need more from Jira? Get a free trial of our Standard plan.
Projects / handwritten digit
HD Sprint 1
10 days remaining
Complete sprint
Epic
GROUP BY
None
Insights
TO DO
IN PROGRESS 1 ISSUE
DONE 3 ISSUES
Sprint 4
HD-8
Sprint 3
HD-7
Sprint 2
HD-6
Sprint 1
HD-5
Quickstart
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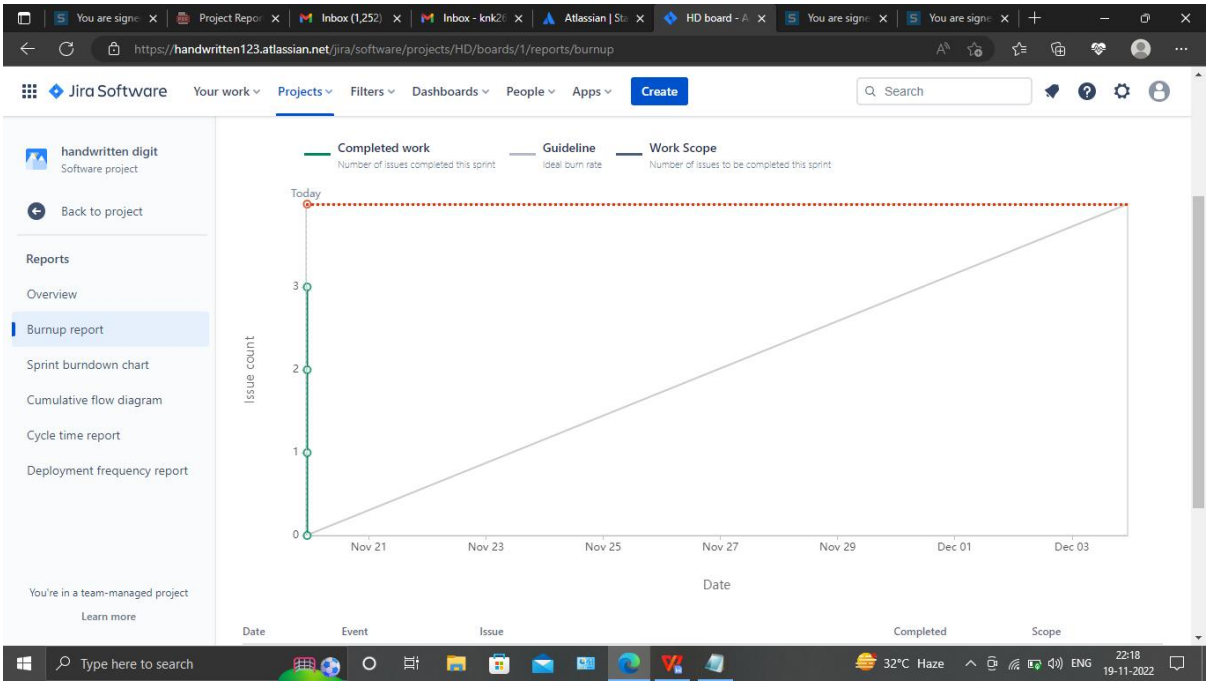
BURN


https://handwritten123.atlassian.net/jira/software/projects/HD/boards/1/reports/burnup
Jira Software
Your work
Projects
Filters
Dashboards
People
Apps
Create
Search
handwritten digit
Software project
Back to project
Reports
Overview
Burnup report
Sprint burndown chart
Cumulative flow diagram
Cycle time report
Deployment frequency report
You're in a team-managed project
Learn more
Completed work
Number of issues completed this sprint
Guideline
Ideal burn rate
Work Scope
Number of issues to be completed this sprint
Today
Issue count
0
1
2
3
Nov 21
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Nov 25
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Event
Issue
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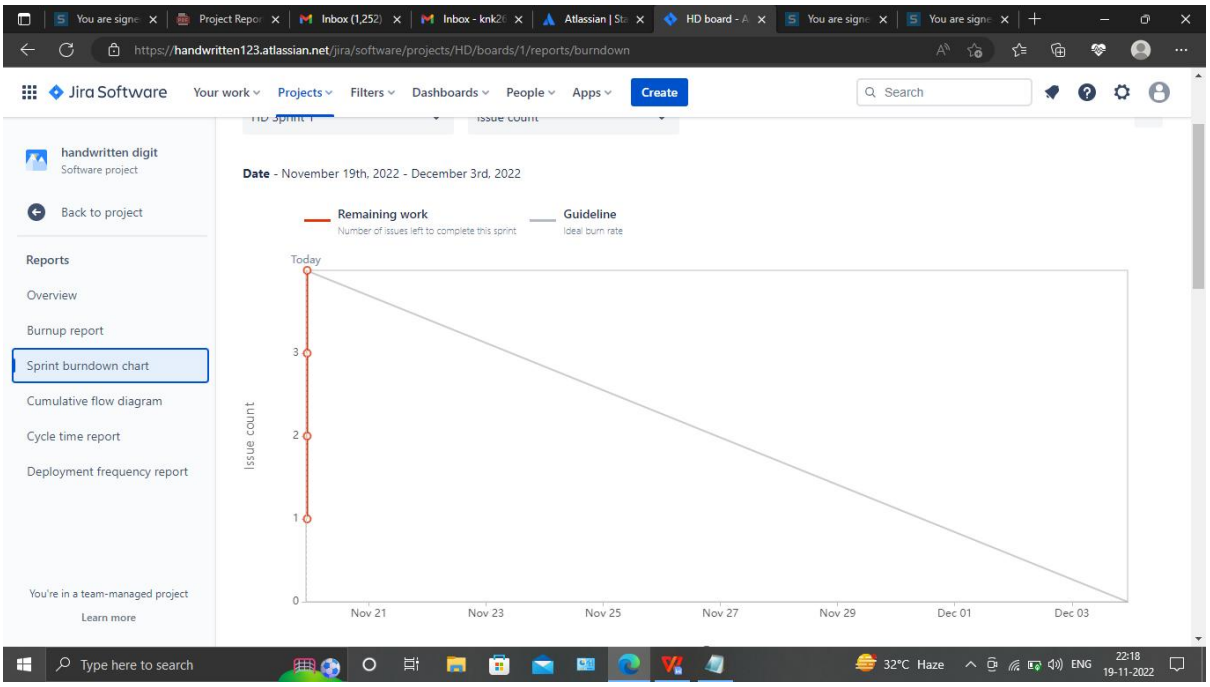
19-11-2022


