

PROJECT REPORT

A NOVEL METHORD FOR HAND WRITTEN DIGIT RECOGNITION SYSTEM

TEAM ID - PNT2022TMID47347

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|--------------------|-------------------------|
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INTRODUCTION

1.1 Project Overview

Machine learning and deep learning play an important role in computer technology and artificial intelligence. With the use of deep learning and machine learning, human effort can be reduced in recognizing, learning, predictions and in many more areas.

Handwritten Digit Recognition is the ability of computer systems to recognize handwritten digits from various sources, such as images, documents, and so on. This project aims to let users take advantage of machine learning to reduce manual tasks in recognizing digits.

1.2 Purpose

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

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 numerals like 1 and 7, 5 and 6, 3 and 8, 2 and 5, 2 and 7, etc. Finally, the individuality and variation of each individual's handwriting influence the structure and appearance of the digits.

2.2 References

| S. NO | TITLE | AUTHOR | YEAR | ABOUT |
|-------|--|--|------|---|
| 1 | A Novel Handwritten Digit Classification System Based on Convolutional Neural Network Approach | Ali Abdullah Yahya , Jieqing Tan and Min Hu | 2019 | The handwritten digit recognition problem is a topic of heated debate in recent years. Despite that there are enormous convolutional neural network algorithms proposed for handwritten digit recognition, issues such as recognition accuracy and computation time still require further improvement. |
| 2 | Handwritten Character Recognition from Images using CNN-ECOC | Mayur Bhargab Bora, Dinthisrang Daimary, Khwairakpam Amitab, Debdatta Kandar | 2020 | The OCR is a process of classifying the optical patterns present in a digital image to the corresponding characters. The OCR is a process of classifying the optical patterns present in a digital image to the corresponding characters. The character recognition is achieved through important steps of feature extraction and classification. The OCR system simulates the human capability to recognize. |
| 3 | Handwritten Digit Recognition using | Ritik Dixit, Rishika | 2021 | Digit recognition has many applications like number plate |

| | | | | |
|---|---|------------------------------|------|--|
| | Machine and Deep Learning Algorithms | Kushwah, Samay Pashine | | recognition, postal mail sorting, bank check processing, etc. In Handwritten digit recognition, we face many challenges because of different styles of writing of different peoples as it is not an Optical character recognition. This research provides a comprehensive comparison between different machine learning and deep learning algorithms for the purpose of handwritten digit recognition. |
| 4 | Deep Convolution Self-Organizing Map Network for Robust Handwritten Digit Recognition | Saleh Ally, Sultan Almotairi | 2020 | Deep Convolution Self-Organizing Map Network for Robust Handwritten Digit Recognition |

2.3 Problem Statement Definition

The problem is recognizing the human handwritten digits by system. The goal is to upload the image of the handwritten digit and identify the digit with accuracy. Digits' are a part of our everyday life, be it License plates on our cars or bikes, the price of a product, speed limit on a road, or details associated with a bank account. The recognition of digits is important because humans can't remember all these numbers, so there is a need for a system to recognize them.

Handwritten digit recognition is the ability of computers to recognize human handwritten digits. It is a hard task for the machine because handwritten digits are not perfect and can be made with many different flavors. The main objective is to compare the accuracy of the models stated above along with their execution time to get the best possible model for digit recognition.


IDEATION & PROPOSED SOLUTION

3.1 Empathy Map Canvas






3.2 Ideation & Brainstorming


Template



Brainstorm & idea prioritization


Use this template in your own brainstorming sessions so your team can unleash their imagination and start shaping concepts even if you're not sitting in the same room.

 10 minutes to prepare
 1 hour to collaborate
 2-8 people recommended



Before you collaborate

A little bit of preparation goes a long way with this session. Here's what you need to do to get going.

 10 minutes

A


Team gathering
Define who should participate in the session and send an invite. Share relevant information or pre-work ahead.

B

Set the goal
Think about the problem you'll be focusing on solving in the brainstorming session.

C


Learn how to use the facilitation tools
Use the Facilitation Superpowers to run a happy and productive session.

[Open article](#) 

1


Define your problem statement

What problem are you trying to solve? Frame your problem as a How Might We statement. This will be the focus of your brainstorm.

 5 minutes


PROBLEM


How might we [your problem statement]?





Key rules of brainstorming


To run an smooth and productive session


 Stay in topic.

 Encourage wild ideas.

 Defer judgment.

 Listen to others.

 Go for volume.

 If possible, be visual.

3

Group Ideas

The common idea among the individual idea

⌂



4

Prioritize

The classification of the idea is based on the important and feasibility.



