

# **A Novel Method For Handwritten Digit Recognition System**

## **A PROJECT REPORT**

*Submitted by*

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## **1. INTRODUCTION**

The project comes with the technique of OCR (Optical Character Recognition) which includes various research sides of computer science. The project is to take a

picture of a character and process it up to recognize the image of that character like a human brain recognize the various digits. The project contains the deep idea of the Image Processing techniques and the big research area of machine learning and the building block of the machine learning called Neural Network. There are two different parts of the project,

(1) Training part

(2) Testing part

The training part comes with the idea of training a child by giving various sets of similar characters but not the totally same and to say them the output of this is “this”. Like this idea, one has to train the newly built neural network with so many characters. This part contains some new algorithm which is self-created and upgraded as the project needs.

The testing part contains the testing of a new dataset. This part always comes after the part of the training. At first one has to teach the child how to recognize the character. Then one has to take the test whether he has given the right answer or not. If not, one has to train him harder by giving new dataset and new entries. Just like that one has to test the algorithm also.

There are many parts of statistical modeling and optimization techniques which come into the project requiring a lot of modeling concept of statistics like optimizer technique and filtering process, that how the mathematics (*How to implement a neural network intermezzo 2 Peter Roelants (2016)) and prediction (Kaiming He et al)*) behind that filtering or the algorithms comes after or which result one actually needs to and ultimately for the prediction of a predictive model creation. Machine learning algorithm is built by concepts of prediction and programming.

## **1.1 Project overview**

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

## **1.2 Purpose**

Handwritten character recognition is one of the practically important issues in pattern recognition applications. The main purpose of this project is to build an automatic handwritten digit recognition method for the recognition of handwritten digit strings. To accomplish the recognition task, first, the digits will be segmented into individual digits. Then, a digit recognition module is employed to classify

each segmented digits completing the handwritten digit string recognition task. The applications of digit recognition include postal mail sorting, bank check processing, form data entry, etc. The heart of the problem lies within the ability to develop an efficient algorithm that can recognize handwritten digits and which is submitted by users by the way of a scanner, tablet, and other digital devices.

## 2. LITERATURE SURVEY

1	<b>Paper title</b>	<b>Handwritten digit recognition is a transnational problem of human writings into machine editable text format. Author – Ganesh Khekare Year-2021.</b>
	<b>Problem definition</b>	<b>In this paper, Convolutional Neural Networks (CNN) is presented for handwritten digit recognition. Edges of the extracted graph were categorized into shape types and vertices were extracted from each of the edges and their layer wise evaluation using deep learning</b>
	<b>Methodology/ Algorithm</b>	<b>The algorithm uses training data for the forward and backward pass.Afterward,we save the trained CNN and prepare for the testing phase.</b>
	<b>Advantages</b>	<b>Electronic storage is that this data only requires far less physical space than the storage of the physical copies.</b>

	<b>Disadvantages</b>	<b>That it is not done in real time as a person writes and therefore not appropriate for immediate text input.</b>
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2	<b>Paper title</b>	<p>A human may not appreciate how difficult it is to solve handwriting. <b>Author -B.Ali Alameer.</b></p> <p>Year – 2021.</p>
	<b>Problem definition</b>	<p>The challenge of visual pattern recognition is only apparent to develop a computer system to read handwriting. The artificial neural networks approach is considered as the best way to develop systems for recognizing handwriting.</p>

	<b>Methodology/ Algorithm</b>	Neural network is a system inspired by human brain function, consists of neurons connected in parallel with the ability to learn. We use back propagation algorithm for computing derivatives
	<b>Advantages</b>	Handwriting allows for organized thoughts, authenticity, and even reading skills. it enhances both literacy and reading comprehension.
	<b>Disadvantages</b>	The issue is that there's a wide range of handwriting – good and bad. This makes it tricky for programmers to provide enough examples of how every character might look.

3	<b>Paper title</b>	Handwritten Digit Recognition using Machine Learning . <b>Author – Nazmule Siddique</b> Year – 2021.
	<b>Problem definition</b>	Handwritten character recognition is one of the practically important issues in pattern recognition applications.
	<b>Methodology/ Algorithm</b>	Several machines learning algorithm namely, Multilayer Perceptron, Support Vector Machine, Naïve Bayes, Bayes Net, Random Forest, J48 and Random Tree has been used for the recognition of digits using WEKA.
	<b>Advantages</b>	The applications of digit recognition includes in postal mail sorting, bank check processing, form data entry, etc

	<b>Disadvantages</b>	In SVM it's better to scale the data always; because it will extremely improve the results. Therefore be cautious with big dataset, as it may leads to the increase in the training time.
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4	Paper title	<p>A progressive learning approach for low resource handwritten text recognition.</p> <p>Author- Mohamed Ali Souibgui</p> <p>Year-2022</p>
	Problem definition	Handwritren text recognition in low resource scenarios, such as manuscripts with rare alphabets, is a challenging problem. we propose a few-shot learning-based handwriting recognition approach that significantly reduces the human annotation process, by requiring only a few images of each alphabet symbols.

	Methodology/ Algorithm	Similarity matrix decoding. An Multidimensional Long ShortTerm Memory (MDLSTM)Approach was proposed.
	Advantages	The evaluation on different datasets shows that our model can lead to competitive results with a significant reduction in human effort
	Disadvantages	the clustering method turned is the segmentation of symbols, because is was often in- accurate, provoking transcription errors.