https://handwritten123.atlassian.net/jira/software/projects/HD/boards/1/reports/burndown
Jira Software
Your work
Projects
Filters
Dashboards
People
Apps
Create
Search
handwritten digit
Software project
Back to project
Reports
Overview
Burnup report
Sprint burndown chart
Cumulative flow diagram
Cycle time report
Deployment frequency report
You're in a team-managed project
Learn more
Date - November 19th, 2022 - December 3rd, 2022
Remaining work
Number of issues left to complete this sprint
Guideline
Ideal burn rate
Today
Issue count
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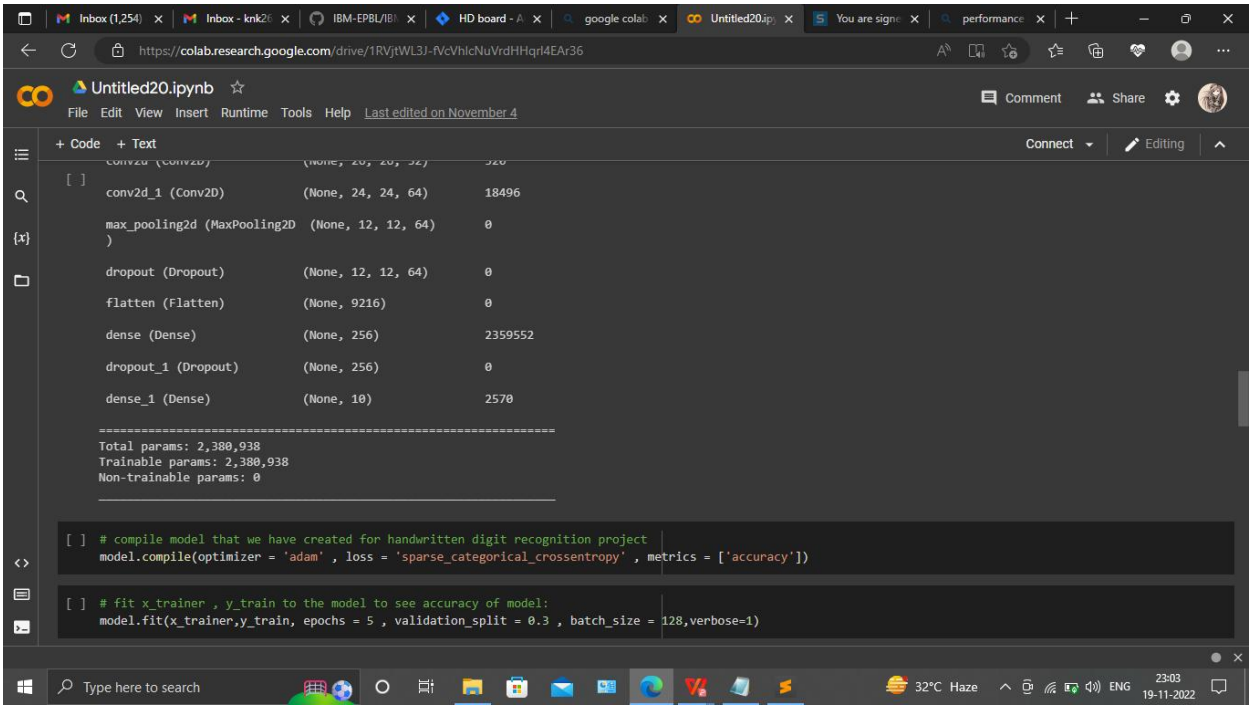
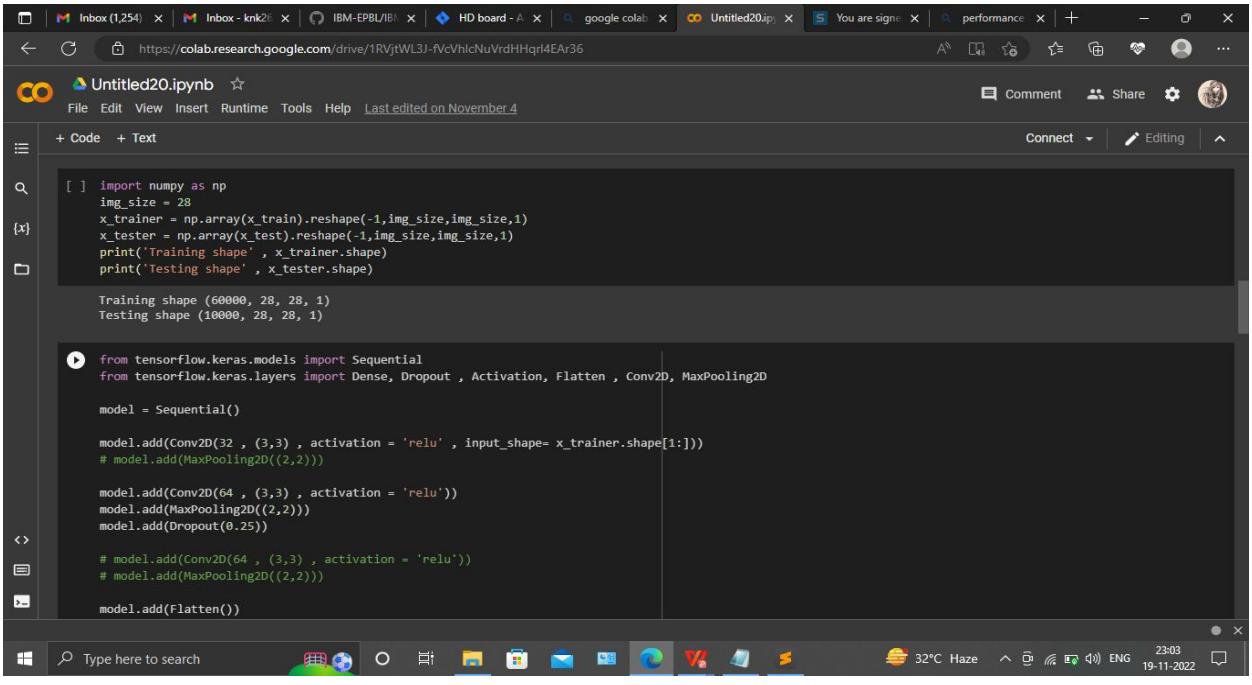
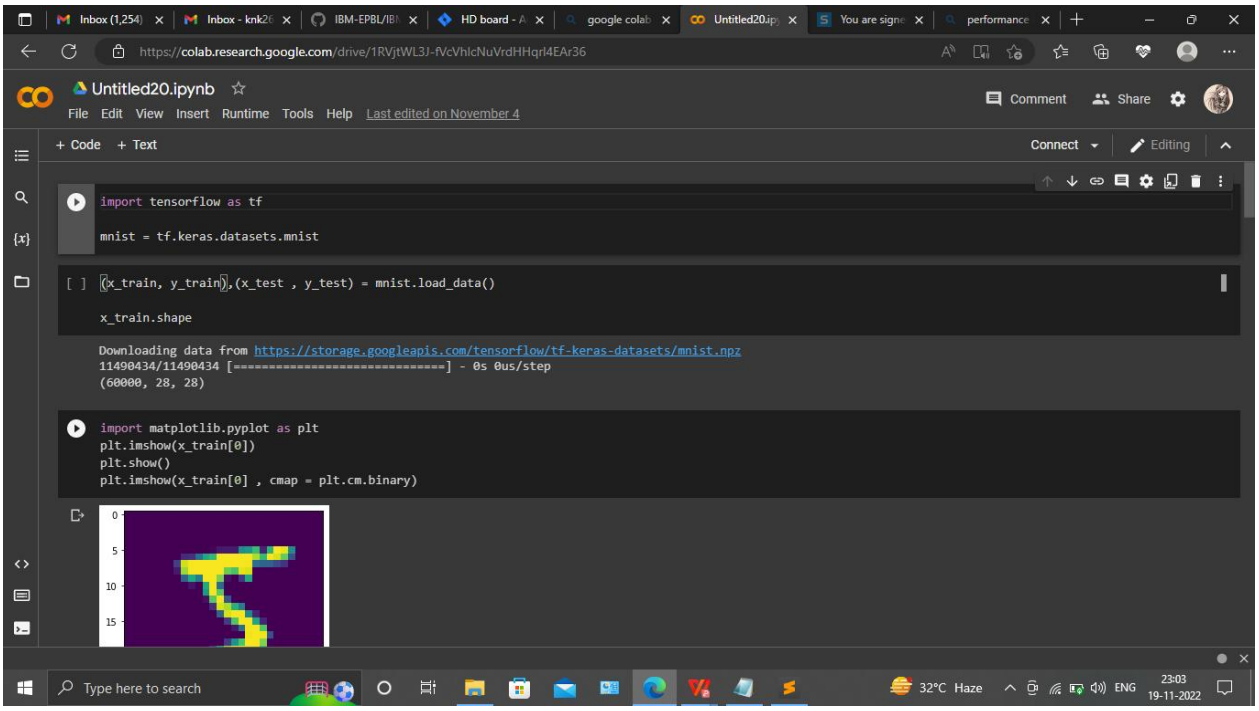
19-11-2022

