HANDWRITTEN DIGIT RECOGNITION

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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, and can be made with many different flavors. The rapid growth in the need for digitizing handwritten data and the availability of massive processing power demands improvement in recognition accuracy. Hence a highly proficient algorithm is required when dealing with handwriting recognition. A neural network is a model inspired by how the brain works. It consists of multiple layers having many activations, this activation resembles neurons of our brain. A neural network tries to learn a set of parameters in a set of data which could help to recognize the underlying relationships. Neural networks can adapt to changing input; so the network generates the best possible result without needing to redesign the output criteria. The MNIST data set is widely used for this recognition process and it has 70000 handwritten digits. Those images are split as train set and test set images. Artificial neural networks are used 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 analysed by the model and the detected result is returned on to the UI.

1.2. PURPOSE

The main aim is to use the neural network approach for recognizing handwritten digits. The Convolution Neural Network has become the center of all deep learning strategies. Optical character recognition (OCR) is a part of image processing that leads to excerpting text from images. Recognizing handwritten digits is part of OCR. Recognizing the numbers is an important and remarkable subject. In this way, since the handwritten digits are not of same size, thickness, position, various difficulties are faced in determining the problem of recognizing handwritten digits. The unlikeness and structure of the compositional styles of many entities further influences the example and presence of the numbers. This is the strategy for perceiving and organizing the written characters. Its applications are such as programmed bank checks, health, post offices, for education, etc.

2. LITERATURE SURVEY

2.1. EXISTING PROBLEM

Because of the progress in science and technology everything is being digitised to reduce human effort. It takes a lot of time and effort on the side of manual workers when sorting through mails by postal codes. It is not an easy task to handle data by human workers. There is also the possibility of human error while processing huge amounts of data. Therefore, digitizing these will help reduce time and labour. The labour cost will also be reduced with the help of machines. There are also the activities of processing bank checks and tax documentations. Large piles of records and archives can be arranged and sorted well, easing the stress and workload from manual labourers. The problem with handwriting is that every individual has a different style of writing. There is a differing thickness of stroke, style and general uniqueness that just brings a level of hardness in identifying the handwriting. The machine must be capable of picking up the digits correctly with a good accuracy rate. Hence a highly proficient algorithm is required when dealing with handwriting recognition. Handwritten digit recognition can be done using deep learning methods effectively.

2.2. REFERENCES

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[2] A comparison of three classification algorithms for the identification of handwritten digits R.G Jadhav.

[3] Development of a high precision handwritten digit recognition detector based on a ConvolutionNeural Network Sonia Flora, Anju kakkad

[4] A Novel Handwritten Digit Classification System Based on Convolutional Neural Network Approach, Ali Abdullah Yahya, 18 September 2021

[5] Own Handwritten Digit recognition using MLP and CNN in tensorflow Deepti D.Nikumbh, Rupali S. Kale.

[6]. Handwritten digit recognition using deep learning, International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), vol. 6, no. 7, A. Dutta and A. Dutta, July 2017.

[7]. HANDWRITTEN DIGIT RECOGNITION USING OPENCV AND CNN K. Swetha, Y. Hithaishi.

[8]. Handwritten DigitsRecognition, Project Report, Gaurav Jain, Jason Ko, University of Toronto, 11/21/2008.

[9]. Handwritten recognition using SVM, KNN and neural network, arXiv preprint arXiv:1702.00723. Hamid, Norhidayu Abdul, and NilamNur Amir Sjarif, 2017.

[10]. Digit Classification using the MNIST Dataset, M. Wu and Z. Zhang, Handwritten, 2010.

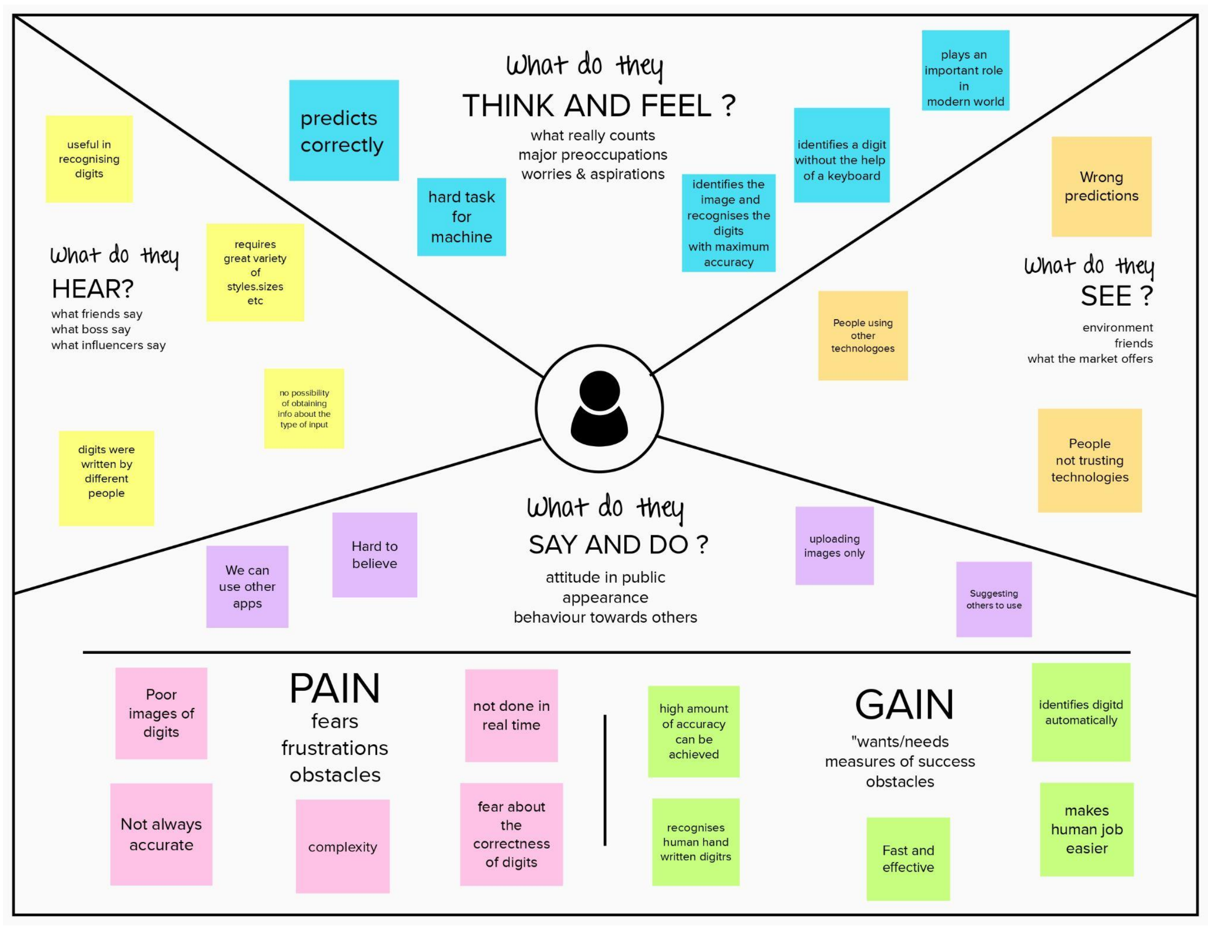
[11]. Handwritten digit classification using support vector machines, R.G.Mihalyi, 2011.