## 2.2 Reference:

- Non-recursive Thinning Algorithms using Chain Codes Paul C K Mwok  
Department of Computer Science The University of Calgary Calgary,  
Canada T2N 1N4
- A dynamic shape preserving thinning algorithm Louisa Lam and  
Ching Y. Suen Centre for Pattern Recognition and Machine  
Intelligence and Department of Computer Science, Concordia

University, 1455 de Maisonneuve Blvd. W., Montrdal, Qudbec H3G  
1M5, Canada

- Object Contour Detection with a Fully Convolutional Encoder-Decoder Network Jimei Yang Adobe Research [jimyang@adobe.com](mailto:jimyang@adobe.com) Brian Price Adobe Research [bprice@adobe.com](mailto:bprice@adobe.com) Scott Cohen Adobe Research [scohen@adobe.com](mailto:scohen@adobe.com) Honglak Lee University of Michigan, Ann Arbor [honglak@umich.edu](mailto:honglak@umich.edu) Ming-Hsuan Yang UC Merced [mhyang@u](mailto:mhyang@u)
- Contour Detection and Image Segmentation by Michael Randolph Maire

B.S. (California Institute of Technology) 2003

- Three-Dimensional Nonlinear invisible Boundary detection ,IEEE Transaction on Image Processing VassiliKovalev,J,Chen
- Unconstrained OCR for Urdu using Deep CNN – RNN Hybrid Networks; Mohit Jain, Minesh Mathew et al.
- Neural Network and Deep Learning by Michael Nielsen.
- How to implement a Neural Network intermezzo 2, Peter Roelants(2016)
- Comparative analysis of methods used to remove salt and pepper noise IJCSMC Journal ZiadAlquadi,Eng. Mahmoud Alledawi
- Understanding Convolutional Neural Network with a Mathematical

model, C.C.JAY.KUO(2016)

- Delving deep into Rectifiers: Surpassing Human level performance on Image Net Classification, Kaiming He et al.

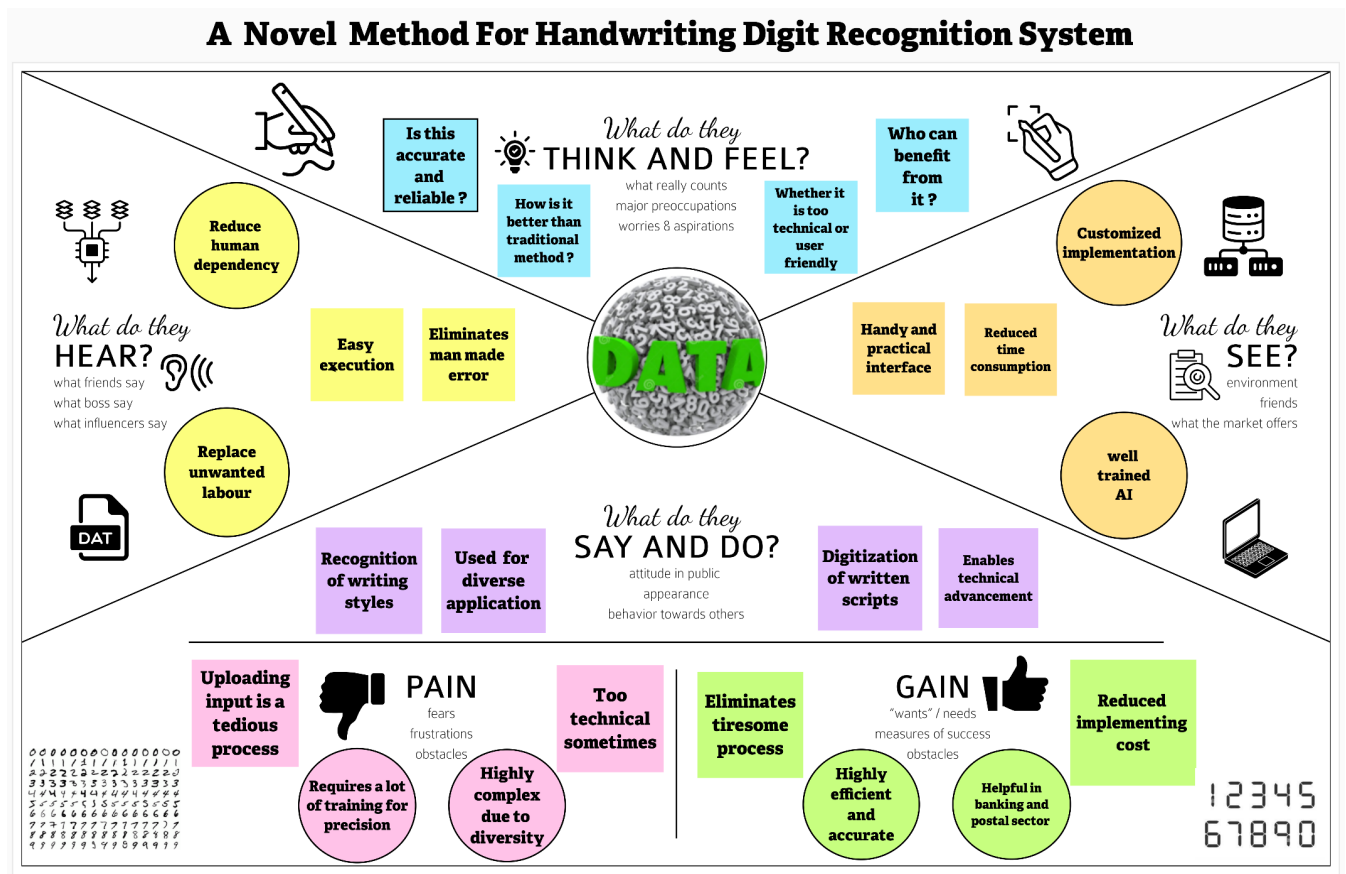
### **2.3 Problem statement definition:**