CHAPTER 7

CODING&SOLUTIONING






Untitled20.ipynb
File Edit View Insert Runtime Tools Help Last edited on November 4
Comment
Share
+ Code + Text
Connect
Editing
import tensorflow as tf
mnist = tf.keras.datasets.mnist
[ ] (x_train, y_train),(x_test , y_test) = mnist.load_data()
x_train.shape
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
11490434/11490434 [==============================] - 0s 0us/step
(60000, 28, 28)
import matplotlib.pyplot as plt
plt.imshow(x_train[0])
plt.show()
plt.imshow(x_train[0] , cmap = plt.cm.binary)
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5
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15
Type here to search
32°C Haze
ENG
23:03
19-11-2022

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
BE_TC_001	Functional	Backend	Check if all the routes are working properly	All the routes should properly work	Working as expected	PASS
RP_TC_001	UI	Result Page	Verify UI elements in the Result Page	The Result page must 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
Total	5	1	3	3	12

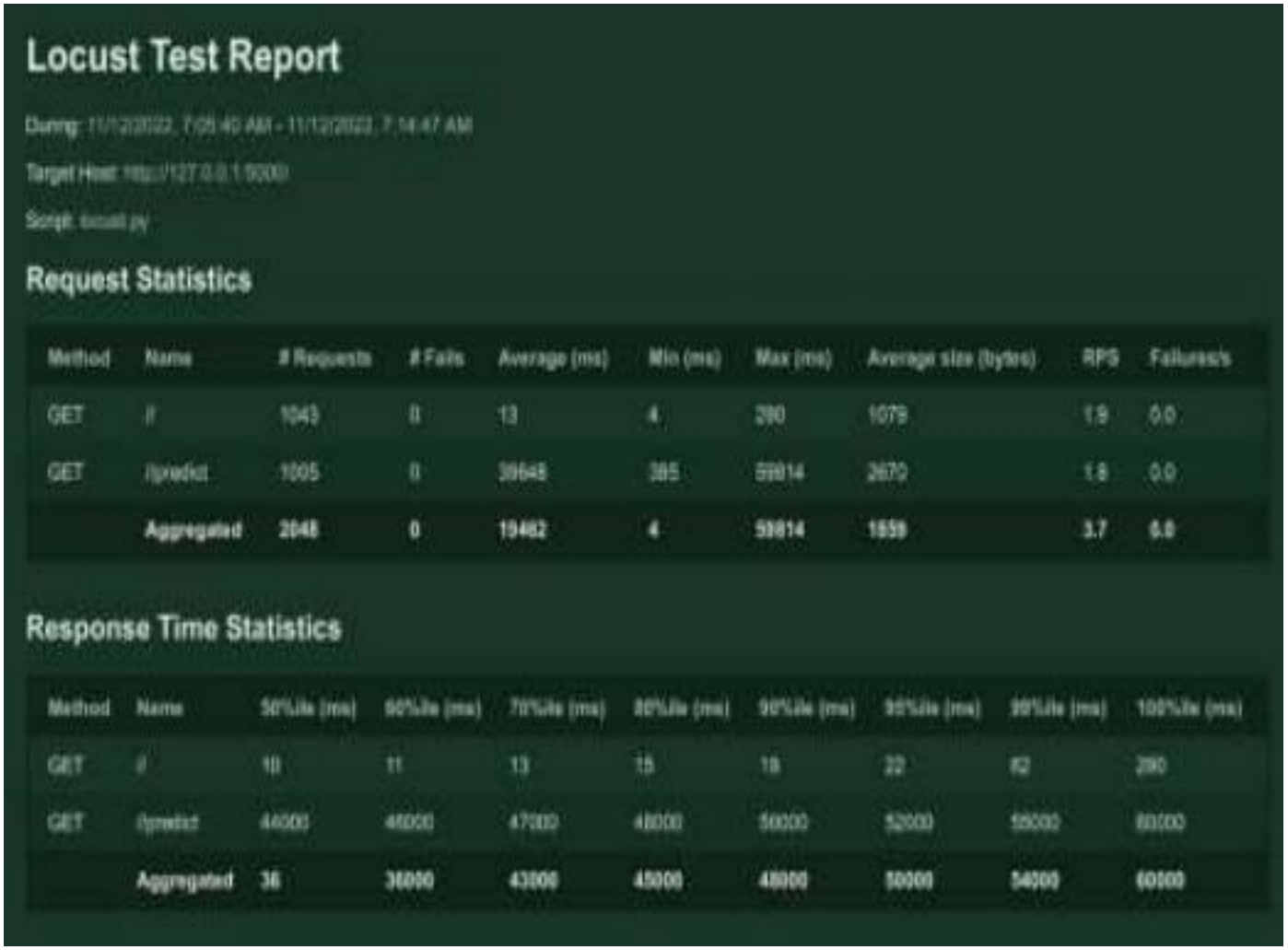
8.2.2 TEST CASE ANALYSIS

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	280	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	18	22	82	280
GET	/predict	44000	46000	47000	48000	56000	52000	56000	60000
	Aggregated	36	38000	43000	45000	48000	50000	54000	60000

CHAPTER 10

ADVANTAGES& DISADVANTAGES

ADVANTAGES

- Reduces manual work
- More accurate than average
- 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 recognize handwritten numbers. Flask, HTML, CSS, JS 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. There are so much improvement, which can be implemented in subsequent versions.