2.3. PROBLEM STATEMENT DEFINITION

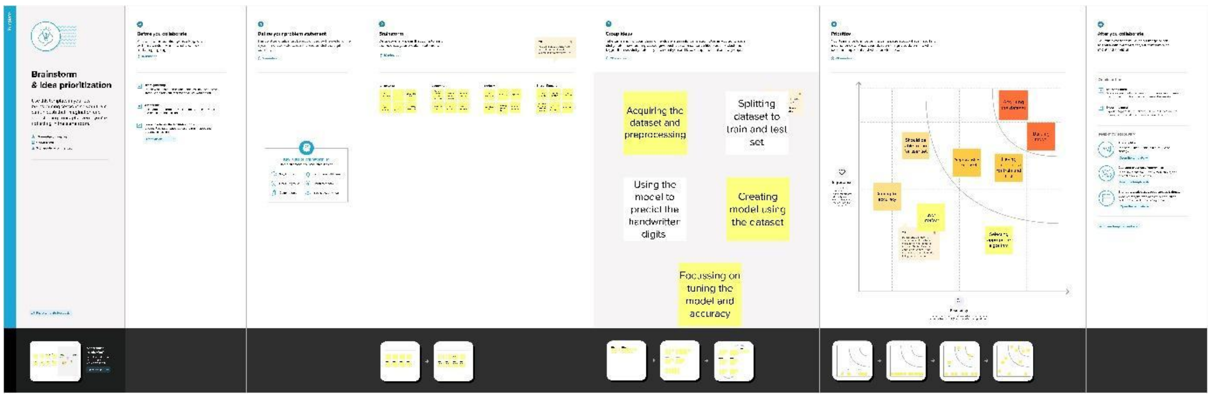
Handwriting recognition is one of the compelling research works going on because every individual in this world has their own style of writing. Since the style of handwriting changes with every individual, it is a challenging task in identifying the characters correctly. The thickness of stroke, style carries uniqueness with different people depending on them. 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. The MNIST data set is widely used for this recognition process and it has 70000 handwritten digits. Artificial neural networks are used to train these images and build a deep learning model. The Convolutional Neural Networks (CNN) is a deep learning algorithm that is highly suitable for image recognition and those tasks involving processing of pixel data. Convolutional neural networks (CNNs) are very effective in perceiving the structure of handwritten characters/words in ways that help in automatic extraction of distinct features and make CNN the most suitable approach for solving handwriting recognition problems. Our aim in the proposed work is to deploy the CNN model effectively and produce a good result with better accuracy. The main objective was to actualize a pattern characterization method to perceive the handwritten digits provided in the MINIST dataset of images of handwritten digits (0‑9). Web application is created where the user can upload an image of a handwritten digit. This image is analysed by the model and the detected result is returned on to the UI.

3. IDEATION AND PROPOSED SOLUTION

3.1. EMPATHY MAP CANVAS



3.2. IDEATION AND BRAINSTORMING

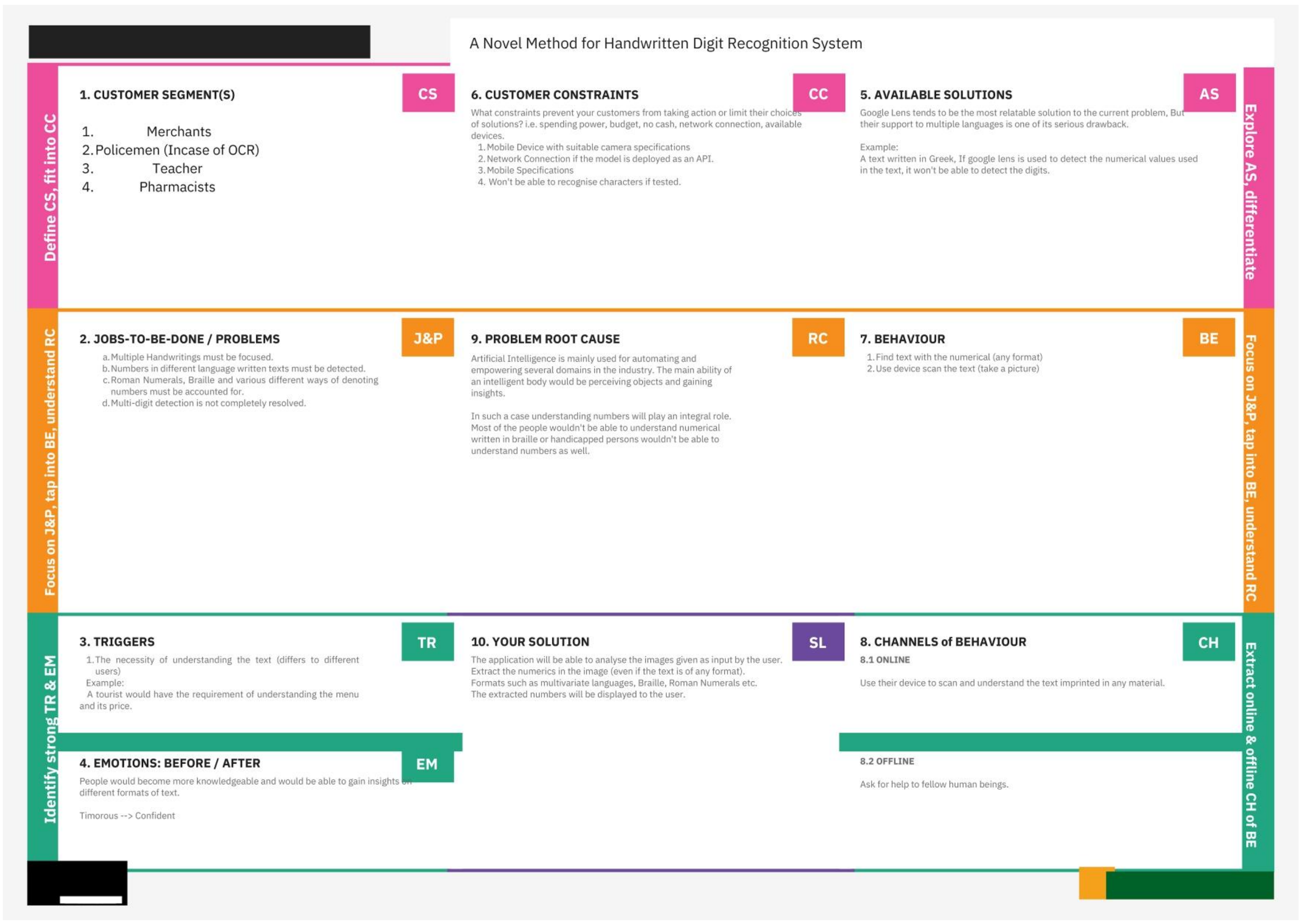


Brainstorm
& idea prioritization
Acquiring the dataset and preprocessing
Splitting dataset to train and test set
Using the model to predict the handwritten digits
Creating model using the dataset
Focussing on tuning the model and accuracy

3.3. PROPOSED SOLUTION

S. No	**Parameter**	**Description**
1.	Problem Statement	To develop a system that will identify the handwritten digit correctly
2.	Idea / Solution Description	a. Predict the digit using deep learning algorithms b. Ensure the correct prediction of digit
3.	Novelty / Uniqueness	a. Predict the digits instantly b. Recognizing digits irrespective of the varying handwriting styles
4.	Social impact / Customer Satisfaction	Serves workers at postal offices and bank, where it can be used for mail sorting and check processing. Also helpful in data form entry. It will reduce the work load from workers and hence reduce stress
5.	Business Model	a. Collaboration with postal office and banks. And other corporations using database b. Saves time and cost with manual labor c. Bank check programming d. Tax documentation
6.	Scalability of the Solution	a. Fine tuning the model aiming to produce more accurate results b. Making it independent with less human intervention

3.4. PROBLEM SOLUTION FIT



[redacted]

A Novel Method for Handwritten Digit Recognition System

Define CS, fit into CC

1. CUSTOMER SEGMENT(S) CS

1. Merchants
2. Policemen (Incase of OCR)
3. Teacher
4. Pharmacists

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.

1. Mobile Device with suitable camera specifications
2. Network Connection if the model is deployed as an API.
3. Mobile Specifications
4. Won't be able to recognise characters if tested.

5. AVAILABLE SOLUTIONS AS

Google Lens tends to be the most relatable solution to the current problem, But their support to multiple languages is one of its serious drawback.

Example:
A text written in Greek, If google lens is used to detect the numerical values used in the text, it won't be able to detect the digits.

Explore AS, differentiate

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

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

a. Multiple Handwritings must be focused.
b. Numbers in different language written texts must be detected.
c. Roman Numerals, Braille and various different ways of denoting numbers must be accounted for.
d. Multi-digit detection is not completely resolved.

9. PROBLEM ROOT CAUSE RC

Artificial Intelligence is mainly used for automating and empowering several domains in the industry. The main ability of an intelligent body would be perceiving objects and gaining insights.

In such a case understanding numbers will play an integral role. Most of the people wouldn't be able to understand numerical written in braille or handicapped persons wouldn't be able to understand numbers as well.

7. BEHAVIOUR BE

1. Find text with the numerical (any format)
2. Use device scan the text (take a picture)

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

Identify strong TR & EM

3. TRIGGERS TR

1. The necessity of understanding the text (differs to different users)

Example:
A tourist would have the requirement of understanding the menu and its price.

4. EMOTIONS: BEFORE / AFTER EM

People would become more knowledgeable and would be able to gain insights on different formats of text.