3.3 Proposed Solution

| S.NO | PARAMETER | DESCRIPTION |
|------|-------------------------------------|--|
| 1 | Problem Statement | The problem is recognizing the human handwritten digits by system. The goal is to upload the image of the handwritten digit and identify the digit with accuracy |
| 2 | Idea/Solution Description | The training and testing has been conducted from publicly available MNIST handwritten databases. Web based, offline and online handwritten digit recognition system is developed by using Convolutional Neural Network. |
| 3 | Novelty/Uniqueness | OCR technology provides higher than 99% accuracy with typed characters in high-quality images. However, the diversity in human writing, spacing differences, and irregularities of handwriting causes less accurate character recognition, as you can see in the featured image. |
| 4 | Social Impact/Customer Satisfaction | Handwritten Digit Recognition has various uses such as less time consumption. It is used in the detection of vehicle numbers, banks for reading cheques, post offices for arranging letters, and other tasks. |
| 5 | Business Model | The main objective of this work is to ensure effective and reliable approaches for recognition of handwritten digits and make banking operations easier and error free. |
| 6 | Scalability of Solution | Recently handwritten digit recognition becomes vital scope and it is appealing many researchers because of its using in variety of machine learning and computer vision applications |

3.4 Problem Solution fit

| | | | | | | |
|-------------------------|--|--|--|---|--|---|
| Define CS, fit into CC | 1. CUSTOMER SEGMENT(S) Who is your customer? i.e. working parents of 0-5 y.o. kids *Government employees *banker *people working with hand-written textual data that want to recognize and process hand-written digits automatically. *A person who needs to read postal addresses, bank check amounts, and forms | CS | 6. CUSTOMER CONSTRAINTS 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. Inaccessibility of proper cameras, lack of stable internet connections, inavailability of devices such as mobiles and laptops It is a hard task for the machine because handwritten digits are not perfect and can be made with many different flavors. The handwritten digit recognition is the solution to this problem which uses the image of a digit and recognizes the digit present in the image. | CC | 5. AVAILABLE SOLUTIONS Which solutions are available to the customers when they face the problem or need to get the job done? What have they tried in the past? What pros & cons do these solutions have? i.e. pen and paper is an alternative to digital notetaking *There are existing alternative solutions for this problem but these approaches are rather inaccurate and are not robust or invariant to rotations and variations. *The capability of a computer to fete the mortal handwritten integers from different sources like images, papers, touch defence. | AS |
| | Focus on J&P, tap into BE, understand RC | 2. JOBS-TO-BE-DONE / PROBLEMS Which jobs-to-be-done (or problems) do you address for your customers? There could be more than one, explore different sides. *Jobs: Recognizing and ascertaining the handwritten digits *Problems: Hard to recognize digits, dim lighting, weak eyesight | J&P | 9. PROBLEM ROOT CAUSE What is the real reason that this problem exists? What is the back story behind the need to do this job? i.e. customers have to do it because of the change in regulations. Hand-written digits are in varying fonts and sizes, thus they are becoming increasingly difficult to ascertain due to various factors such as weakening eye-sight, time constraints, etc. | RC | 7. BEHAVIOUR What does your customer do to address the problem and get the job done? i.e. directly related: find the right solar panel installer, calculate usage and benefits; indirectly associated: customers spend free time on volunteering work (i.e. Greenpeace) Customer seeks quality cameras and stable internet connection services. Customer may also obtain devices such as mobiles and laptops |
| Identify strong TR & EM | | 3. TRIGGERS What triggers customers to act? i.e. seeing their neighbour installing solar panels, reading about a more efficient solution in the news. The live recognition rate highly depends on the digit skew, as automatic de-skewing was not implemented, but manually performed. | TR | 10. YOUR SOLUTION If you are working on an existing business, write down your current solution first, fill in the canvas, and check how much it fits reality. If you are working on a new business proposition, then keep it blank until you fill in the canvas and come up with a solution that fits within customer limitations, solves a problem and matches customer behaviour. The proposed solution aims to accurately recognize hand-written digits using deep learning and computer vision techniques thereby saving costs to the organization and improving employee productivity. | SL | 8. CHANNELS of BEHAVIOUR 8.1 ONLINE What kind of actions do customers take online? Extract online channels from #7 Stable internet connection is required for uploading and processing of the images. 8.2 OFFLINE What kind of actions do customers take offline? Extract offline channels from #7 and use them for customer development. Procure modern electronic devices and ensure they're working |
| | | 4. EMOTIONS: BEFORE / AFTER How do customers feel when they face a problem or a job and afterwards? i.e. lost, insecure > confident, in control - use it in your communication strategy & design. Customers will be able to increase productivity and reduce time taken for tasks. Recognition reveals more information therefore provides more opportunities for personal characteristics estimation, particularly, emotional state | EM | | | |