CHAPTER 12

FUTURE SCOPE

This project needs lots of improvement.The future scopes are:

1) Recognize digits from complex images
2) Recognize multiple digits
3) Detect multiple digits and save the results
4) Needs support to different languages to help users all over the world.

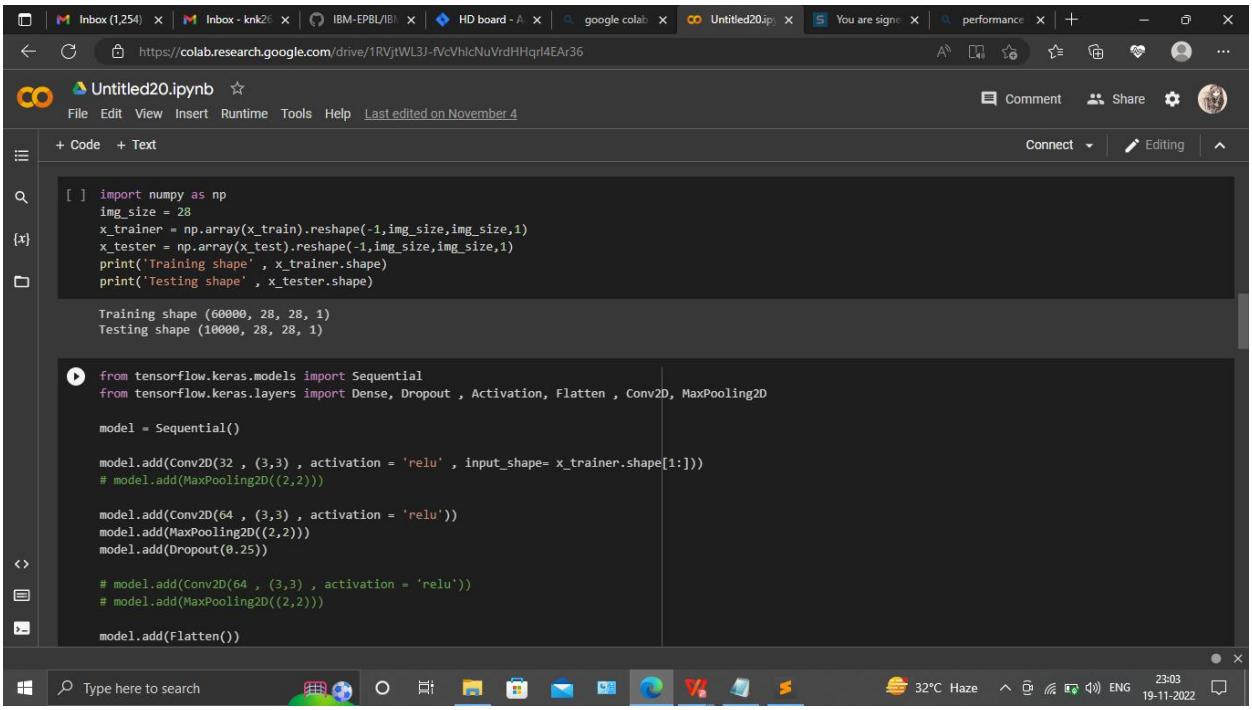
This project can be enhanced to be better by implementing more accurate model which reduces the workload on many workers, enhancing overall work efficiency.