The handwritten digit recognition is the capability of computer applications to recognize the human handwritten digits. It is a hard task for the machine because handwritten digits are not perfect and can be made with many different shapes and sizes. The handwritten digit recognition system is a way to tackle this problem which uses the image of a digit and recognizes the digit present in the image. Convolutional Neural Network model created using PyTorch library over the MNIST data set to recognize handwritten digits

Handwritten Digit Recognition is the capability of a computer to fetch the mortal handwritten integers from different sources like images, papers, touch devices, etc, and classify them into predefined classes. This has been a content of bottomless- exploration in the field of deep literacy. Number recognition has numerous operations like number plate recognition, postal correspondence sorting, bank check processing, etc. In Handwritten number recognition, we face numerous challenges. because of different styles of jotting of different people as it is not an Optic character recognition. This exploration provides a comprehensive comparison between different machine literacy and deep literacy algorithms for handwritten number recognition. For this, we've used Support Vector Machine, Multi layer Perceptron, and Convolutional Neural Network. The comparison between these algorithms is carried out on the basis of their delicacy, crimes, and testing- training time corroborated by plots and maps that have been constructed using diplomatic for visualization.

### 3. Ideation & proposed solution

#### 3.1 Empathy Map Canvas




Ideation Phase



## 3.2 Brainstorm & Idea Prioritization Template:

step 1:

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

[Share template feedback](#)

➔

**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


**Problem Statement**

**A Novel Method for Handwritten Digit Recognition System**

🕒 5 minutes

PROBLEM

How we are going to get better accuracy in hand written digit recognition?



#### 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.

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## step 2 : Brainstorm, Idea Listing and Grouping:

1

**Brainstorm**  
We write about the ideas that comes to our mind that helps us address our problem statement.  

10 minutes

**SARAVANAN S**

It is essential feature for machines to understand the human handwriting

Adding more trained and test models to the system helps for better results

The system should be developed for different types of handwriting digit recognition

The system should be designed with simple user interface

**DELLIBABU S**

To ensure effective and reliable approaches for recognition

Handwritten digit recognition is to recognize human handwritten digits

Based on the shape analysis of the digit image and extract slant

the problem the handwritten digits are not perfect and can be made with different flavors

**PRAKASH S T**

The errors are corrected using lexicons or spelling checkers

The image of the document is segmented into lines words and individual character

It is used to understand the human handwriting by using machine

The handwriting to be recognized is digitized through scanners or camera

**THARUNKUMAR S**

The digit recognition includes in postal mail sorting, bank check processing, form data entry

Typed text in images and convert it into editable text

The human handwritten digits from different sources like images, papers, touch screens

The no possibility of obtaining information about the type of the input.

3

**Group ideas**  
Here the common ideas about our project is mentioned below while discussed on brainstorming session  

20 minutes

The system is should developed for different types of handwriting digit recognition

Handwritten digit recognition is the ability of a computer to recognize the human handwritten digits from different sources like images, papers, touch screens

Based on the shape analysis of the digit image and extract slant or slope information

The image of the document is segmented into lines words and individual character

Handwritten digit recognition is to provide the ability to machines to recognize human handwritten digits

There's a wide range of handwriting good and bad.

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### 3. Proposed solution:

Proposed Solution Template:

Project team shall fill the following information in proposed solution template.

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	Handwritten are difficult to understand by users. Handwritten may vary for different people's. Sometimes it makes harder to understand what's written in it. We have to convert that handwritten into a common format which anyone can understand.
2.	Idea / Solution description	We have to train our model with datasets and ready to perform. Then we have to create application with user friendly interface where the user can upload the image which contains handwritten. Then our model will convert the digits into binary format and then convert to user understandable text format.

3.	Novelty / Uniqueness	*Live scanning of digit included with upload image option. *Our AI will also format the special type of digits also.
4.	Social Impact / Customer Satisfaction	User interface will be quiet friendly to the user. The Machine text format will be very easy for the user to understand than any other format.
5.	Business Model (Revenue Model)	*In medical field it will be useful to understand the doctor's handwritten prescription. *In education field it will easily convert the handwritten notes into document format.
6.	Scalability of the Solution	It will scan almost all types of handwritten and provides the maximum accuracy.