Explore AS, differentiate

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

Extract online & offline CH of BE

REQUIREMENT ANALYSIS

4.1 Functional requirement

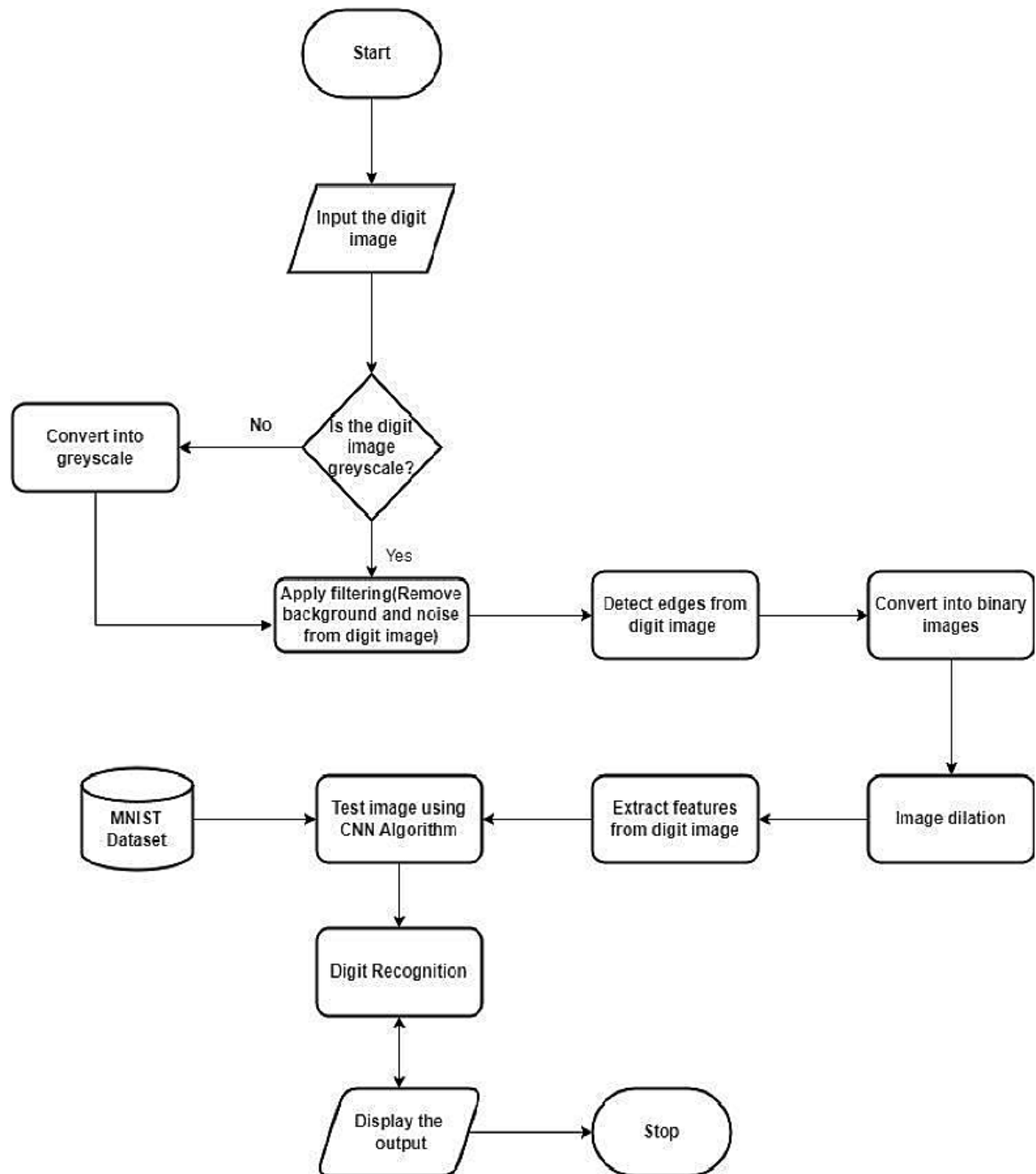
| FR NO | FUNCTIONAL REQUIREMENT AND DESCRIPTION |
|-------|--|
| FR-1 | Image Data: Handwritten digit recognition is the ability of a computer to recognize the human handwritten digits from different sources like images, papers, touch screens, etc, and classify them into 10 predefined classes (0-9). This has been a topic of boundless-research in the field of deep learning. |
| FR-2 | Website: Web hosting makes the files that comprise a website (code, images, etc.) available for viewing online. Every website you've ever visited is hosted on a server. The amount of space allocated on a server to a website depends on the type of hosting. The main types of hosting are shared, dedicated, VPS and reseller. |
| FR-3 | Digit_Classifier_Model: Use the MNIST database of handwritten digits to train a convolutional network to predict the digit given an image. First obtain the training and validation data. |
| FR-4 | MNIST dataset: The MNIST dataset is an acronym that stands for the Modified National Institute of Standards and Technology dataset |
| FR-5 | databases, software, virtual storage, and networking, among others. In layman's terms, Cloud Computing is defined as a virtual platform that allows you to store and access your data over the internet without any limitations. |