Timorous --> Confident

10. YOUR SOLUTION SL

The application will be able to analyse the images given as input by the user.
Extract the numerics in the image (even if the text is of any format).
Formats such as multivariate languages, Braille, Roman Numerals etc.
The extracted numbers will be displayed to the user.

8. CHANNELS of BEHAVIOUR CH

8.1 ONLINE

Use their device to scan and understand the text imprinted in any material.

8.2 OFFLINE

Ask for help to fellow human beings.

Extract online & offline CH of BE

[redacted]

4.0. REQUIREMENT ANALYSIS

4.1. FUNCTIONAL REQUIREMENTS

Following are the functional requirements of the proposed solution

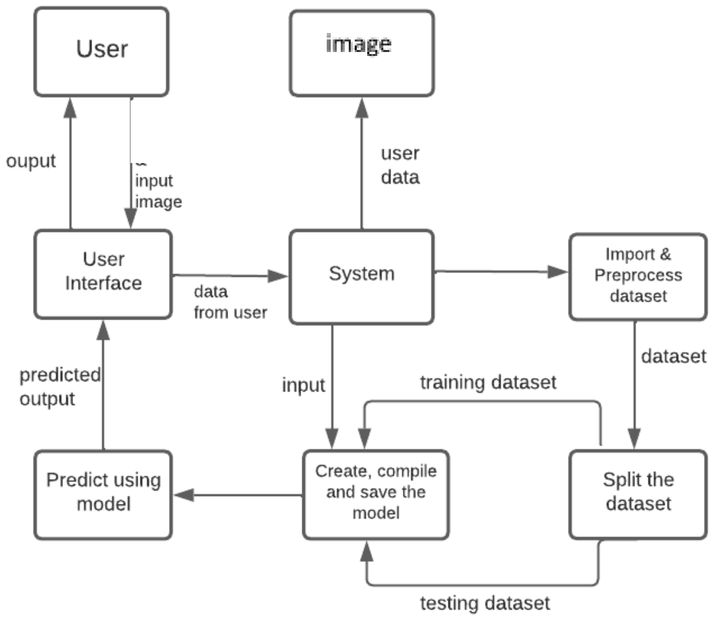
FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	User Registration	Registration through Form and Google Auth
FR-2	User Confirmation	Confirmation via Email
FR-3	Image Input Form	A flask wtf form with image upload as fields
FR-4	Result	Result is displayed as a popup and an email notification is sent to the user
FR-5	User Details	The user can view/update user details.
FR-6	ChatBot	A chatbot for assistance.

4.2. NON-FUNCTIONAL REQUIREMENTS

FR No.	Non-Functional Requirement	Description
NFR-1	**Usability**	Responsive and interactive UI allows the user to access the app with ease
NFR-2	**Security**	The user data is encrypted and stored securely. By using authentication mechanisms user accounts are secured
NFR-3	**Reliability**	Data Loss wouldn’t occur since the usage of IBM Cloud.
NFR-4	**Performance**	The prediction model Performance will be dynamic and improves over time. The user interface requires less heavy APIs and libraries to render
NFR-5	**Availability**	Will be available throughout the time since the application is deployed in IBM Cloud.
NFR-6	**Scalability**	The application is scalable and can cater users based on traffic

5. PROJECT DESIGN

5.1. DATA FLOW DIAGRAM



1. User Interface
2. Input from the user
3. System loads the dataset
4. Splitting into training and testing
5. CNN modelling
6. Output prediction
7. Display the output

5.2. SOLUTION AND TECHNICAL ARCHITECTURE

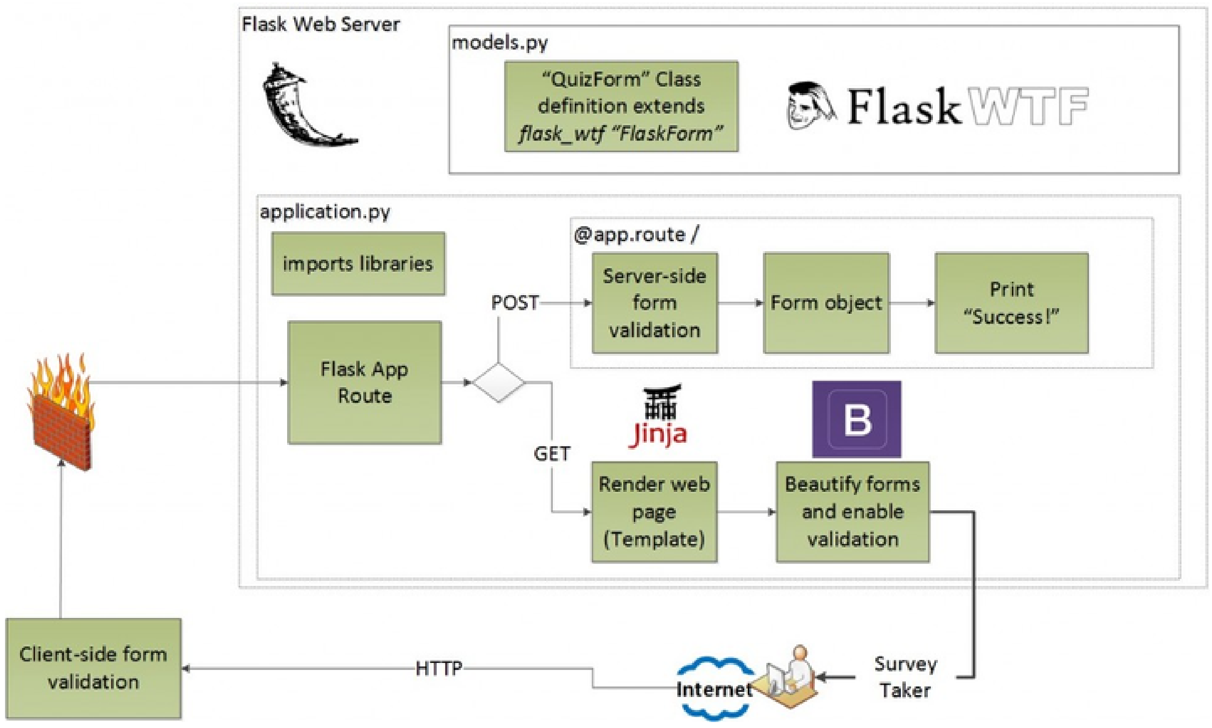
Solution Architecture

Deep learning has evolved into an extensive field within research and development. In image analysis, **convolutional neural networks (CNN)** have been particularly successful. Modified National Institute of Standards and Technology (MNIST) is a large set of computer vision dataset which is extensively used for training and testing different systems. It was created from the two special datasets of National Institute of Standards and Technology (NIST) which holds binary images of handwritten digits. The training set contains handwritten digits from 250 people, among them 50% training dataset was employees from the Census Bureau and the rest of it was from high school students. However, it is often attributed as the first datasets among other datasets to prove the effectiveness of the neural networks.

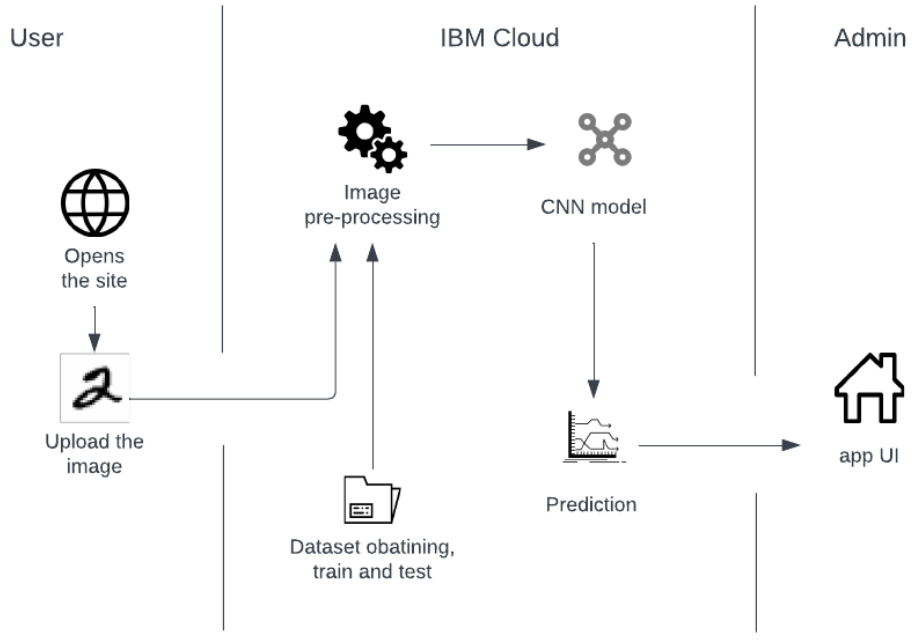
The major steps involved in this.