### 3.4 Problem Solution fit

Define CS, fit into CC	<b>1. CUSTOMER SEGMENT(S)</b> Who is your customer?  The main customers for our project are: <ul style="list-style-type: none"> <li>Person who wants to recognize the handwritten digit.</li> <li>Person who deals with digits in sector like Schools, Bank, etc.,</li> </ul>	<b>6. CUSTOMER CONSTRAINTS</b> What constraints prevent your customers from taking action or limit their choices of solutions?  <ul style="list-style-type: none"> <li>It is not possible to give a accurate digit recognition which are written by human all the time. Sometimes it will give an error.</li> <li>It is hard to implement a machine to find a digit.</li> </ul>	<b>5. AVAILABLE SOLUTIONS</b> 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?  The solution is to recognize the numeral and Make notes on paper and a pen. As opposed to employing a system.	Explore AS, differentiate
	<b>2. JOBS-TO-BE-DONE / PROBLEMS</b> Which jobs-to-be-done (or problems) do you address for your customers? There could be more than one; explore different sides.  <ul style="list-style-type: none"> <li>Create a platform to facilitate Handwritten Digit Recognition.</li> <li>A platform to make it simpler to recognize the handwritten words.</li> <li>Make the recognizing complex words written by human simpler.</li> </ul>	<b>9. PROBLEM ROOT CAUSE</b> 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.  <ul style="list-style-type: none"> <li>In order to recognize handwritten numbers, we must overcome many obstacles. Due to varying writing habits and a lack of Optic character recognition. This study provides a thorough comparison of several machine literacy and deep literacy approaches.</li> </ul>	<b>7. BEHAVIOUR</b> 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)  Finding the finest software to more quickly and accurately recognize digits	
Identify strong TR & EM	<b>3. TRIGGERS</b> What triggers customers to act? i.e., seeing their neighbors installing solar panels, reading about a more efficient solution in the news.  <ul style="list-style-type: none"> <li>It is necessary to make aware of this system is available among the people and make use of it.</li> <li>How to use this system efficiently.</li> </ul>	<b>10. YOUR SOLUTION</b> 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.  The Handwritten Digit Recognition System, which uses an image of a digit to identify the digit present in the image, offers a solution to this issue. To recognize handwritten numbers, a convolutional neural network model created using PyTorch was deployed to the MNIST dataset.	<b>8. CHANNELS OF BEHAVIOUR</b> 8.1 ONLINE What kind of actions do customers take online? Extract online channels from #7 Use software that is accessible online. enlisting the aid of individuals in the area in order to recognize the digits that their clients have written  8.2 OFFLINE What kind of actions do customers take offline? Extract offline channels from #7 and use them for customer development. Obtain current electronics and make sure they function.	Extract online & offline CH of BE
	<b>4. EMOTIONS: BEFORE / AFTER</b> How do customers feel when they face a problem or a job and afterwards? Before: Make sure the system works correctly at most of the time. After: How to find a solution while facing a problem.			



Problem-Solution fit canvas is licensed under a Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International license. Created by Daria /



## 4. Requirement analysis:

### Solution Requirements (Functional & Non-functional)

#### 4.1 Requirements:Functional

Following are the functional requirements of the proposed solution.

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	Input correlation	Image Correlation is a technique used to recognize characters from images.
FR-2	Data Preparation	Collecting data and prepare it for training

<b>FR-3</b>	<b>Feature extraction</b>	Feature extraction is analysing the images and derive some characteristics from these images that identify each specific element
<b>FR-4</b>	<b>Character classification</b>	During the classification phase, the attributes of the data in the picture are compared to the classes in the database to determine which class the picture belongs to.

## 4.2 Non-functional Requirements:

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

<b>FR No.</b>	<b>Non-Functional Requirement</b>	<b>Description</b>
NFR-1	<b>Usability</b>	The software is very easy to use and reduces the learning work.To recognize the digits from bank cheque,papers,numeric entry in forms etc.
NFR-2	<b>Security</b>	The handwritten digit recognition can be used by banking sector where it can be used to maintain the security pin numbers, it can be also used for blind peoples by using sound output.
NFR-3	<b>Reliability</b>	This software will work reliably for low resolution images and not for graphical images.
NFR-4	<b>Performance</b>	Handwritten characters in the input image will be recognized with an accuracy of about 90% and more.

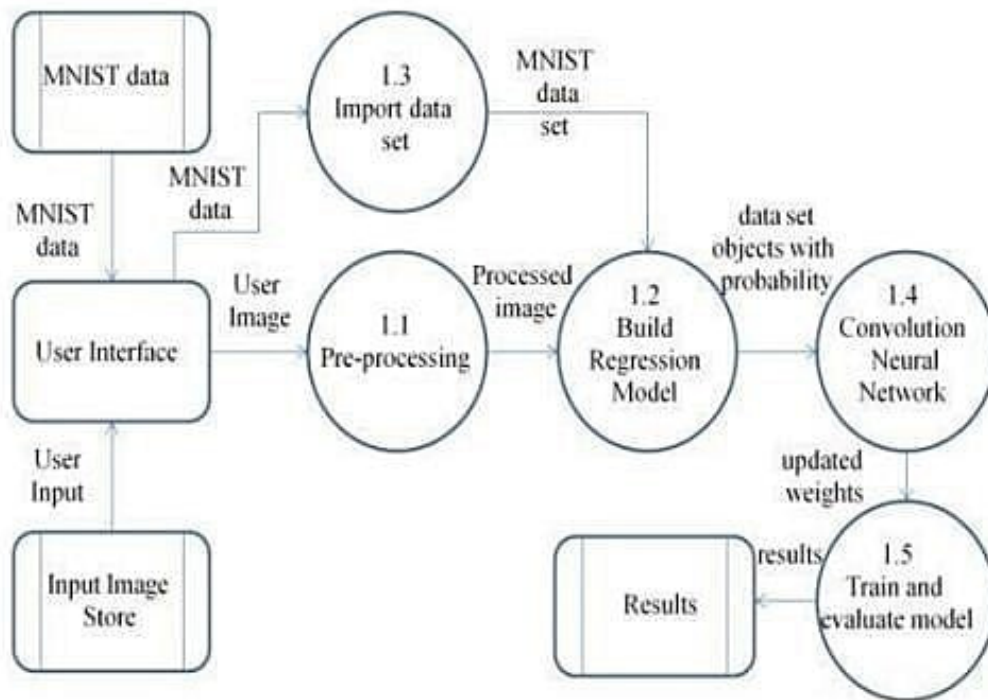
NFR-5	<b>Availability</b>	This system will retrieve the handwritten text regions only if the image contains written text in it.
NFR-6	<b>Scalability</b>	It contains thousands of handwritten digits that have been used in the development of programs .