4.2 Non-Functional requirements

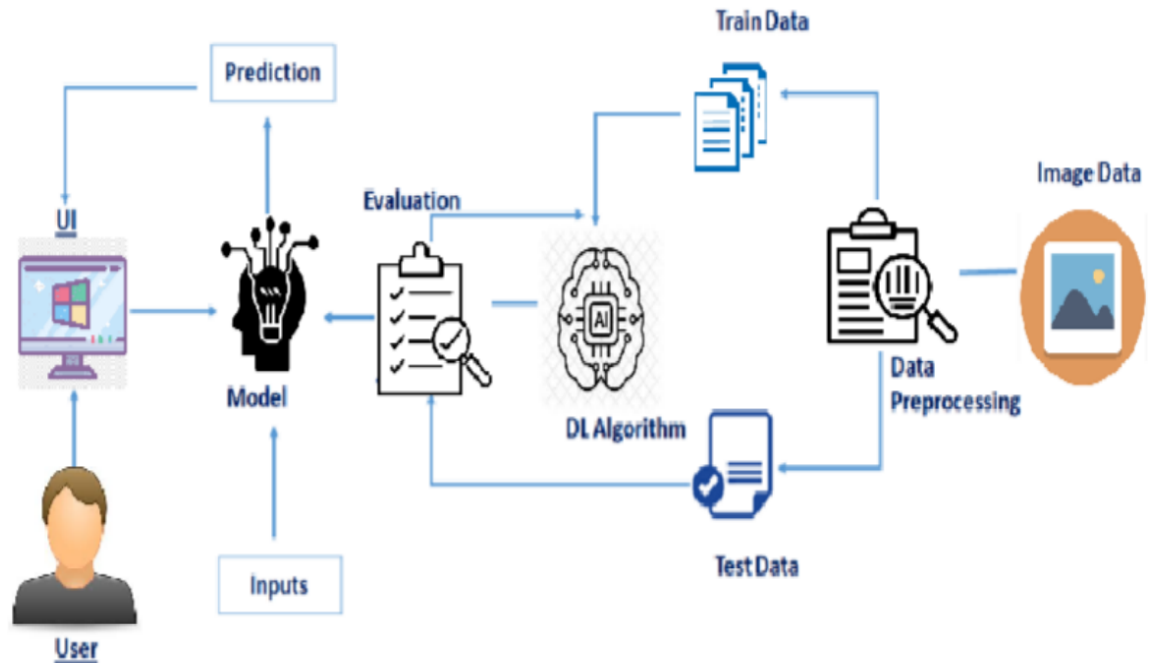
| NFR NO | NON-FUNCTIONAL REQUIREMENT |
|--------|--|
| NFR-1 | Usability: Handwritten character recognition is one of the practically important issues in pattern recognition applications. The applications of digit recognition include postal mail sorting, bank check processing, form data entry, etc. |
| NFR-2 | Reliability: 1) The system not only produces a classification of the digit but also a rich description of the instantiation parameters which can yield information such as the writing style. 2)The generative models can perform recognition driven segmentation. 3) The method involves a relative. |
| NFR-3 | Performance: The neural network uses the examples to automatically infer rules for recognizing handwritten digits. Furthermore, by increasing the number of training examples, the network can learn more about handwriting, and so improve its accuracy. There are a number of ways and algorithms to recognize handwritten digits, including Deep Learning/CNN, SVM, Gaussian Naive Bayes, KNN, Decision Trees, Random Forests, etc. |
| NFR-4 | Accuracy: Optical Character Recognition (OCR) technology provides higher than 99% accuracy with typed characters in high quality images. However, the diversity in human writing types, spacing differences, and irregularities of handwriting causes less accurate character recognition. |

PROJECT DESIGN

5.1 Data Flow Diagrams



5.2 Solution & Technical Architecture



5.3 User Stories

| Personas | Entice | Enter | Engage | Exit | Extend |
|---|---|--|--|---|--|
| Browsing, looking, attending, and rating a local city tour | How does someone initially become aware of this process? | What do people experience as they begin the process? | In the core moments in the process, what happens? | What do people typically experience as the process finishes? | What happens after the experience is over? |
| Steps What steps does the person (or group) typically experience? | Import the libraries and load the dataset. Preprocess the data and Create the model | Find the website for handwritten information. Open, signup and login into website | Access the dashboard. Choose either image upload or draw in canvas. Give input by importing image or by draw in canvas | Display the output. Save the output. Terminate the process | Enter quality of experience. Services become wider |
| Interactions What interactions do they have at each step along the way? • People: Who do they see or talk to? • Places: Where are they? • Things: What digital touchpoints or physical objects would they use? | Search in browsers. Recommended by other persons. Interaction through advertisements | Find a space or button to upload image. Find a space to draw in canvas | Scan the document. The user can upload and he can upload the picture, text and etc | The website gives an error that result. The customer get required output. Terminate the process | Share experience. Get reviews from customer |
| Goals & motivations At each step, what is a person's primary goal or motivation? ("help me..." or "help me avoid...") | Should have good accuracy. Identify the best website for handwritten digit recognition. Looking for a secured website | Constantly check the site for new options that meet his criteria. Help me reduce typing time. | Writing & sending SMS in written format. Their motive is to obtain a better performance from the website. | Their motive is to obtain an accurate result. Utilize the ultimate features of the website | User satisfaction. Customer success rate |
| Positive moments What steps does a typical person find enjoyable, productive, fun, motivating, delightful, or exciting? | They feel happy when they select a good website. If they get the best website, they feel delighted. | They feel happy when they see the user interface is simple. They get excited by experiencing that the registration process is simple | Better accuracy. They have a good feeling while using this website. Good performance | Better performance. Effective and quick result | They can share their good experience with the website with their friends. They can use again |
| Negative moments What steps does a typical person find frustrating, confusing, angering, costly, or time-consuming? | It is a time consuming process. Website without real service | Slow loading page. Service slow down after experience | Output with less accuracy. Slow time due to data processing | The website don't correct the error. Only digits can be selected | Expect good service. Expect better performance |
| Areas of opportunity How might we make each step better? What does do we have? What have others suggested? | It is an exciting service. Compared to most website, it has better service | Faster response. Very nice interface | Improve the recognition time. Make with secure digitization. Quickly capture image | We can take a report action. We can add a report other online form page | Available in multiple platform. Access anytime anywhere. No advertisement online |