1. Load the dataset
2. Splitting into training and testing
3. CNN modelling
   3.1. Convolution
   3.2. Pooling
   3.3. Fully connected
4. Output prediction

Architecture Diagram


Flask Web Server
models.py
"QuizForm" Class definition extends flask_wtf "FlaskForm"
Flask WTF
application.py
imports libraries
@app.route /
POST
Server-side form validation
Form object
Print "Success!"
Flask App Route
Jinja
GET
Render web page (Template)
B
Beautify forms and enable validation
Client-side form validation
HTTP
Internet
Survey Taker

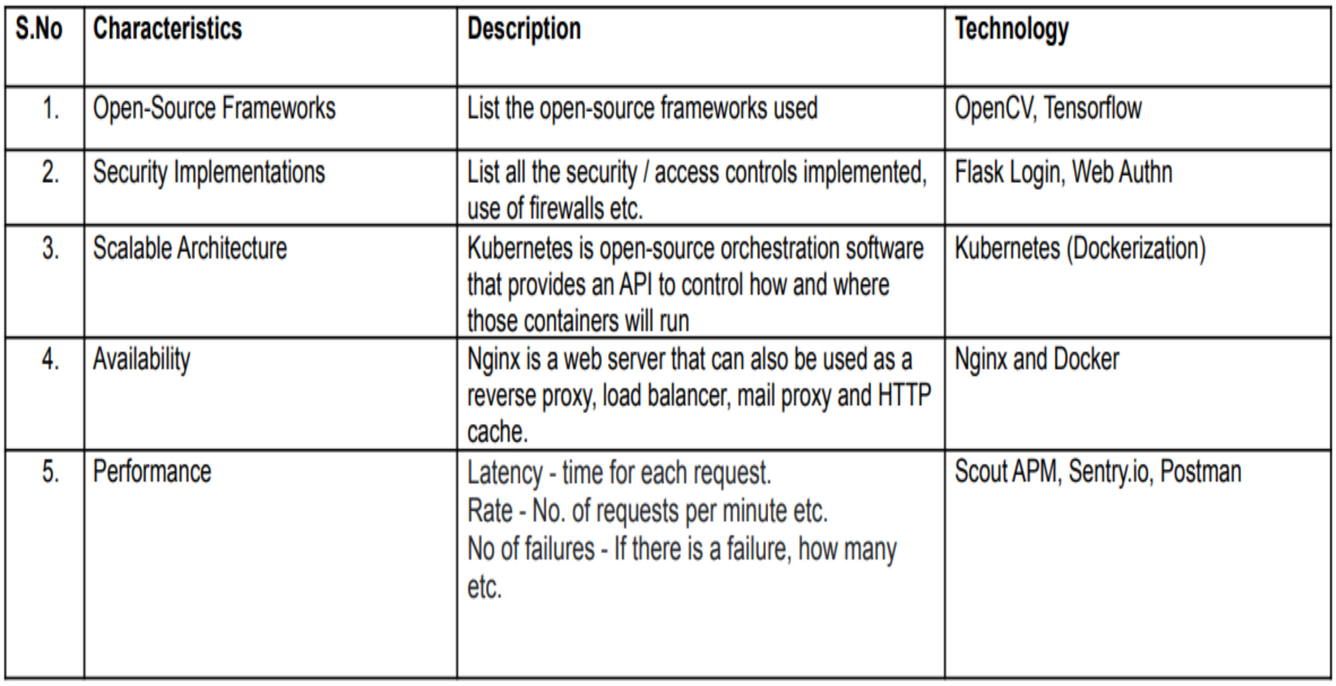
Technical architecture



Components & Technologies:

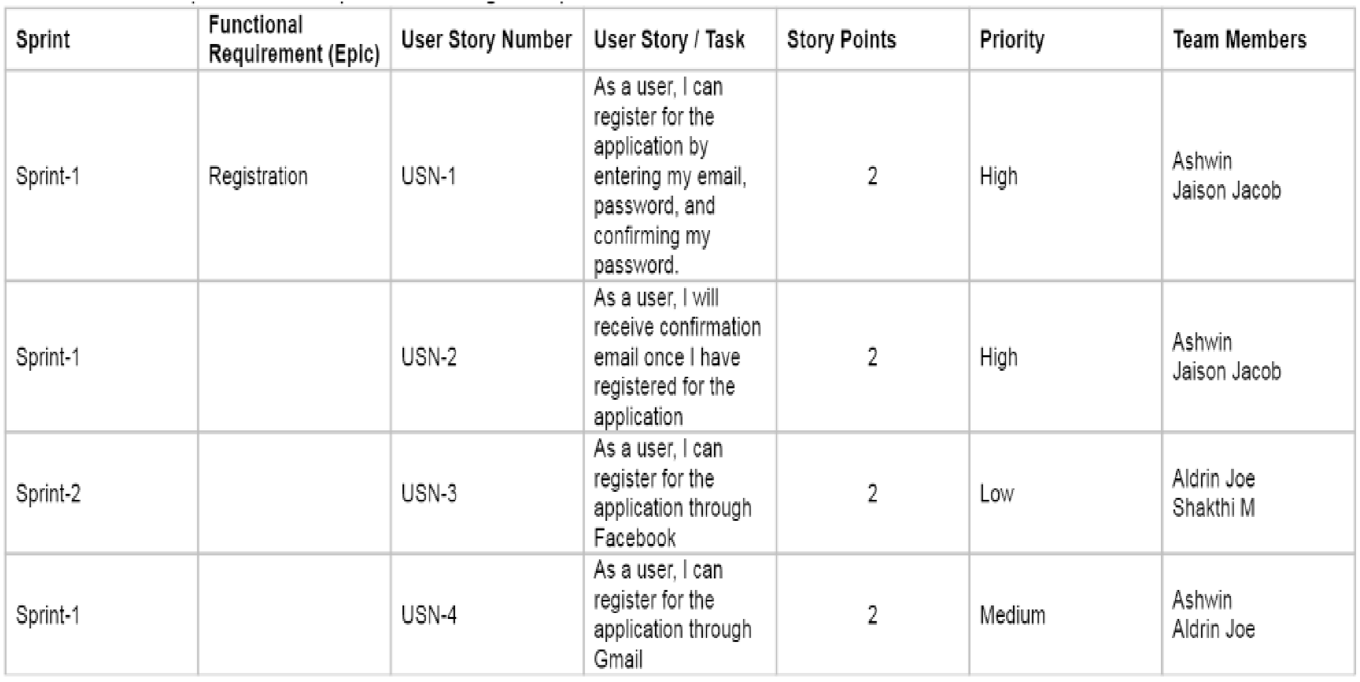
S.No	Component	Description	Technology
1.	User Interface	User Interface consist of multiple pages 1. Home Page 2. Sign In Page 3. Sign Up Page 4. User Page	HTML, CSS, JavaScript
2.	Application Logic-1	Auth Logic: 1. Checking whether the user is present 2. Password requirements 3. email id requirements	Python
3.	Application Logic-2	Image Processing Logic 1. Initial Image cropping 2. Adding filters for smoothening (Gaussian Blur)	Python
4.	Application Logic-3	Automatic Chatbot	IBM Watson Assistant
5.	Database	2 tables (user table, image mapping table)	MySQL
6.	Cloud Database	Database Service on Cloud	IBM DB2, IBM Cloudant etc.
7.	File Storage	File storage requirements	IBM Block Storage or Other Storage Service or Local Filesystem
8.	External API-1	Purpose of External API used in the application	IBM Weather API, etc.
9.	Machine Learning Model	Tensorflow model (.h5 format) developed using V6616 net.	Object Recognition Model, etc.

