

A NOVEL METHOD FOR HANDWRITTEN DIGIT RECOGNITION SYSTEM

NALAIYA THIRAN PROJECT-BASED LEARNING

on

**PROFESSIONAL READINESS FOR INNOVATION, EMPLOYABILITY
AND ENTREPRENEURSHIP**

A PROJECT REPORT

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ABSTRACT

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.

CHAPTER 1

INTRODUCTION

It is difficult to understand one's unique hand-writing and hence it is often confused with letter written by someone in notebook, cheque and other crucial documents. Eventhough almost everything is digitalized in the contemporary era, hand-written documents are still used in several administrial processing, say like banking. In banking systems, the cheques are in hand-written even now. So, it is imminent to build an automated hand-written digit recognition system to ensure maximum accuracy and reliability.

The ability of computer systems to recognise handwritten digits from various sources, such as photographs, papers, and so on, is known as handwritten digit recognition.

While building an AI system for hand-written digit recognition system we may encounter problems like, as manually-written digits aren't of a comparable size, thickness, position and irection, numerous difficulties need to be taken into consideration to decide the problem of handwritten digit recognition. The distinctiveness and collection in the composition styles of numerous people additionally affect the instance and presence of the digits. Therefore, deep learning techniques using Convolutional Neural Networks can be the best solution to overcome these problems.

CHAPTER 2

OBJECTIVE

Objective of the proposed project would be:

- To build an automation tool to be used by banks to recognize digits in a cheque to speed up the cheque approval process which usually takes time with high accuracy.
- To build an automation tool to be used by postal agencies to sort out mails using pin code to increase profit by cutting man power and speed up the delivery process to gain customer trust.
- To build a data entry tool to reduce manual data entry errors and improve entry speed with high accuracy to increase profit, reduce manual work and improve performance.
- To build a digit recognition tool to be used by the department of traffic enforcement to integrate with traffic monitoring system to remove manual monitoring which is error prone and impose penalty for speeding online.

CHAPTER 3

IDEATION PHASE

3.1 LITERATURE SURVEY

Kaliappan, A. V. and et al. in [9] have designed the combination of convolution neural network (CNN) and weighted contribution of feature point-based methods, Which are used to recognize the Tamil alphabet in this paper. Also various CNN configuration and feature point methods BRISK, ORB, KAZE are put into test. In the feature point based method K-nearest neighbor, decision tree, regression and multi-layer perceptron classifiers are used. So the best point based configuration and CNN configuration is combined in this hybrid approach. The KAZE MLP is found to be the best feature point based classifier and CNN 15 is the best classifier. By getting 95.6% accuracy the hybrid model performed better than CNN and Point based methods. k means clustering is the algorithm used. In this approach, evaluation has focused on 12 classes of Tamil vowels only.

Gnanasivam P. and et al. in [7] proposed a convolutional neural network model is used for converting digitized handwritten Tamil words to readable format. Initially the input image needs to be preprocessed. Preprocess includes image resizing, formatting etc. Then using filters of convolutional layers, the features such as corners, edges are extracted. It uses handwritten data sets to train the module. Also using the Google cloud translation API the audio is created from the recognised characters by the module. Algorithm used is CNN. Only certain Tamil

characters are used to train the model so not all Tamil characters are recognized.

Hossain, M. T. and et al. in [8] recognized the Bangla handwritten words. This paper proposes a method in which first the images are preprocessed and characters are isolated by finding the “matra” and then segmenting each character from it. 3 zones are created. The upper zone is the one above the “matra” and the lower zone is created by making pixels white to a certain thickness beyond the minimum character height below the upper zone. after these preprocessing a temporary decision about each character is made and final decision is made by combining all 3 zones. Results show that there is an 82% accuracy using CNN algorithm. Accuracy for consonants are less the consonants without the vowel modifiers also show better results than the consonants with the vowel modifiers Main reason for this is to managing the vowel modifier containing consonants with separate logic.