6. PROJECT PLANNING & SCHEDULING

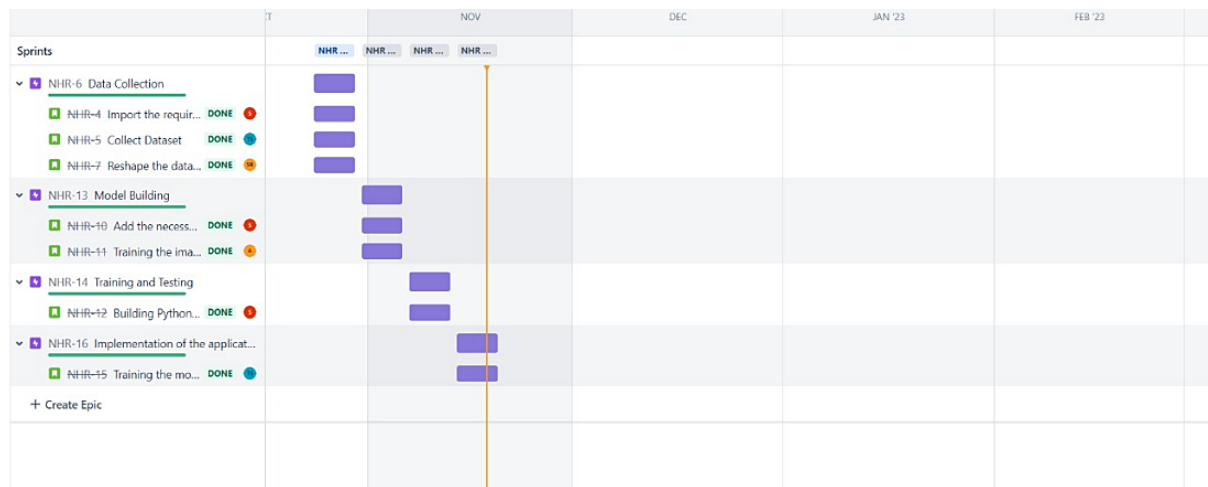
6.1 Sprint Planning & Estimation

| Sprint | Functional Requirement | User Story Number | User Story / Task | Story Points | Priority | Team Members |
|----------|--|-------------------|---|--------------|----------|--|
| Sprint-1 | Data Collection | USN-1 | Import the required libraries and Collect Dataset . | 2 | High | Kowshalya S, Khavya priya S |
| Sprint-1 | | USN-2 | Reshape the data and apply one hot encoding | 1 | Medium | Savithri R, Kavya M |
| Sprint-2 | Model Building | USN-3 | Add the necessary layers and compile the model | 2 | High | KIavya M, Khavya priya S |
| Sprint-2 | | USN-4 | Training the image classification model using CNN | 1 | Medium | Savithri R, Gayathri T |
| Sprint-3 | Training and Testing | USN-5 | Building Python code and run the application | 2 | High | Kowshalya S, Kavya M, Savithri R, Gayathri T, Khavya priya S |
| Sprint-4 | Implementati on of the application and deployment on cloud | USN-5 | Training the model on IBM cloud. | 2 | High | Kowshalya S, Kavya M, Savithri R, Gayathri T, Khavya priya 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 |

6.3 Reports from JIRA



7. CODING & SOLUTIONING

```
X_train = X_train.reshape(60000, 28, 28, 1).astype('float32')
X_test = X_test.reshape(10000, 28, 28, 1).astype('float32')
```

```
number_of_classes = 10
Y_train = np_utils.to_categorical(y_train, number_of_classes)
Y_test = np_utils.to_categorical(y_test, number_of_classes)
```

```
Y_train[0]
```

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

```
model = Sequential()
model.add(Conv2D(64, (3, 3), input_shape=(28, 28, 1), activation="relu"))
model.add(Conv2D(32, (3, 3), activation="relu"))
model.add(Flatten())
model.add(Dense(number_of_classes, activation="softmax"))
```

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

```
model.fit(X_train, Y_train, batch_size=32, epochs=5, validation_data=(X_test, Y_test))
```

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from keras.utils import np_utils
from tensorflow.keras.datasets import mnist
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, Dense, Flatten
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.models import load_model
from PIL import Image, ImageOps
import numpy
```

```
metrics = model.evaluate(X_test, Y_test, verbose=0)
print("Metrics (Test Loss & Test Accuracy): ")
print(metrics)
```

```
Metrics (Test Loss & Test Accuracy):
[0.10052110999822617, 0.9764000177383423]
```

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