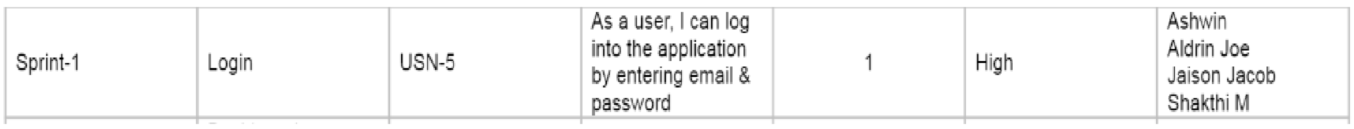
Application Characteristics:



S.No	Characteristics	Description	Technology
1.	Open-Source Frameworks	List the open-source frameworks used	OpenCV, Tensorflow
2.	Security Implementations	List all the security / access controls implemented, use of firewalls etc.	Flask Login, Web Authn
3.	Scalable Architecture	Kubernetes is open-source orchestration software that provides an API to control how and where those containers will run	Kubernetes (Dockerization)
4.	Availability	Nginx is a web server that can also be used as a reverse proxy, load balancer, mail proxy and HTTP cache.	Nginx and Docker
5.	Performance	Latency - time for each request. Rate - No. of requests per minute etc. No of failures - If there is a failure, how many etc.	Scout APM, Sentry.io, Postman

5.3. USER STORIES

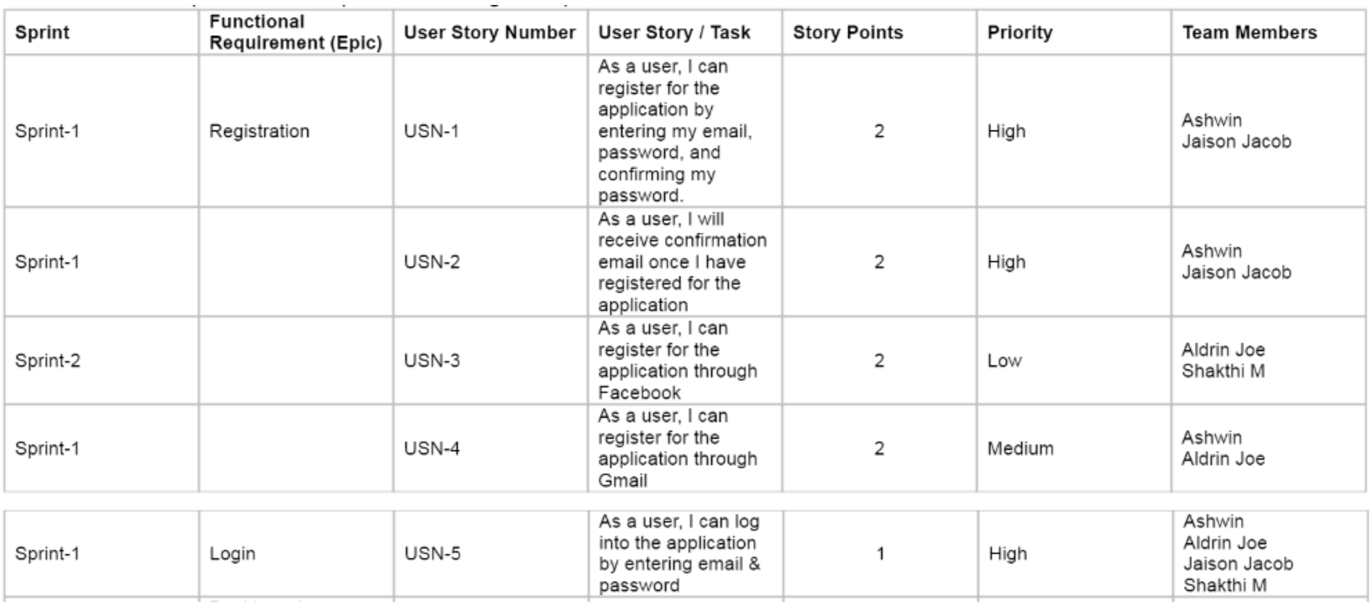




Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	2	High	Ashwin Jaison Jacob
Sprint-1		USN-2	As a user, I will receive confirmation email once I have registered for the application	2	High	Ashwin Jaison Jacob
Sprint-2		USN-3	As a user, I can register for the application through Facebook	2	Low	Aldrin Joe Shakthi M
Sprint-1		USN-4	As a user, I can register for the application through Gmail	2	Medium	Ashwin Aldrin Joe
Sprint-1	Login	USN-5	As a user, I can log into the application by entering email & password	1	High	Ashwin Aldrin Joe Jaison Jacob Shakthi M

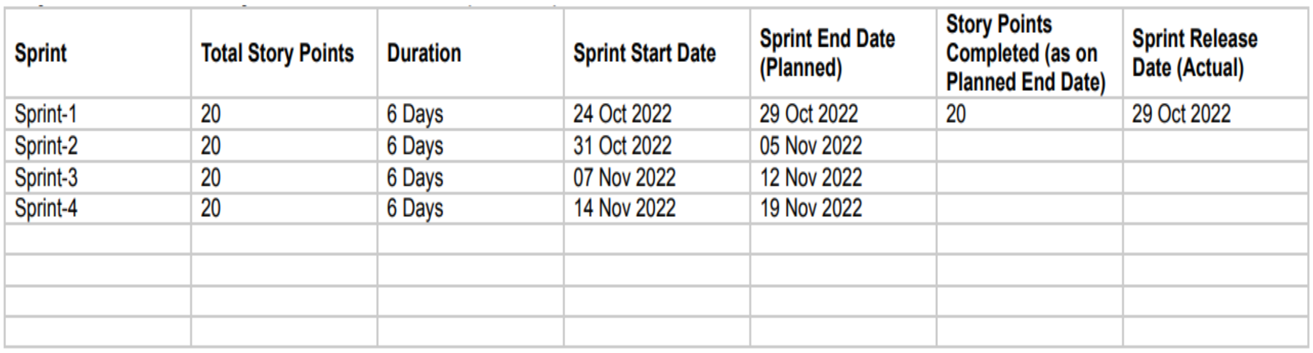
6. PROJECT PLANNING & SCHEDULING

6.1. SPRINT PLANNING AND ESTIMATION



Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	2	High	Ashwin Jaison Jacob
Sprint-1		USN-2	As a user, I will receive confirmation email once I have registered for the application	2	High	Ashwin Jaison Jacob
Sprint-2		USN-3	As a user, I can register for the application through Facebook	2	Low	Aldrin Joe Shakthi M
Sprint-1		USN-4	As a user, I can register for the application through Gmail	2	Medium	Ashwin Aldrin Joe
Sprint-1	Login	USN-5	As a user, I can log into the application by entering email & password	1	High	Ashwin Aldrin Joe Jaison Jacob Shakthi M

6.2. SPRINT DELIVERY SCHEDULE



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

6.3. REPORTS FROM JIRA

Velocity:

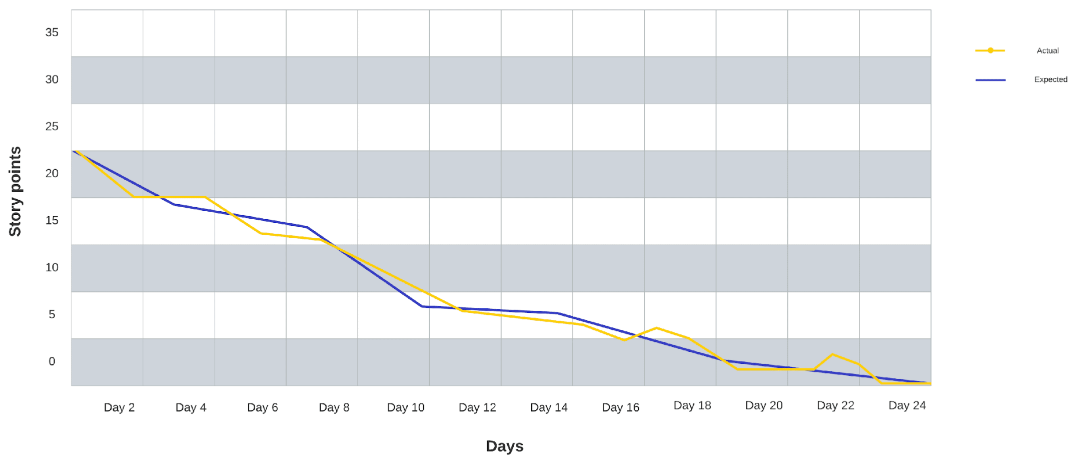
Imagine we have a 6-day sprint duration, and the velocity of the team is 20 (points per sprint). Let's calculate the team's average velocity (AV) per iteration unit (story points per day)

$$\boxed{\textbf{AV} = \textbf{\textit{sprint duration / velocity}}}$$

AV = 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.