Kowsalyaand et al. in[10] focused to increase the efficiency of Tamil character recognition. Various image processing techniques are applied in order to finally get each character separately and then the character is recognized using a modified neural network and weights are updated using elephant herding optimization. On the basis of these metrics the proposed method is evaluated and the results were also compared to existing classifiers. The comparative results showed that the proposed MNN method provides better accuracy results than classifiers. Algorithm used is the Modified Neural Network using elephant herding optimization. Accuracy is less when compared to other existing works for Tamil character recognition. Not all Tamil characters are recognized with this model as only few are used to train the model.

Chung, J.and et al. in[3] proposed a less computationally expensive framework for recognizing the full page handwritten text. Text localization is done first by identifying to find out the handwritten passage and then line segmentation-conversion of words to lines using clustering algorithm. Next Text recognition takes place which also has 2 stages first Handwriting recognition which is done using CNN and bi-LSTM, CNN is useful for extracting features from images and downsampled images. These features are given as input to the bidirectional LSTM and it generates the output then Language modeling the noisy input is given, it denoises and produces the candidate strings (using beam search algorithm). This methodology uses less time and memory and it has CER of 8.50. Algorithm used is the combination of Convolutional Neural Network and Long Short Term Memory. Several short words, typically less than three characters, are not detected properly. Only the English language is considered.

Dixit, U. D.and et al. in[5] focus to achieve the accurate word image recognition for handwritten word using SVM and K-NN classification methods. Each word in the input is segmented into characters of images. Histogram of Oriented Gradients (HOG) features of image character dataset is used to train the classifiers. The method used in this paper consists of pre-processing where the noise in the image is removed using median equation. Followed by segmentation of the word happens then extraction of feature for segmented characters is done using HOG. Using the obtained features classification is done by K-NN ($k=1$) and SVM algorithm. Finally combining all the identified characters the word is recognized. Using the HOG features combined with K-NN or SVM classifiers,

SVM gives a good recognition rate of 75%.Algorithm used is the Histogram of Oriented Gradients (HOG),K-NN,SVM.The recognition approach is done only for words and not for the entire document. Also the recognition rate is less.

Ayyadevaraand et al. in [1] recognized the handwritten character is recognized using a combination of three different feature extraction techniques and MLP BP the MLP neural network using LevenbergMarquardt algorithm and the CNN.The three feature extraction methods used here are gradient, geometric, zone based hybrid feature extraction. These techniques are applied individually as well as in the combination form. The results obtained implies that the feature extraction technique will affect the accuracy of character recognition. The combined feature extraction technique gives the best accuracy and CNN gives best accuracy rate compared to the other neural networks such as MLP BP and MLP LM.

Prakash and et al. in [16] usedthe Convolutional Neural Network for the classification of image and text can be extracted by using Tesseract.The CNN is used to overcome the overfitting problem.The character pattern recognition and line recognition can be done by using the LSTM.The CNN gives better accuracy compared to the SVM.

Mishra, Pand et al. in [12] In this paper,the deep Convolutional Neural Network architecture is proposed to recognise the isolated tamil characters in offline mode.The proposed network contains 2 convolutional layer followed by Max pooling layer and 2 fully connected layer followed by an output layer.124 (unique symbols) classes considered for classification. Achieved training accuracy

is 88.2% and the achieved testing accuracy is 71.1%.The main disadvantage found was that highly similar symbols were misclassified regularly that leads to the reduction of testing accuracy.

Goria.and et al. in [6] recognized the handwritten text by using the OCR and convergence of CNN and RNN.The Handwritten Text Recognition divided into two parts: 1. Character Recognition 2.WordRecognition. Input image consists of a sentence that will have several words. Torecognise a particular word, you need to identify each character in the word. The letters will be used to predict the word. To implement the handwritten character recognition, two kinds of Neural Network model is used: 1. 5 layer of Convolutional Neural Network (CNN)- to extract features from the image . 2. 2 layers of Recurrent Neural Network(RNN) – to determine the word .CER and WER acts as performance metrics to judge the accuracy of the model.