CHAPTER 13

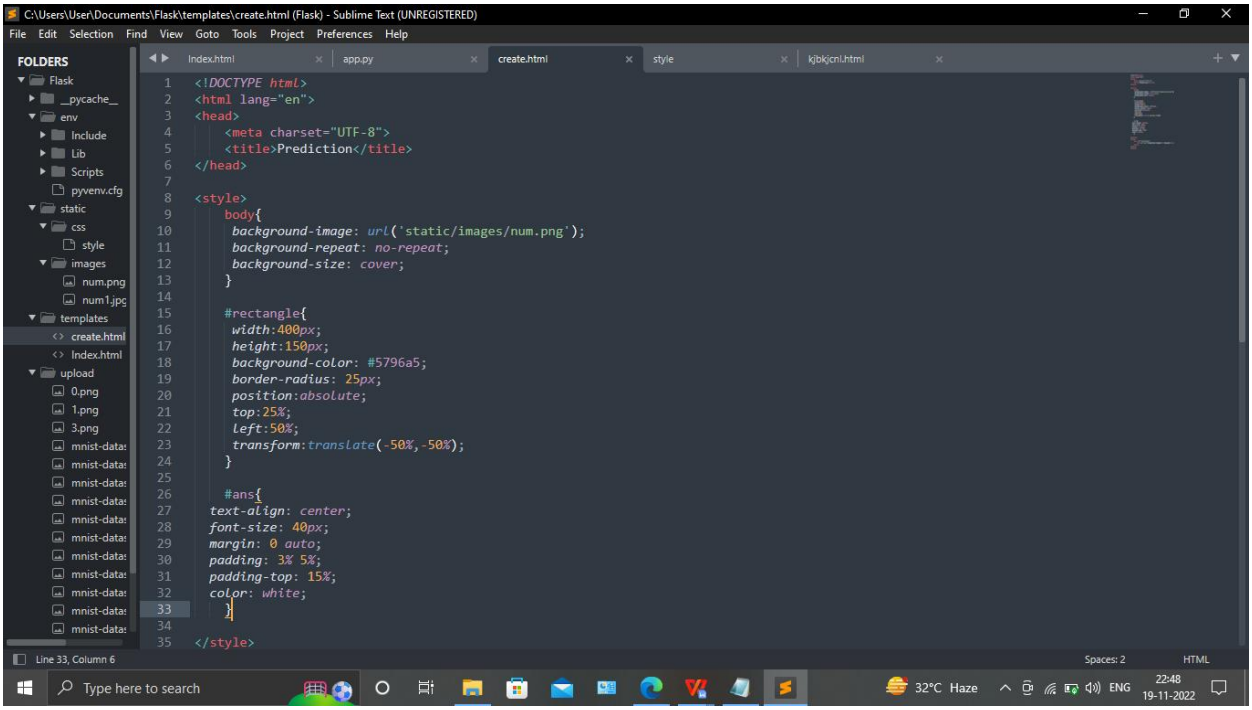
APPENDIX

SOURCE CODE

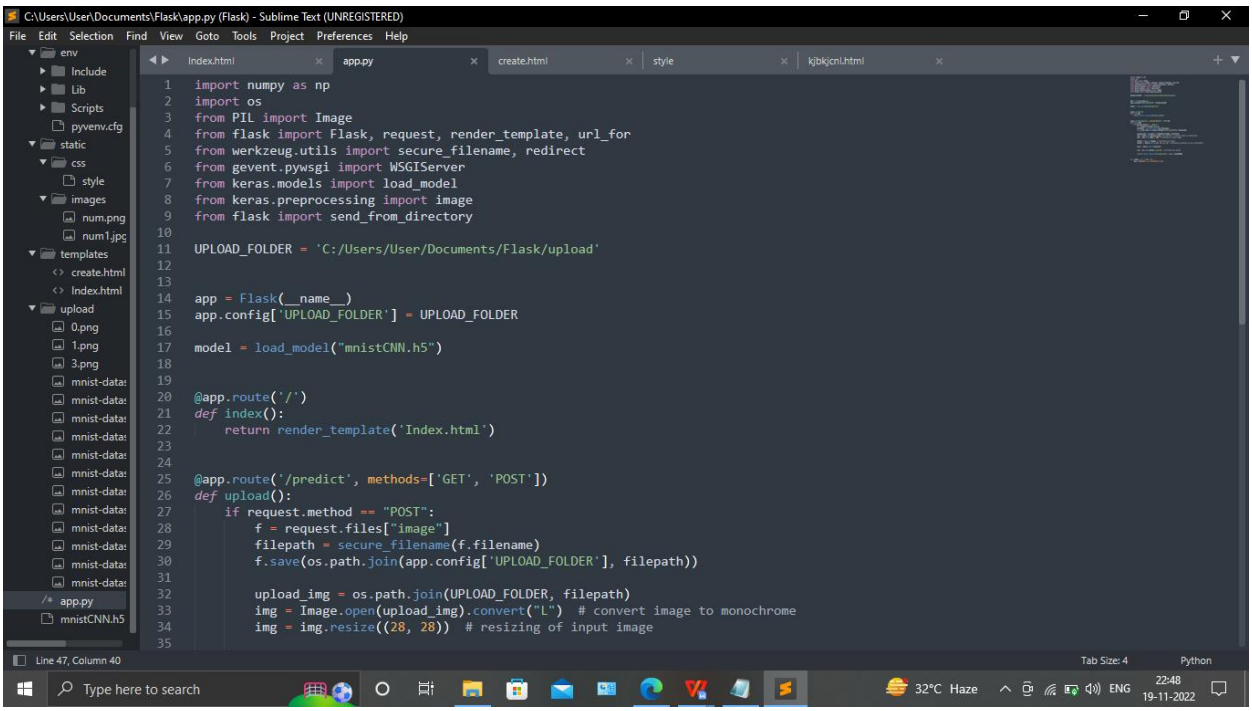
MODEL CREATION

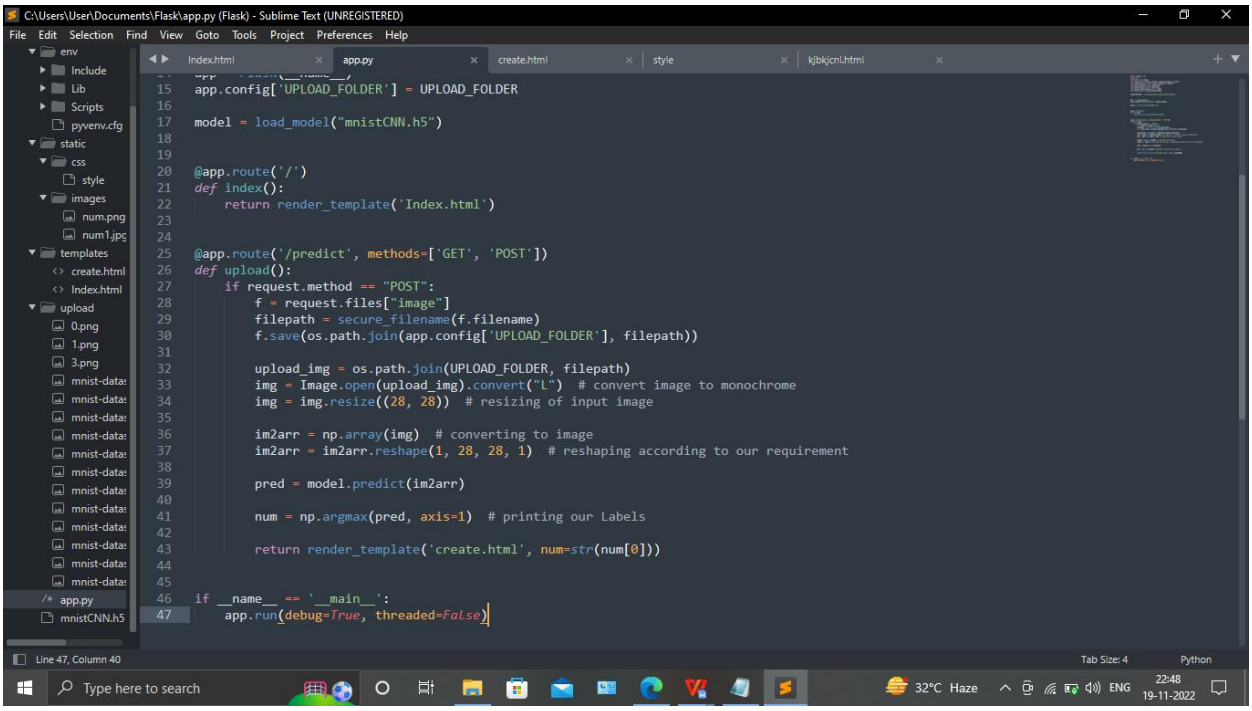


HOME PAGE (HTML)



app.py




C:\Users\User\Documents\Flask\app.py (Flask) - Sublime Text (UNREGISTERED)
File Edit Selection Find View Goto Tools Project Preferences Help
app.config['UPLOAD_FOLDER'] = UPLOAD_FOLDER
model = load_model("mnistCNN.h5")
@app.route('/')
def index():
return render_template('Index.html')
@app.route('/predict', methods=['GET', 'POST'])
def upload():
if request.method == "POST":
f = request.files["image"]
filepath = secure_filename(f.filename)
f.save(os.path.join(app.config['UPLOAD_FOLDER'], filepath))