7. CODING AND SOLUTIONING

7.1. FEATURE-1 MODEL BUILDING

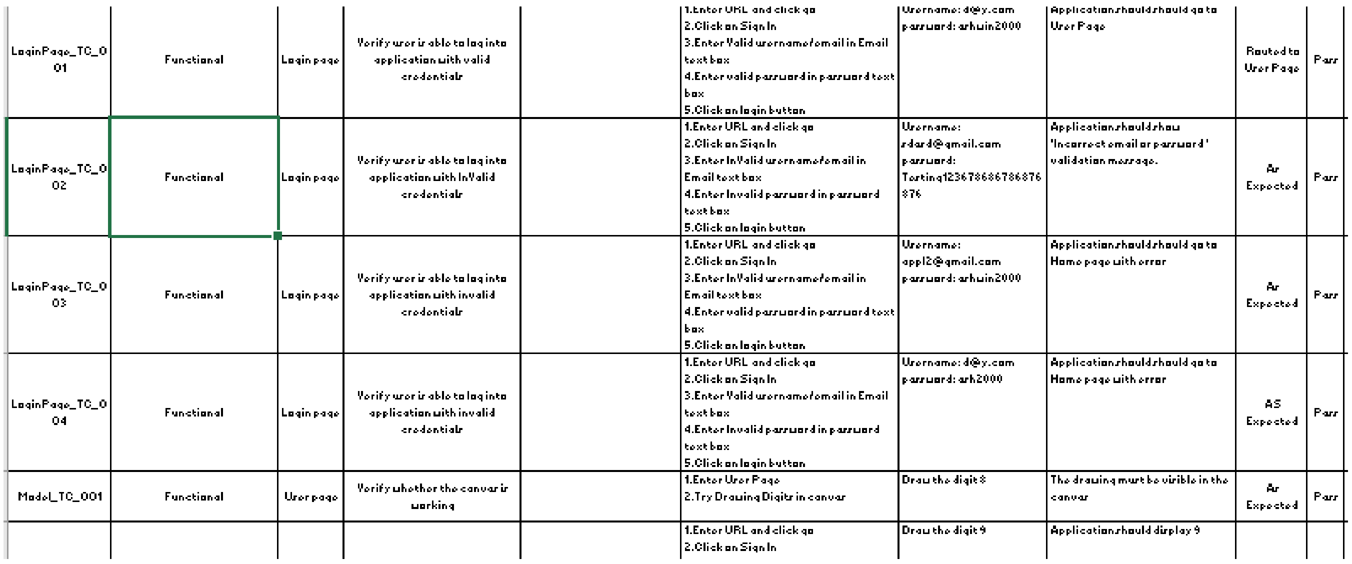
ML depends heavily on data, without data, it is impossible for a machine to learn. It is the most crucial aspect that makes algorithm training possible. In Machine Learning projects, we need a training data set. It is the actual data set used to train the model for performing various actions. TensorFlow already has a MNIST Data set so there is no need to explicitly download or create Dataset. The MNIST dataset contains ten classes: Digits from 0-9. Each digit is taken as a class. The required libraries are imported which are required for the model to run. The dataset for this model is imported from the Keras module. The data is split into train and test. Using the training dataset, the model is trained and the testing dataset is used to predict the results. Basically, the pixel values range from 0-255. The value of each image is stored is y_train. The model is built with convolutional, pooling and dense layers. The created model is then compiled and saved.

7.2. FEATURE-2 WEB APP

HTML, CSS and JavaScript are used to create the web pages for the front end. An html page that takes in image files as input using form and submits to the back end is created. A flask app is created using python flask, where it receives the image files from the templates, html pages and the prediction operation is done over this image. Later the predicted output is sent to the result page.

8. TESTING

8.1 TEST CASES



LoginPage_TC_001	Functional	Login page	Verify user is able to log into application with valid credentials		1.Enter URL and click go 2.Click on Sign In 3.Enter Valid username/email in Email text box 4.Enter valid password in password text box 5.Click on login button	Username: d@y.com password: ashwin2000	Application should should go to User Page	Routed to User Page	Pass
LoginPage_TC_002	Functional	Login page	Verify user is able to log into application with InValid credentials		1.Enter URL and click go 2.Click on Sign In 3.Enter InValid username/email in Email text box 4.Enter Invalid password in password text box 5.Click on login button	Username: sdasd@gmail.com password: Testing123678686786876876	Application should show 'Incorrect email or password ' validation message.	As Expected	Pass
LoginPage_TC_003	Functional	Login page	Verify user is able to log into application with invalid credentials		1.Enter URL and click go 2.Click on Sign In 3.Enter InValid username/email in Email text box 4.Enter valid password in password text box 5.Click on login button	Username: appl2@gmail.com password: ashwin2000	Application should should go to Home page with error	As Expected	Pass
LoginPage_TC_004	Functional	Login page	Verify user is able to log into application with invalid credentials		1.Enter URL and click go 2.Click on Sign In 3.Enter Valid username/email in Email text box 4.Enter Invalid password in password text box 5.Click on login button	Username: d@y.com password: ash2000	Application should should go to Home page with error	AS Expected	Pass
Model_TC_001	Functional	User page	Verify whether the canvas is working		1.Enter User Page 2.Try Drawing Digits in canvas	Draw the digit 8	The drawing must be visible in the canvas	As Expected	Pass
					1.Enter URL and click go 2.Click on Sign In	Draw the digit 9	Application should display 9		

8.2 USER ACCEPTANCE TEST

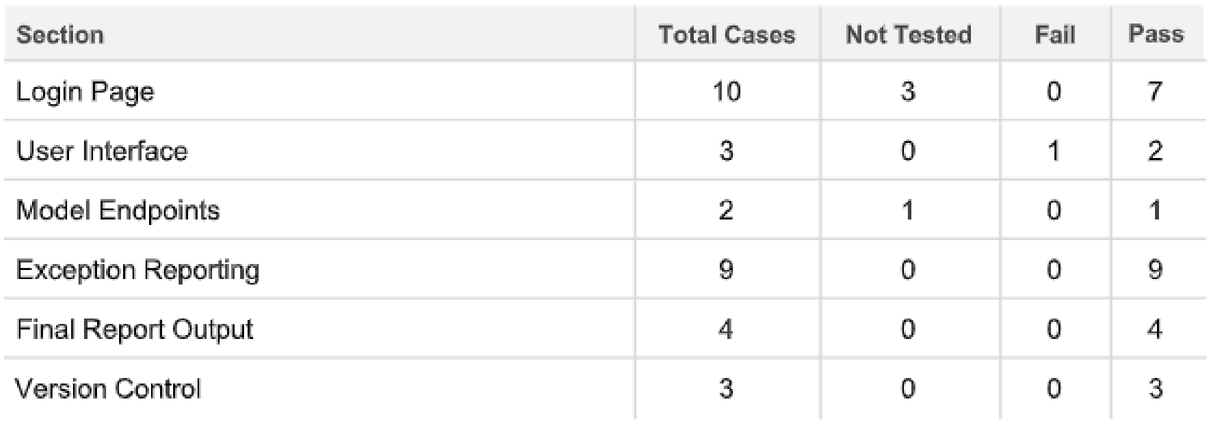
Defect Analysis

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	0	4	2	3	9
Duplicate	1	0	3	0	4
External	2	3	0	1	6
Fixed	20	0	1	0	21
Not Reproduced	0	0	1	0	1
Skipped	0	0	0	2	2
Won't Fix	2	0	0	0	2
Totals	25	7	7	7	45