Adrian MLOISE and et al. in [13] developed a system which takes the computer written text as input and outputs the converted braille to a device which is used by blind to read embedded text.Where a FSM finite state machine is implemented using a software approach.The finite state machines states are considered with corresponding output. Which is then implemented in a software approach as code.The system is divided into two units hardware and software. In which the hardware contains a microcontroller and a usb connected to the computer. When a key is pressed in the keyboard its ascii value is stored in the buffer and its sent to the finite state machine which sends the signal to the 6 needles that are touched by the blink to read.The software will control the 6 pins

activation according the finite state machine result and the code build in by the concepts mentioned above.The system is tested against various inputs from alphabets to special characters, which gave a braille result with a delay of 2 sec between each characters.

Mainkar and et al. in [11] implemented an android application which captures an image of the hand written text and in return an editable text document as an output. Main objective is to bring the conversion in offline and mobile application.This is done by 5 steps which are image acquisition, preprocessing,segmentation,feature extraction and postprocessing.In the image acquisition step the image is captured using the mobile application camera and in a gray scale.Its followed by the preprocessing on the gray scale image that are binarization,skewing,normalization and thinning.Then the segmentation of the each individual characters is done from the sentence and then in words. After the segmentation the OCR does the feature extraction where the characters are recognized according to their slant,height and curve.The classified characters are then written to a text document and are stored in the mobile application.This stored application can be edited latter also can be viewed. It gives a significant result of the scanned image as a text.

Deepa and et al. in [4] used the Convolutional Neural Network for the classification of image and text can be extracted by using Tesseract.The CNN is used to overcome the overfitting problem.The character pattern recognition and line recognition can be done by using the LSTM.The CNN gives better accuracy compared to the SVM.

Sarika and et al. in [18] gives the description of OCR and the CNN layers ,architecture and its implementation. OCR is used to convert the text in an image to text format. OCR has different phases like digitization, pre processing, segmentation, feature extraction. CNN is used for recognizing the handwritten telugu characters.CNN layers are convolutional layer ,pooling layer,ReLU layer and fully connected layer.The CNN architectures discussed in this paper are LeNet,AlexNet and ZFNet. VGG-16 architecture which consists of one input layer, one output layer and other six layers is used and trained with telugu character dataset here. Survey made on several CNN techniques which are used for classification of handwritten character recognition.

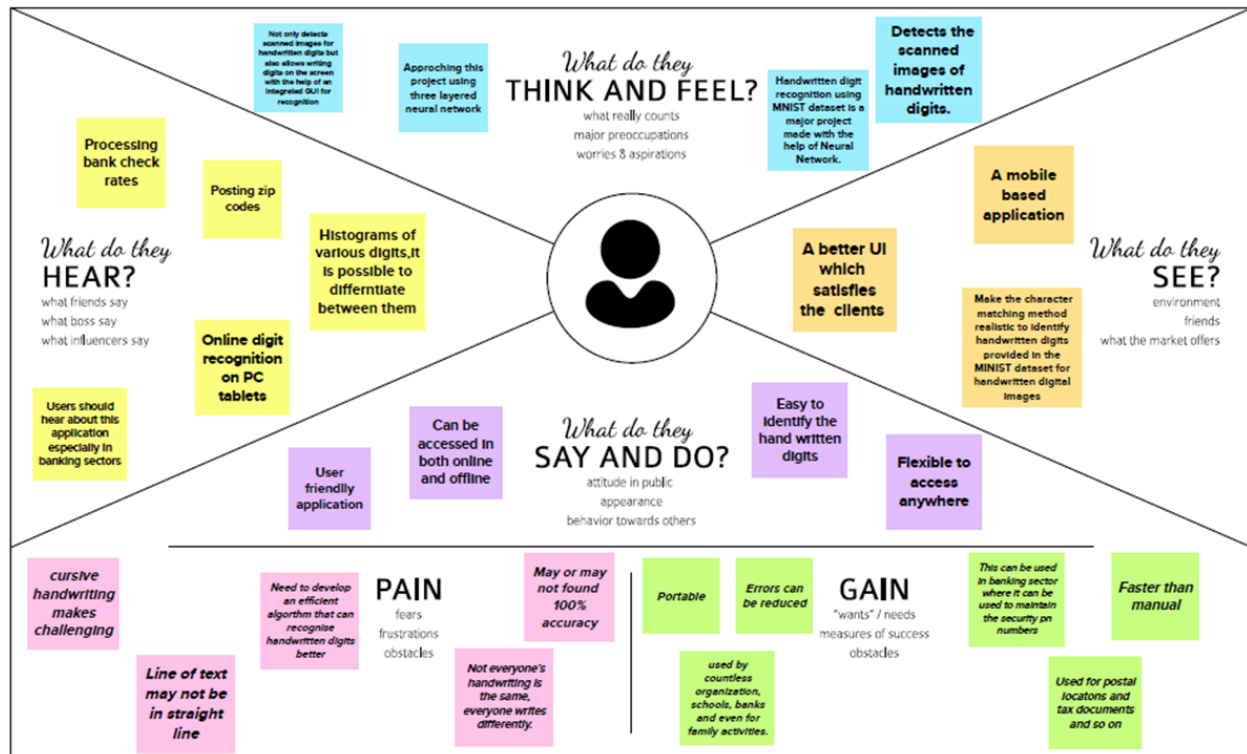
Vaidya and et al.in [20] developed the system for recognising the handwritten character based on image segmentation.The convolutional neural network model is used here.The Neural network is trained using a tensorflow and the image processing operations are carried out by open source library OpenCV.The steps involved in the process are preprocessing,conversion of gray scale ,thresholding and image segmentation.Finally the recognition of characters happens through the neural network.Limitations of this paper are the recognition of cursive handwriting is not possible,this system only supports for the English language and the recognition of letters and digits are possible whereas the recognition of special symbols is not possible.