```
1/1 [=====] - 0s 92ms/step
[[1.5678695e-09 1.6640128e-14 2.0494097e-12 1.5698962e-08 5.4015579e-15
 3.6338055e-13 2.2240399e-20 1.0000000e+00 2.9577885e-08 1.9005494e-08]
 [5.8188578e-09 1.2512093e-10 9.9999821e-01 7.4831279e-09 1.0770124e-10
 2.9252167e-18 1.6483800e-06 1.5410843e-14 1.2811967e-07 3.3103555e-12]
 [1.2689595e-09 9.9028254e-01 3.9091717e-08 1.3732340e-10 9.6216686e-03
 2.9094124e-07 1.9340013e-10 4.5208512e-07 9.5003670e-05 2.4108826e-10]
 [1.0000000e+00 7.3556976e-16 3.5439882e-12 4.7910155e-14 3.2022885e-12
 1.5000925e-12 1.5939531e-11 4.1566353e-14 7.7353792e-12 1.2456662e-09]]
```

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

8. TESTING

8.1 Test Cases



8.2 User Acceptance Testing

| Test Case ID | Feature Type | Component | Test Scenario | Steps To Execute | Test Data | Expected Result | Actual Result | Status |
|---------------------|--------------|-------------------|--|--|-----------|---|---------------------|--------|
| HomePage_TC_001 | Functional | Home Page | Verify user is able to see the Login/Signup popup when user clicked on My account button | 1.Enter URL and click go 2.Click on My Account icon 3.Verify login/signup popup displayed or not | - | Login/Signup popup should display | Working as expected | Pass |
| RegisterPage_TC_001 | UI | Registration Page | Verify the UI elements in Register/Signup page | 1.Enter URL and click go 2.Click on My Account dropdown button 3.Verify Register/Signup popup with below UI elements: a.name text box b. email text box c. phone number text box d. password text box e. gender text box f. Already have an account? Click login | - | Application should show below UI elements: a.name text box b. email text box c. phone number text box d. password text box e. gender text box f. Already have an account? Click login | Working as expected | Pass |
| RegisterPage_TC_002 | Functional | Registration Page | Verify the users entering the unique email | 1.Enter URL and click go 2.Click on My Account dropdown button 3.Verify Register/Signup page accepts only unique email | - | Application should allow only unique email address | Working as expected | Pass |
| RegisterPage_TC_002 | Functional | Registration Page | Verify that the user can able to register with valid credentials | 1.Enter URL and click go 2.Click on My Account dropdown button 3.Click Register/Signup popup A. Enter name b. Enter email c. Enter phone number d. Enter password e. Enter gender f. Click Register button | - | User should navigate to sign in page | Working as expected | Pass |

8.2.1 Defect Analysis

| Resolution | Severity 1 | Severity 2 | Severity 3 | Severity 4 | Subtotal |
|----------------|------------|------------|------------|------------|----------|
| By Design | 20 | 4 | 2 | 10 | 36 |
| Duplicate | 1 | 0 | 0 | 1 | 2 |
| External | 2 | 4 | 1 | 2 | 9 |
| Fixed | 3 | 6 | 4 | 10 | 23 |
| Not Reproduced | 1 | 2 | 1 | 1 | 5 |
| Skipped | 1 | 1 | 0 | 1 | 3 |
| Won't Fix | 0 | 5 | 3 | 7 | 15 |
| Totals | 28 | 22 | 11 | 32 | 99 |

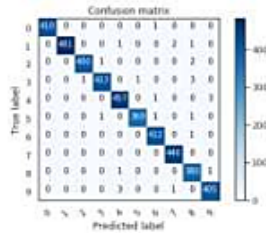
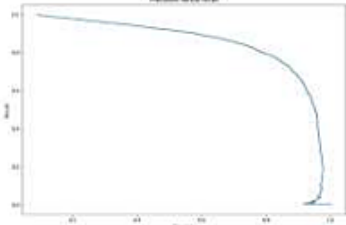
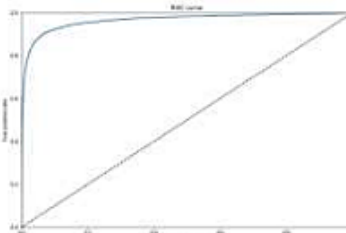
8.2.2 Testcase Analysis

| Section | Total Cases | Not Tested | Fail | Pass |
|---------------------|-------------|------------|------|------|
| Print Engine | 10 | 0 | 0 | 10 |
| Client Application | 20 | 0 | 0 | 20 |
| Security | 2 | 0 | 0 | 2 |
| Exception Reporting | 9 | 0 | 0 | 9 |
| Final Report Output | 7 | 0 | 0 | 7 |
| Version Control | 2 | 0 | 0 | 2 |

9. RESULTS

9.1 Performance Metrics

| S.No. | Parameter | Values | Screenshot |
|-------|---------------|---|---|
| 1. | 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>from tensorflow.keras.models import load_model model=load_model("digit.h5") 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 -0.9979166388511658 Validation Accuracy -0.98089998960495 | <pre>metrics = model.evaluate(X_test1, y_test1, verbose=0) print("Metrics (Test Loss & Test Accuracy): ") print(metrics) Metrics (Test loss & Test Accuracy): [0.14383905787467957, 0.98089998960495] metrics = model.evaluate(X_train1, y_train1, verbose=0) print("Metrics (Train loss & Train Accuracy): ") print(metrics) Metrics (Train loss & Train Accuracy): [0.0072404348060487388, 0.9979166388511658]</pre> |
| 3. | Metrics | Classification Model: precision,recall,f1-score,support | <pre>Classification report for classifier: precision recall f1-score support 0 1.00 0.99 0.99 88 1 0.99 0.97 0.98 93 2 0.99 0.99 0.99 86 3 0.98 0.97 0.92 71 4 0.99 0.96 0.97 93 5 0.95 0.97 0.96 93 6 0.99 0.99 0.99 93 7 0.99 0.99 0.99 88 8 0.94 1.00 0.97 89 9 0.95 0.98 0.95 92 accuracy 0.97 0.97 0.97 800 macro avg 0.97 0.97 0.97 800 weighted avg 0.97 0.97 0.97 800</pre> |

| | | | |
|----|---------|--|--|
| 4. | Metrics | Confusion Matrix |  <p>Confusion matrix</p> <p>True label</p> <p>Predicted label</p> |
| 5. | Metrics | Precision-Recall or PR curve |  <p>Precision-recall curve</p> <p>Precision</p> <p>Recall</p> |
| 6. | Metrics | ROC (Receiver Operating Characteristics) curve |  <p>ROC curve</p> <p>True positive rate</p> <p>False positive rate</p> |

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 recognize 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 98% 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

This project is far from complete and there is a lot of room for improvement. Some of the improvements that can be made to this project are as follows:

- Add support to detect digits from manual writing in canvas
- Add support to detect multiple digits
- Improve model to detect digits from complex images
- Add support to different languages to help users from all over the world

This project has endless potential and can always be enhanced to become better. Implementing this concept in the real world will benefit several industries and reduce the workload on many workers, enhancing overall work efficiency.

13. APPENDIX

DEMO LINK -

<https://drive.google.com/file/d/1q54LR063baXH4EIPgeh9PS2-pfrSq5L2/view?usp=drivesdk>

13.1 Source Code

MODEL CREATION:

```
from keras.datasets import mnist
from matplotlib import pyplot
(X_train,y_train),(X_test,y_test)=mnist.load_data()
print('X_train:' +str(X_train.shape))
print('y_train:' +str(y_train.shape))
print('X_test:' +str(X_test.shape))
print('y_test:' +str(y_test.shape))
from matplotlib import pyplot
for i in range(9):
    pyplot.subplot(330+1+i)
    pyplot.imshow(X_train[i],cmap=pyplot.get_cmap('gray'))
    pyplot.show()
```

RECOGNIZER(PYTHON):

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from keras.utils import np_utils
from tensorflow.keras.datasets import mnist
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, Dense, Flatten
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.models import load_model
from PIL import Image, ImageOps import numpy
```

INDEX PAGE(HTML):

```

<!DOCTYPE html>
<html lang="en">
<head>
<meta charset="UTF-8">
<meta http-equiv="X-UA-Compatible" content="IE=edge">
<meta name="viewport" content="width=device-width, initial-scale=1.0">
<title>User Account Dropdown Menu Using Html CSS & Vanilla Javascript</title>
<link rel="stylesheet" href="style.css">
<link
href="https://fonts.googleapis.com/css2?family=Poppins:wght@200;300;400;600&display=s
wap"
rel="stylesheet">
<link
href="https://fonts.googleapis.com/css?family=Material+Icons|Material+Icons+Outlined|Mat
erial+Icons+Two+
Tone|Material+Icons+Round|Material+Icons+Sharp" rel="stylesheet">
<style>
*{
font-family: "poppins", sans-serif;
margin: 0;
padding: 0;
}
.icons-size{
color: white;
font-size: 14px;
}
.text{
position: fixed;
right: 950px;
top:22px
}
.action{
position: fixed;
right: 1450px;
top:20px
}
.action .profile{
border-radius: 50%;
cursor: pointer;