Test Case Analysis

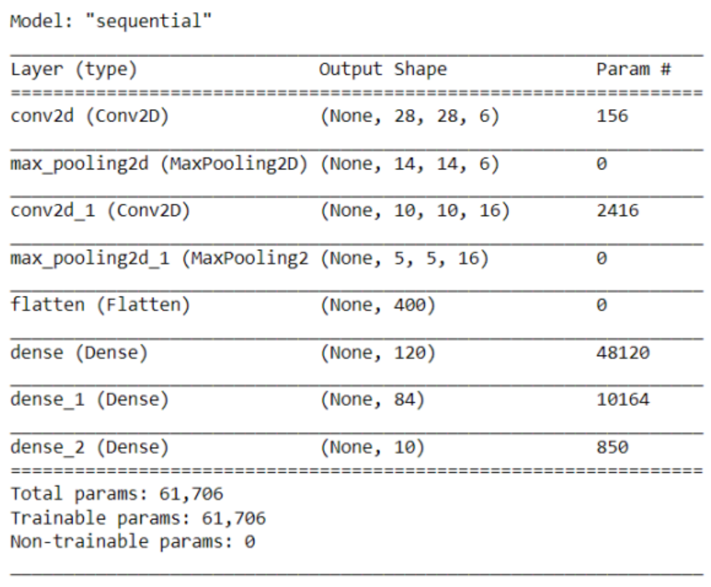
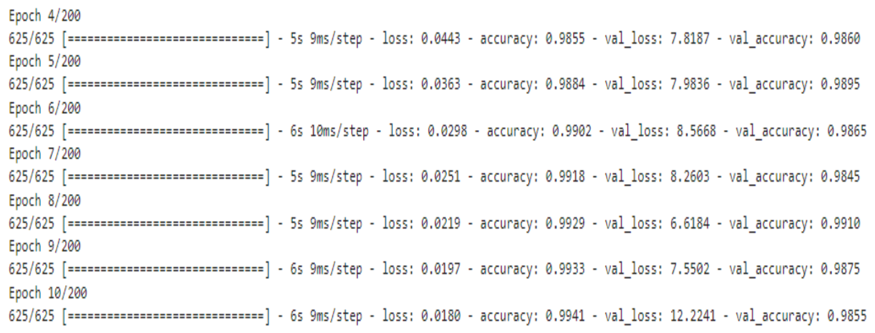
This report shows the number of test cases that have passed, failed, and untested



Section	Total Cases	Not Tested	Fail	Pass
Login Page	10	3	0	7
User Interface	3	0	1	2
Model Endpoints	2	1	0	1
Exception Reporting	9	0	0	9
Final Report Output	4	0	0	4
Version Control	3	0	0	3

9. RESULTS

9.1 PERFORMANCE METRICS

S.No.	Parameter	Values	Screenshot
1.	Model Summary		
2.	Accuracy	Training Accuracy 99.2 % Validation Accuracy 99.8 % Epochs Trained 200	

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 28, 28, 6)         156
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 10, 10, 16)        2416
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 5, 5, 16)          0
_________________________________________________________________
flatten (Flatten)            (None, 400)               0
_________________________________________________________________
dense (Dense)                (None, 120)               48120
_________________________________________________________________
dense_1 (Dense)              (None, 84)                10164
_________________________________________________________________
dense_2 (Dense)              (None, 10)                850
=================================================================
Total params: 61,706
Trainable params: 61,706
Non-trainable params: 0
_________________________________________________________________
```

```
Epoch 4/200
625/625 [==============================] - 5s 9ms/step - loss: 0.0443 - accuracy: 0.9855 - val_loss: 7.8187 - val_accuracy: 0.9860
Epoch 5/200
625/625 [==============================] - 5s 9ms/step - loss: 0.0363 - accuracy: 0.9884 - val_loss: 7.9836 - val_accuracy: 0.9895
Epoch 6/200
625/625 [==============================] - 6s 10ms/step - loss: 0.0298 - accuracy: 0.9902 - val_loss: 8.5668 - val_accuracy: 0.9865
Epoch 7/200
625/625 [==============================] - 5s 9ms/step - loss: 0.0251 - accuracy: 0.9918 - val_loss: 8.2603 - val_accuracy: 0.9845
Epoch 8/200
625/625 [==============================] - 5s 9ms/step - loss: 0.0219 - accuracy: 0.9929 - val_loss: 6.6184 - val_accuracy: 0.9910
Epoch 9/200
625/625 [==============================] - 6s 9ms/step - loss: 0.0197 - accuracy: 0.9933 - val_loss: 7.5502 - val_accuracy: 0.9875
Epoch 10/200
625/625 [==============================] - 6s 9ms/step - loss: 0.0180 - accuracy: 0.9941 - val_loss: 12.2241 - val_accuracy: 0.9855
```

10. ADVANTAGES & DISADVANTEGES

ADVANTAGES:

- It saves times for arranging and sorting huge amount of data
- Only requires far less physical space than the storage of the physical copies.
- Recognising multiple digits on a single frame using sequential model in Keras.
- Data storage, for an example, there are many files, contracts and some personal records that contains some handwritten digits.
- It reduces human effort and labour cost
- This can be used for sorting through mail by postal code

DISADVANTAGES

- The system build is complex and holds difficulty
- The handwriting of every individual varies which proves to be a challenge for the system to predict
- Possible unemployment of labour that is typical of technology growth
- The accuracy is not guarantees and there are risk of errors

11. CONCLUSION

Handwritten digit recognition has immense applications in the field of medical, banking, student management, and taxation process etc. Many classifiers like KNN, SVM, and CNN are used to identify the digit from the handwritten image. Here we've used CNN for implementation. Convolutional Neural Network gets trained from the real-time data and makes the model very simple by reducing the number of variables and gives relevant accuracy. MNIST dataset consist of handwritten numbers from 0-9 and it is a standard dataset used to find performance of classifiers.

Results of HDR is improved a lot by using CNN classifier but it can be improved further in terms of complexity, duration of execution and accuracy of results by making combination of classifiers or using some additional algorithm with it. More accurate results can be established with more convolution layers and more number of hidden neurons. It can completely abolish the need for typing. Digit recognition is an excellent prototype problem for learning about neural networks and it gives a great way to develop more advanced techniques of deep learning.

12. FUTURE SCOPE

In future, different architectures of CNN, namely, hybrid CNN, viz., CNN-RNN and CNN-HMM models, and domain-specific recognition systems, can be investigated. Evolutionary algorithms can be explored for optimizing CNN learning parameters, namely, the number of layers, learning rate and kernel sizes of convolutional filters. The future development of the applications based on algorithms of deep and machine learning is practically boundless.

In the future, we can work on a denser or hybrid algorithm than the current set of algorithms with more manifold data to achieve the solutions to many problems. In future, the application of these algorithms lies from the public to high-level authorities, as from the differentiation of the algorithms above and with future development we can attain high-level functioning applications which can be used in the classified or government agencies as well as for the common people. Currently only the digits are recognized. In future the all the characters in all the language can be predicted with high accuracy rate.

13. APPENDIX

Source code

The necessary libraries are imported.

```
import keras
import tensorflow
from keras.datasets import mnist
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPooling2D
from keras import backend as K
from tensorflow.keras.utils import to_categorical
import matplotlib.pyplot as plt
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D
from tensorflow.keras.layers import MaxPooling2D
from tensorflow.keras.layers import Dense
from tensorflow.keras.layers import Flatten
from tensorflow.keras.optimizers import SGD
```

The MNIST dataset is downloaded from the keras library and the data is analyzed.

```
# the data, split between train and test sets
(x_train,y_train),(x_test,y_test)=mnist.load_data()
print(x_train.shape,y_train.shape)
print(x_test.shape,y_test.shape)
x_train[0]
```

The data is pre-processed and reshaped

```
#Preprocess the data
num_classes=10
x_train=x_train.reshape(x_train.shape[0],28,28,1)
x_test=x_test.reshape(x_test.shape[0],28,28,1)
input_shape = (28,28,1)
```

Applying one-hot encoding. The class vectors are converted to binary class matrices.

```
#Convert class vectors to binary class matrices
y_train=keras.utils.to_categorical(y_train,num_classes)
y_test=keras.utils.to_categorical(y_test,num_classes)
x_train=x_train.astype('float32')
x_test=x_test.astype('float32')
x_train=x_train/255
x_test=x_test/255
print('x_train shape:',x_train.shape)
print(x_train.shape[0],'train samples')
```

The CNN model is created. The activation function is Rectified linear unit(ReLU). The pooling layers, dense layers are added and flattened.

```
#Create the Model
batch_size=128
num_classes=10
epochs=20
model = Sequential()
model.add(Conv2D(32,
kernel_size=(3,3),activation='relu',input_shape=input_shape))
model.add(Conv2D(64,(3,3),activation='relu'))
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(64,activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes,activation='softmax'))
```

The model is then compiled

```
model.compile(loss=keras.losses.categorical_crossentropy,
optimizer=keras.optimizers.
Adadelta(),metrics=['accuracy'])
```

The model is trained

```
hist = model.fit(x_train,
y_train,batch_size=20,epochs=5,verbose=1,validation_data=(x_test, y_test))
```

Observing the metrics and testing the model

```
metrics = model.evaluate(x_test, y_test, verbose=0)
print("Metrics(Loss and Accuracy):")
print(metrics)
prediction = model.predict(x_test[:4])
print(prediction)
```

The model is saved and then tested. A sample image is given in to test the saved model. The image is reshaped and then predicted.