## 5. Project design :

### 5.1 Data flow diagrams:

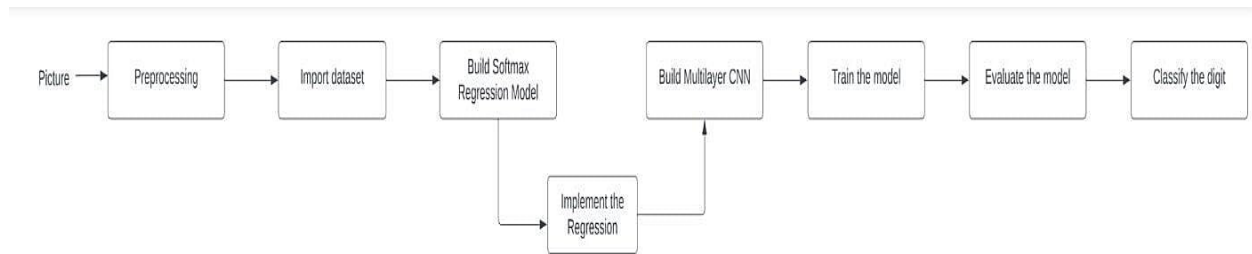
A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.

#### Example:

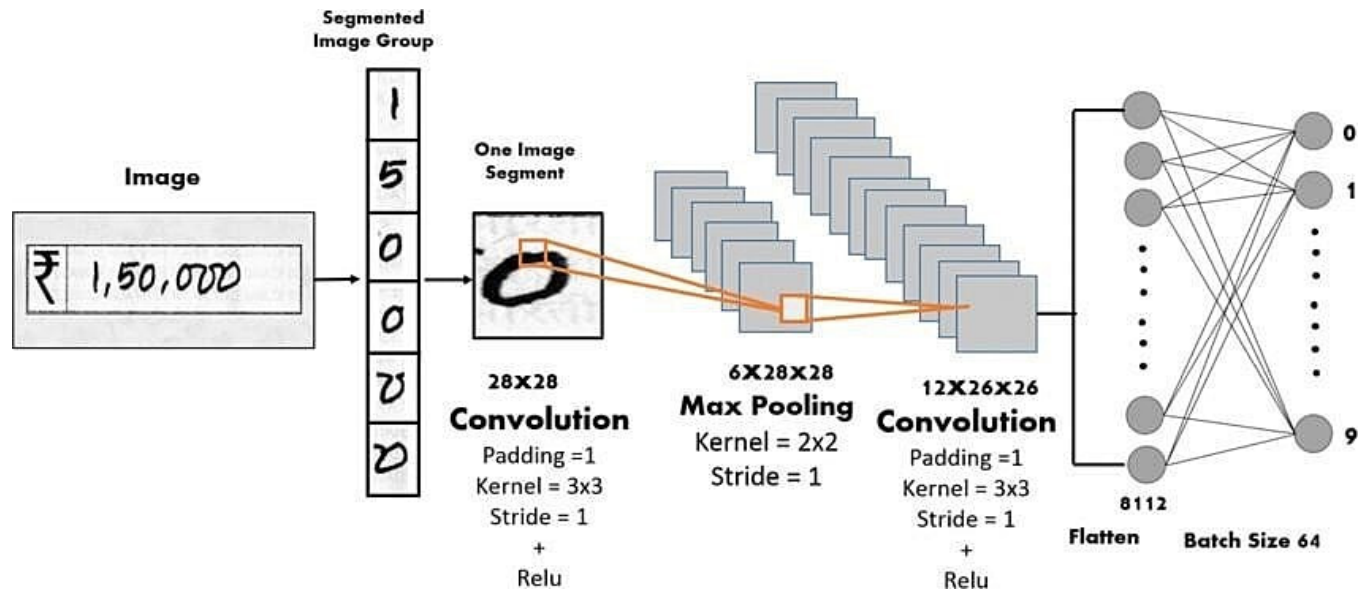


### 5.2 Solution & Technical Architecture



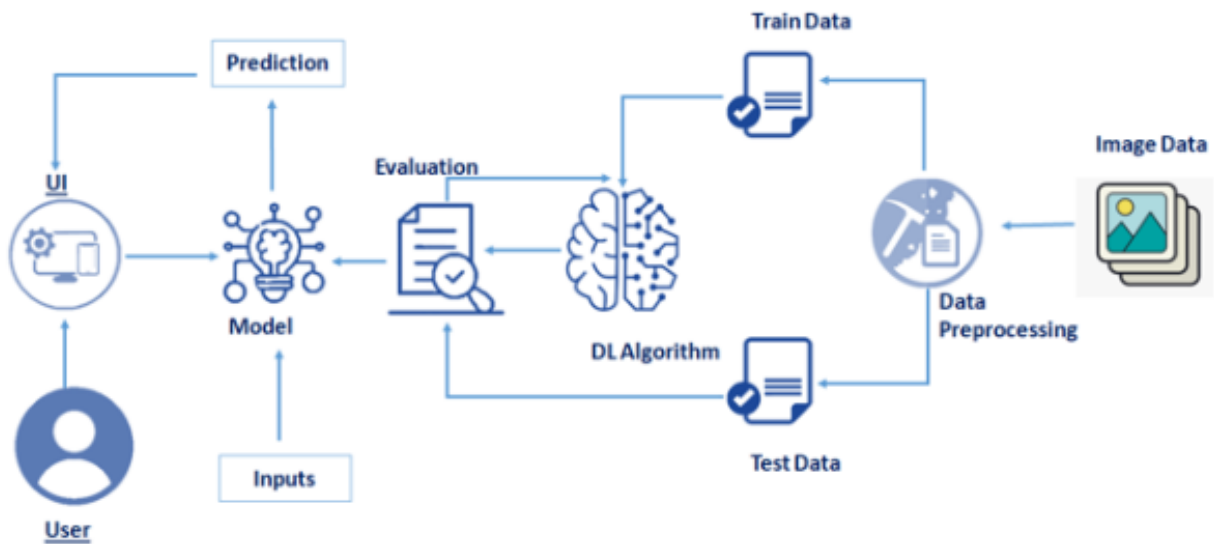


**Architecture diagram for handwritten digit recognition**



**CNN architecture diagram for hand written digit recognition**

## Technical Architecture:



### 5.3 User stories:

use the below template to list the user stories for the product

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release

Customer	Dashboard	USN-1	As a user, they can see the information regarding the prediction of handwritten digit recognition.	I can see the information regarding digit recognition.	High	Sprint 1
----------	-----------	-------	--	--	------	----------

	Launch	USN-2	On clicking the launch button, it will redirect the user to a page where the images to be predicted can be uploaded.	I can see the launch button.	High	Sprint 1
	Upload	USN-3	Users can select the image from the local storage.	I can upload the image.	High	Sprint 2
	Predict	USN-4	Once the image is uploaded, it will predict the respective image.		High	Sprint 3

	Display	USN-5	The predicted image will be displayed with the accuracy chart.	I can see the result with accuracy.	High	Sprint 4
--	---------	-------	--	-------------------------------------	------	----------

## **Solution Architecture:**

- Solution architecture is the detailed and structured description of the features, process and behavior of the solution.
- It acts as the base of the solution to define, deliver, manage and operate the development process of the solution.