```

```
height: 60px;
overflow: hidden;
position: relative;
width: 60px;
}
.action .profile img{
width: 100%;
top:0;
position: absolute;
object-fit: cover;
left: 0;
height: 100%;
}
.action .menu{
background-color:#FFF;
box-sizing:0 5px 25px rgba(0,0,0,0.1);
border-radius: 15px;
padding: 10px 20px;
position: absolute;
left: -10px;
width: 200px;
transition: 0.5s;
top: 120px;
visibility: hidden;
opacity: 0;
}
.action .menu.active{
opacity: 1;
top: 80px;
visibility: visible;
}
.action .menu::before{
background-color:#fff;
content: ";
height: 20px;
position: absolute;
right: 190px;
transform:rotate(45deg);
top:-5px;
width: 20px;
```

```
}  
.action .menu h3{  
  color: #555;  
  font-size: 16px;  
  font-weight: 600;  
  line-height: 1.3em;  
  padding: 20px 0px;  
  text-align: left;  
  width: 100%;  
}  
.action .menu h3 div{  
  color: #818181;  
  font-size: 14px;  
  font-weight: 400;  
}  
.action .menu ul li{  
  align-items: center;  
  border-top: 1px solid rgba(0,0,0,0.05);  
  display: flex;  
  justify-content: left;  
  list-style: none;  
  padding: 10px 0px;  
}  
.action .menu ul li img{  
  max-width: 20px;  
  margin-right: 10px;  
  opacity: 0.5;  
  transition: 0.5s  
}  
.action .menu ul li a{  
  display: inline-block;  
  color: #555;  
  font-size: 14px;  
  font-weight: 600;  
  padding-left: 15px;  
  text-decoration: none;  
  text-transform: uppercase;  
  transition: 0.5s;  
}  
.action .menu ul li: hover img{
```



```

opacity: 1;
}
.action .menu ul li:hover a{
color:#ff00ff;
}
.msg{
position: fixed;
right: 950px;
left:0px;
top:250px
}
.image {
background-image: url("{ { url_for('static', filename='images/index2.jpg') }}" );
background-color: #cccccc;
height: 753px;
width: 1536px;
background-position: center;
background-repeat: no-repeat;
background-size: cover;
}
</style>
</head>
<body>
<div class="image">
<div class="action">
<div class="profile" onclick="menuToggle();">

</div>
<div class="menu">
<h3>
User Account
</h3>
<ul>
<li>
<span class="material-icons icons-size">person</span>
<a href="/register/">Sign-up</a>
</li>
<li>
<span class="material-icons icons-size">mode</span>
<a href="/login">Sign-in</a>

```

```

</li>
</ul>
</div>
</div>
<div class="text">
<h1 style="color: white;">Handwritten digit Recognisor</h1>
</div>
<div class="msg">
<h1 style="color: white;font-size: 50px;">
<pre>
Numbers
Rule
The
Universe
</pre>
</h1>
</div>
</div>
<script>
function menuToggle(){
const toggleMenu = document.querySelector('.menu');
toggleMenu.classList.toggle('active')
}
</script></body>

```

HOME PAGE (HTML):

```

<!DOCTYPE html>
<html lang="en">
<head>
<!-- Required meta tags -->
<meta charset="utf-8">
<meta name="viewport" content="width=device-width, initial-scale=1, shrink-to-fit=no">
<link rel="stylesheet" type="text/css" href="{{ url_for('static',filename='css/style.css')}}">
<!-- Bootstrap CSS -->
<link rel="stylesheet"
href="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/css/bootstrap.min.css"
integrity="sha384-
ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"
crossorigin="anonymous">
<title>Handwritten Digit Recognition</title>

```

```

</head>
<body>
<div class="bg-nav text-light d-flex flex-column flex-md-row align-items-center p-3 px-md-4
mb-3 bg-dark
border-bottom shadow-sm" >
  <h5 class="my-0 mr-md-auto" style="color: black;font-weight: bolder;">Handwritten Digit
  Recognisor</h5>
  <a class="btn btn-outline-primary" href="/logout" style="color: whitesmoke;">Log Out</a>
</div>
<main role="main">
<section class="album py-3 text-center">
<form action="/predictpage" method="post">
<div class="button">
  <input type="submit" class="btn btn-primary btn-block btn-lg" value="Proceed to recognise
  the handwritten
  digits">
</div>
</form>
</section>
<div class="jumbotron py-8 bg-dark">
  <div class="container">
<div class="row">
  <div class="card mb-2 shadow-sm">
    <div class="card-body" style="border:5px solid black;">
      <h3 style="text-align: center;">Description</h3><br>
      <p class="card-text" style="font-size: 20px;">The handwritten digit recognition is the ability
      of
      computers to recognize human handwritten digits.
      It is a hard task for the machine because handwritten digits are not perfect, vary from person-
      to-person
      and can be made with many different flavors.
      The handwritten digit recognition is the solution to this problem which uses the image of a
      digit and
      recognizes the digit present in the image.</p>
    </div>
  </div><br><br>
  </div>
</div>
</div>
</div>
</div>
</div>
</main>

```

```
<script src="https://code.jquery.com/jquery-3.3.1.slim.min.js" integrity="sha384-q8i/X+965DzO0rT7abK41JStQIAqVgRVzpbzo5smXKp4YfRvH+8abtTE1Pi6jizo"
crossorigin="anonymous"></script>
<script src="https://cdn.jsdelivr.net/npm/popper.js@1.14.7/dist/umd/popper.min.js"
integrity="sha384-
UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHNDz0W1"
crossorigin="anonymous"></script>
<script src="https://cdn.jsdelivr.net/npm/bootstrap@4.3.1/dist/js/bootstrap.min.js"
integrity="sha384-
JjSmVgyd0p3pXB1rRibZUAYoIIy6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B07jRM"
crossorigin="anonymous"></script>
</body>
</html>
```

HOME PAGE (CSS):

```
.bg-nav
{
background: #e704c9; /* fallback for old browsers */
background: -webkit-linear-gradient(to right, #E5E5BE, #db0ac2); /* Chrome 10-25, Safari
5.1-6 */
background: linear-gradient(to right, #E5E5BE, #f104b6); /* W3C, IE 10+/ Edge, Firefox
16+, Chrome 26+,
Opera 12+, Safari 7+ */
}
.row{
margin-top:80px;
```