upload_img = os.path.join(UPLOAD_FOLDER, filepath)
img = Image.open(upload_img).convert("L") # convert image to monochrome
img = img.resize((28, 28)) # resizing of input image
im2arr = np.array(img) # converting to image
im2arr = im2arr.reshape(1, 28, 28, 1) # reshaping according to our requirement
pred = model.predict(im2arr)
num = np.argmax(pred, axis=1) # printing our Labels
return render_template('create.html', num=str(num[0]))
if __name__ == '__main__':
app.run(debug=True, threaded=False)
Line 47, Column 40
Tab Size: 4
Python
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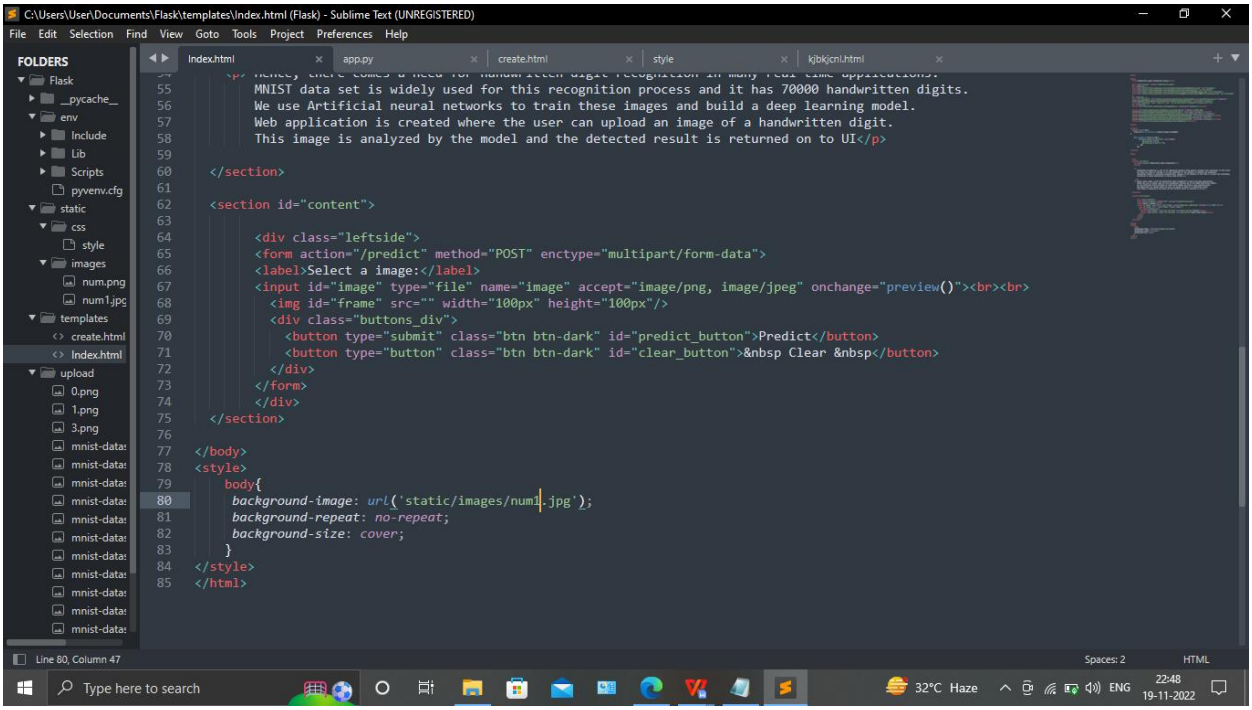
32°C Haze
ENG
22:48
19-11-2022