- It identifies the alternatives of the solutions and its components.
- It is a basic architecture of the offered solution.

## **6. PROJECT PLANNING AND SCHEDULING:**

Project Planning Phase Project Planning Template

(Product Backlog, Sprint Planning, Stories, Story points)

Product Backlog, Sprint Schedule, and Estimation

Use the below template to create product backlog and sprint schedule

### **6.1 Sprint Planning & Estimation**

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members

Sprint-1	Dashboard	USN-1	As a user, they can see the information regarding the prediction of handwritten digit recognition.	2	High	Saravanan S Prakash S T Tharun kumar S Dellibabu S
Sprint-1	Launch	USN-2	On clicking the launch button, it will redirect the user to a page where the images to be predicted can be uploaded.	2	High	Saravanan S Prakash S T Tharun kumar S Dellibabu S
Sprint-2	Upload	USN-3	Users can select the image from the local storage.	2	High	Saravanan S Dellibabu S
Sprint-3	Predict	USN-4	Once the image is uploaded, it will predict the respective image.	2	High	Prakash S T Tharun kumar S

Sprint-4	Display	USN-5	The predicted image will be displayed with the accuracy chart.	2	High	Saravanan S Prakash S T Tharun kumar S Dellibabu S
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## 6.2 Sprint Delivery Schedule

### Project Tracker, Velocity & Burndown Chart:

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:

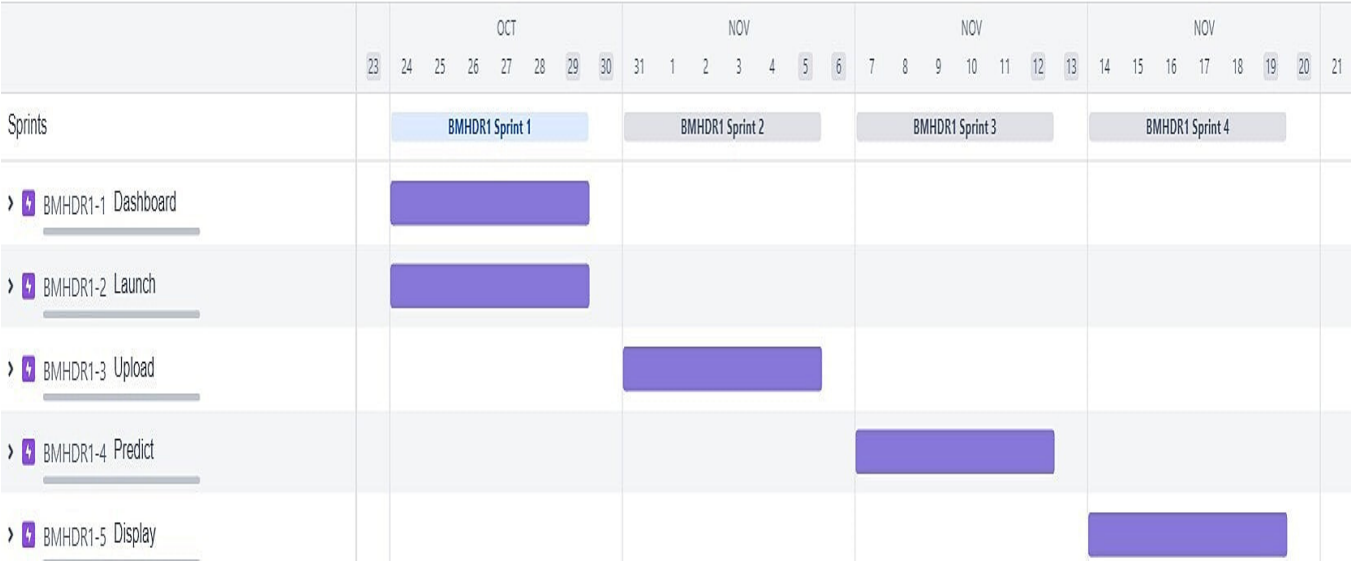
Imagine we have a 10-day sprint duration, and the velocity of the team is 20 (points per sprint). Let's calculate the team's average velocity (AV) per iteration unit (story points per day)