```
model.save('digit_classifier.h5')
from keras.utils.image_utils import img_to_array
from tensorflow.keras.models import load_model
model = load_model('/content/digit_classifier.h5')
from PIL import Image
import numpy as np

img = Image.open('/content/sample.png').convert("L")
img = img.resize((28,28))
im2arr = np.array(img)
im2arr = im2arr.reshape(1,28,28,1)

#display the image
import matplotlib.pyplot as plt
plt.imshow(img)

#predict the image
y_predict = model.predict(im2arr)
print(np.argmax(y_predict[0]))
```

The pages to display the home and recognise page with navigation bar.

HDR front end.html

```
<html>
    <head>
        <style>
            body {
              background-image:
url('https://cdn.pixabay.com/photo/2020/09/23/03/54/background-5594879_1280.jp
g');
              margin: 0;
              font-family: 'Times New Roman', Times, serif, Helvetica,
sans-serif;
            }

            .topnav {
              overflow: hidden;
              background-color: rgb(255, 255, 255);
            }

            .topnav a {
              float: left;
              color: #480557;
              text-align: center;
              padding: 14px 16px;
              text-decoration: none;
              font-size: 17px;
            }

            .topnav a:hover {
              background-color: rgb(57, 55, 55);
              color: rgb(250, 248, 248);
            }

            .topnav a.active {
              background-color: #f8e406;
              color: rgb(19, 19, 19);
            }
            p{
                text-align: center;
                background-color: rgb(8, 0, 0);
                margin-left: 25%;
                margin-right: 25%;
                margin-top: 5%;
                font-family:'Times New Roman', Times, serif;
                color:aliceblue;
                font-size: large;
            }
            </style>
    </head>
    <body>

        <div class="topnav">
            <a class="active" href="#home">Home</a>
            <a href="recognise.html">Recognise</a>
        </div>
        <p style="font-size:larger">Handwritten Digit Recognition</p>
        <p>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</p>
    </body>
</html>
```

The recognise page where the user can upload the image for prediction

recognise.html

```
<html>
    <head>
        <meta charset="UTF-8">
        <meta http-equiv="X-UA-Compatible" content="IE=edge" />
        <title>Digit Recognition</title>
        <style>
            body {
              background-image:
url('https://img.freepik.com/premium-vector/falling-colorful-messy-numbers-mat
h-study-concept-with-flying-digits-fascinating-back-school-mathematics-banner-
white-background-falling-numbers-vector-illustration_174187-2929.jpg?w=2000');
              margin: 0;
              font-family: 'Times New Roman', Times, serif, Helvetica,
sans-serif;
              height: 100%;
              width: 100%;
            }
            h1 {
                display: block;
                font-size: 3.5em;
                margin-top: 5.4em;
                margin-bottom: 0em;
                margin-left: 50%;
                margin-right: 0;
                font-weight: bold;
            }


            .button {
                border:#e5b9f3;
                color: rgb(56, 1, 69);
                padding: 15px 32px;
                text-align: center;
                text-decoration: none;
                display: inline-block;
                font-size: 16px;
                margin: 4px 2px;
                cursor: pointer;
                }

            .button1 {
                background-color: #b6e6f0;
                margin-top: 5.4em;
                margin-left: 56%;
                margin-right: 0;
                border: black;
            }
            .button2 {
                background-color: #b6e6f0;
                margin-top: 5.5em;
                margin-left: 55%;
                margin-right: 0;
                border: black;
            }
        </style>
        <script>
            function view() {
                frame.src=URL.createObjectURL(event.target.files[0]);
            }

            $('#submit').click(function(){
                $.ajax({
                    url: 'app.py',
                    type: 'POST',
                })
            })

            var input = document.getElementById('image');
            var infoArea = document.getElementById('frame');

            input.addEventListener('change', showFileName);

            function showFileName(event) {
                var input = event.srcElement;
                var fileName = input.files[0].name;
                infoArea.textContent = 'File name: ' + fileName;
            }

        </script>
        <script src="https://kit.fontawesome.com/b3aed9cb07.js"
crossorigin="anonymous"></script>
        <script src="https://code.jquery.com/jquery-3.3.1.slim.min.js"
integrity="sha384-q8i/X+965DzO0rT7abK41JStQIAqVgRVzpbzo5smXKp4YfRvH+8abtTE1Pi6
jizo" crossorigin="anonymous"></script>
        <script
src="https://cdnjs.cloudflare.com/ajax/libs/popper.js/1.14.7/umd/popper.min.js
"
integrity="sha384-UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHND
z0W1" crossorigin="anonymous"></script>
        <script
src="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/js/bootstrap.min.js"
integrity="sha384-JjSmVgyd0p3pXB1rRibZUAYoIIy6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B0
7jRM" crossorigin="anonymous"></script>
        <script
src="https://cdn.jsdelivr.net/npm/@tensorflow/tfjs@latest"></script>
        <script
src="https://ajax.googleis.com/ajax/libs/jquery/3.1.0/jquery.min.js"></script>

    </head>
    <body>
        <h1 style = "color: rgb(2, 60, 0)">Digit Recognition
        <br>
        <br>
        <form action="/predict" method="POST" enctype="multipart/form-data">

        <input id="image" type="file" name="image" accept="image/png,
image/jpeg" onchange="view()"><br><br>
        <img id="frame" type="submit" src="" width="100px" height="100px"/>



        <input type="submit" value="Recognise" class="button button2"/>
    </h1>
        </form>
    </body>
</html>
```

The page where the predicted output is displayed

predict.html

```
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <meta http-equiv="X-UA-Compatible" content="IE=edge" />
    <title>Prediction</title>
</head>

<style>
    body{
     background-image:
url('https://img.freepik.com/premium-vector/falling-colorful-messy-numbers-mat
h-study-concept-with-flying-digits-fascinating-back-school-mathematics-banner-
white-background-falling-numbers-vector-illustration_174187-2929.jpg?w=2000');
     background-repeat: no-repeat;
     height: 100%;
     width: 100%
    }
    .button{
        border:#e5b9f3;
        color: rgb(56, 1, 69);
        padding: 15px 32px;
        text-align: center;
        text-decoration: none;
        display: inline-block;
        font-size: 16px;
        margin-left:45%;
        cursor: pointer;

    }


    #pred{
        text-align: center;
        font-family: 'Times New Roman', Times, serif;
        font-size: 40px;
        margin: 0 auto;
        padding: 3% 5%;
        padding-top: 15%;
        color: rgb(0, 10, 80);
    }
```

```html
</style>

<body>

        <p id="pred">PREDICTION : {{ num }}</p>
        <p>
        <a href="recognise.html">
            <button data-inline="True" class="button">Back</button>
        </a>
        </p>
</body>
</html>
```

The flask app.py python code to calculate the prediction value from processing the image uploaded by the user

app.py

```python
import os
import numpy as np
from flask import Flask, render_template, request
import tensorflow as tf
from PIL import Image
from werkzeug.utils import secure_filename

UPLOAD_FOLDER = 'C:\Users\AKSHAYA\Pictures\static\images'

app = Flask(__name__)
app.config['UPLOAD_FOLDER'] = UPLOAD_FOLDER

@app.route('/')
def index():
    return render_template('recognise.html')


model = tf.keras.models.load_model("digit_classifier.h5")

@app.route('/predict', methods = ['GET','POST'])
def upload_image_file():
    if request.method == 'POST':
        imagefile = request.files['image']
        filename = secure_filename(imagefile.filename)
        imagefile.save(os.path.join(app.config['UPLOAD_FOLDER'], filename))
        path_img = os.path.join(UPLOAD_FOLDER, filename)
        img = Image.open(path_img).convert("L")
        img = img.resize((28,28))
        im2arr = np.array(img)
        im2arr = im2arr.reshape(1,28,28,1)
        y_pred = model.predict(im2arr)

        return render_template('predict.html', num = str(y_pred))

if __name__ == '__main__' :
    app.run(host='0.0.0.0', port=8000, debug=True)
```

Github

https://github.com/IBM-EPBL/IBM-Project-37884-1660361840

Demo link