index.html


C:\Users\User\Documents\Flask\templates\Index.html (Flask) - Sublime Text (UNREGISTERED)
File Edit Selection Find View Goto Tools Project Preferences Help
FOLDERS
MNIST data set is widely used for this recognition process and it has 70000 handwritten digits.
We use Artificial neural networks to train these images and build a deep learning model.
Web application is created where the user can upload an image of a handwritten digit.
This image is analyzed by the model and the detected result is returned on to UI</p>
</section>
<section id="content">

<form action="/predict" method="POST" enctype="multipart/form-data">
<label>Select a image:</label>
<input id="image" type="file" name="image" accept="image/png, image/jpeg" onchange="preview()">

<button type="submit" class="btn btn-dark" id="predict_button">Predict</button>
<button type="button" class="btn btn-dark" id="clear_button"> Clear </button>

</form>

</section>
</body>
<style>
body{
background-image: url('static/images/num1.jpg');
background-repeat: no-repeat;
background-size: cover;
}
</style>
</html>
Line 80, Column 47
Spaces: 2
HTML
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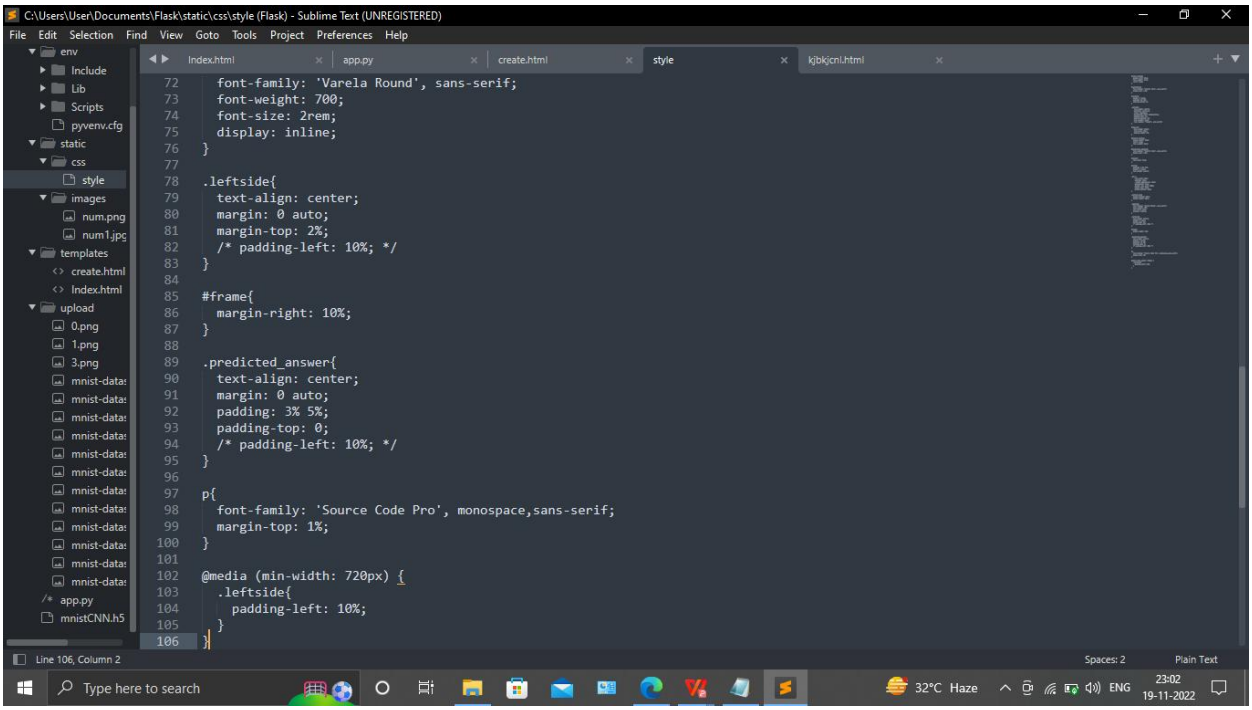
ENG
22:48
19-11-2022

CSS



GITHUB

IBM-EPBL/IBM-Project-2306-1658469467: A Novel Method for Handwritten Digit Recognition System (github.com)