$$AV = \frac{\textit{Sprint Duration}}{\textit{Velocity}} = \frac{20}{6} = 3.33$$

## 6.3 Reports from JIRA

Burndown Chart:

A burndown 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 & SOLUTIONING (Explain the features added in the project along with code)

```
app.py
1  import numpy as np
2  import os
3  from PIL import Image
4  from flask import Flask, request, render_template, url_for
5  from werkzeug.utils import secure_filename, redirect
6  #from gevent.pywsgi import WSGIServer
7  from keras.models import load_model
8  from keras.preprocessing import image
9  from flask import send_from_directory
10
11  UPLOAD_FOLDER = 'data'
12
13
14  app = Flask(__name__, template_folder='static')
15  app.config['UPLOAD_FOLDER'] = UPLOAD_FOLDER
16
17  model = load_model('models\mnistCNN.h5')
18
19  @app.route('/')
20  def index():
21      return render_template('index.html')
22
23
24  @app.route('/predict', methods=['GET', 'POST'])
25  def upload():
26      if request.method == 'POST':
27          f = request.files["image"]
28          filepath = secure_filename(f.filename)
29          f.save(os.path.join(app.config['UPLOAD_FOLDER'], filepath))
30
31          upload_img = os.path.join(UPLOAD_FOLDER, filepath)
32          img = Image.open(upload_img).convert("L") # convert image to monochrome
33          img = img.resize((28, 28)) # resizing of input image
34
35          im2arr = np.array(img) # converting to image
36          im2arr = im2arr.reshape(1, 28, 28, 1) # reshaping according to our requirement
37
38          pred = model.predict(im2arr)
39
40          num = np.argmax(pred, axis=1) # printing our Labels
41
42          return render_template('predict.html', num=str(num[0]))
43
44
45  if __name__ == '__main__':
46      app.run(debug=True)
47
```

## 8. TESTING

### 8.1 Test Cases

Test case ID	Feature Type	Component	Test Scenario	Expected Result	Actual Result	Status
Homepage_TC_OO1	Functional	Home Page	Verify user is able to see the Homepage when clicked on the link	Home Page should be displayed.	Working as expected	Pass
Homepage_TC_OO2	UI	Home Page	Verify the UI elements in Homepage	Application should show below UI elements: a.choose file button b.predict button c.clear button	Working as expected	Pass
Homepage_TC_OO3	Functional	Home Page	Verify user is able to choose file from the local system and click on predict	Choose file popup screen must be displayed	Working as expected	Pass

				and user should be able to click on predict button		
Homepage_TC_OO4	Functional	Home page	Verify user able to select invalid file format	Application won't allow to attach formats other than ".png, .jiff, .pjp, .jpeg, .jpg, .jpeg"	Working as expected	Pass
Predict_TC_OO5	Functional	Predict page	Verify user is able to navigate to the predict to and view the predicted result	User must be navigated to the predict page and must view the predicted result	Working as expected	Pass

## 8.2 User Acceptance Testing

## Defect Analysis

Resolution	Severity 1	Severity 2	Severity 3	Severity 4	Subtotal
By Design	0	0	0	0	0
Duplicate	0	0	0	0	0
External	0	0	0	0	0
Fixed	0	0	0	0	0
Not Reproduced	0	0	0	0	0
Skipped	0	0	0	0	0
Won't Fix	0	0	0	0	0
Totals	0	0	0	0	0

## Test Case Analysis

Section	Total Cases	Not Tested	Fail	Pass
Client Application	5	0	0	5
Security	5	0	0	5
Final Report Output	5	0	0	5
Performance	5	0	0	5

## 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	290	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	19	22	62	290
GET	//predict	44000	46000	47000	48000	50000	52000	55000	60000
Aggregated		36	36000	43000	45000	48000	50000	54000	60000

## 10. ADVANTAGES & DISADVANTAGES

## **Advantages**

1. Reduces manual work.
2. More accurate than average human.
3. Capable of handling a lot of data.
4. Can be used anywhere from any device.

## **Disadvantages**

1. Cannot handle complex data.
2. All the data must be in digital format.
3. Requires high performance server for faster predictions.
4. 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 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 realworld 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:

1. Add support to detect from digits multiple images and save the results
2. Add support to detect multiple digits
3. Improve model to detect digits from complex images
4. 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**

### **13.1 Source Code**

**HTML AND CSS: [index.html](#):**

```

1 static > < index.html > @html
2 <html>
3
4 <head>
5 <title>HWR</title>
6
7 <meta name="viewport" content="width=device-width">
8 <link rel="stylesheet" href="static/css/style.css">
9 <link rel="stylesheet" href="https://cdn.jsdelivr.net/npm/bootstrap@4.6.1/dist/css/bootstrap.min.css">
10 <script src="https://cdn.jsdelivr.net/npm/jquery@3.6.0/dist/jquery.slim.min.js"></script>
11 <script src="https://cdn.jsdelivr.net/npm/popper.js@1.16.1/dist/umd/popper.min.js"></script>
12 <script src="https://cdn.jsdelivr.net/npm/bootstrap@4.6.1/dist/js/bootstrap.bundle.min.js"></script>
13 </head>
14
15 <body background="static/images/bcl.jpg">
16
17 <nav class="navbar navbar-expand-lg navbar-light bg-light">
18 <div class="container-fluid">
19 <a class="navbar-brand" href="#">HANDWRITTEN RECOGNITION SYSTEM</a>
20 <button class="navbar-toggler" type="button" data-bs-toggle="collapse" data-bs-target="#navbarToggle02" aria-controls="navbarToggle02" aria-expanded="false" aria-label="Toggle navigation">
21 <span class="navbar-toggler-icon"></span>
22 </button>
23 <div class="collapse navbar-collapse" id="navbarToggle02">
24 <ul class="navbar-nav mr-auto mb-2 mb-lg-0">
25 <li class="nav-item">
26 <a class="nav-link active" aria-current="page" href="#">Home</a>
27 </li>
28 </ul>
29 </div>
30 </div>
31 </left>
32 </div>
33 </nav>
34
35 <div class="container p-3 my-3 bg-dark text-white">
36 <div class="container-fluid">
37 <div class="row">
38 <div class="col">
39 <div class="text">
40 <div class="text">
41 <div class="text">
42 <div class="text">
43 <div class="text">
44 <div class="text">
45 <div class="text">
46 <div class="text">
47 <div class="text">
48 <div class="text">
49 <div class="text">
50 <div class="text">
51 <div class="text">
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65 <div class="text">
66 <div class="text">
67 <div class="text">
68 <div class="text">
69 <div class="text">
70 <div class="text">
71 <div class="text">

```

**Predict.html:**

```

static > <> predict.html > html > head
1  <!DOCTYPE html>
2  <html lang="en">
3  <head>
4  |   <meta charset="UTF-8">
5  |   <title>Prediction</title>
6  </head>
7
8  <style>
9
10 |   body{
11 |     background-repeat: no-repeat;
12 |     background-size: cover;
13 |   }
14
15
16 |   #rectangle{
17 |     width:400px;
18 |     height:150px;
19 |     background-color: ■ #000000;
20 |     border-radius: 15px;
21 |     position:absolute;
22 |     box-shadow: 0px 0px 10px 5px □ white;
23 |     top:25%;
24 |     left:50%;
25 |     transform:translate(-50%,-50%);
26 |   }
27
28 |   #head{
29 |     text-align: center;
30 |     font-size: 30px;
31 |     margin: 0 auto;
32 |     padding: 3% 5%;
33 |     font-family: Arial, Helvetica, sans-serif;
34 |     color: □ white;
35 |   }
36
37 |   #num{
38 |     font-size: 50px;
39 |   }
40
41 </style>
42
43 <body background="static\images\bcl.jpg" >
44
45 |   <div id="rectangle">
46 |     <h1 id="head">Predicted Number : <br><center id="num">{{num}}</center></h1>
47 |   </div>
48
49 </body>
50 </html>
51

```

## Style.css :

```
static > css > # style.css > body
1  body{
2      background-repeat: no-repeat;
3      background-size: cover;
4  }
5  #clear_button{
6      margin-left: 15px;
7      font-weight: bold;
8      color: rgb(0, 174, 255);
9  }
10
11  #confidence{
12      font-family: 'Josefin Sans', sans-serif;
13      margin-top: 7.5%;
14  }
15
16  #content{
17      margin: 0 auto;
18      padding: 2% 15%;
19      padding-bottom: 0;
20  }
21
22
23
24  #team_id{
25      text-align: right;
26      font-size: 25px;
27      padding-right: 3%;
28  }
29
30  #predict_button{
31      margin-right: 15px;
32      color: rgb(0, 255, 72);
33      font-weight: bold;
34  }
35
36  #prediction_heading{
37      font-family: 'Josefin Sans', sans-serif;
38      margin-top: 7.5%;
39  }
40
41  #result{
42      font-size: 5rem;
43  }
44
45  #title{
46      padding: 1.5% 15%;
47      margin: 0 auto;
48      text-align: center;
49  }
```

```

51 .btn {
52     font-size: 15px;
53     padding: 10px;
54     /* -webkit-appearance: none; */
55     background: #eee;
56     border: 1px solid #888;
57     margin-top: 20px;
58     margin-bottom: 20px;
59 }
60
61 .buttons_div{
62     margin-bottom: 30px;
63     margin-right: 80px;
64 }
65
66
67
68 .leftside{
69     text-align: center;
70     margin: 0 auto;
71     margin-top: 2%;
72     /* padding-left: 10%; */
73 }
74
75 #frame{
76     margin-right: 10%;
77 }
78
79
80
81 h1{
82     text-align: center;
83     color: white;
84     padding: 100px 50px 65px 100px;
85 }
86

```

## 13.2 GitHub & Project Demo Link

**GitHub Link:**

<https://github.com/IBM-EPBL/IBM-Project-17596-1659673849>

**Demo Video:**

<https://youtu.be/3Vp2S4ER7pg>