Vinjit and et al. in [21] reviewed the task involved in identification of the handwritten characters and Digitizing manually written text.It is known as Handwritten Character Recognition.The various techniques have been discussed to

recognize different handwritings. The exact recognition of letters is directly depends on the nature and quality of the material. Choosing the relevant characteristic feature extraction and classification techniques is the key to get good recognition rate. This paper will help to know the methodologies used in the field of handwritten character recognition till now along with their advantages, limitations and accuracy rate. Similar Characters like '1' and '7', '4' and '9' are difficult to recognise. To overcome this larger training data set and better neural network designs are to be used. Although there are several techniques proposed but none of the methods is fully perfect and still improvement have to be done in the system.

The related works were surveyed and the limitations were identified to propose an organised work for our research, as described in the following elaborative headings. Keeping the challenges face by the previous researches, the model to be developed has been carefully designed, which would be cost effective as well.

3.2 EMPATHY MAP



3.3 PROBLEM STATEMENT

Who does the problem affect?	The handwritten digits are not always of the same size, width, orientation and justified to margins as they differ from writing of person to person.
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What are the boundaries of the problem?	One of the difficulties in the overall recognition of hand-written digits is the variation and distortion of the hand-written digit collection, because different cultures will employ multiple handwriting kinds and control to extract the characters and identical patterns from their recognized language.
What is the issue?	Digital recognition is also remarkable an important issue.
When does the issue occur?	As the manually written digits aren't of a comparable size, thickness, position and direction, numerous difficulties need to be taken into consideration to decide the problem of handwritten digit recognition. The distinctiveness and collection in the composition styles of numerous people additionally affect the instance and presence of the digits.

Where does the issue occur?	Recognizing handwritten text is a problem that can be traced back to the first automatic machines that needed to recognize individual characters in handwritten documents. Think about, for example, the ZIP codes on letters at the post office and the automation needed to recognize these five digits.
Why is it important that we fix the problem?	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.
What solution to solve this issue?	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.
What methodology used to solve the issue?	Deep learning techniques are used to 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 Python library over the MNIST dataset to recognize handwritten digits.

Problem Statements :

1. Banks need an automation tool to recognize digits in a cheque to speed up the cheque approval process which usually takes time with high accuracy.
2. Postal agencies need an automation tool to sort out mails using pin code to increase profit by cutting man power and speed up the delivery process to gain customer trust.
3. Companies need a data entry tool to reduce manual data entry errors and improve entry speed with high accuracy to increase profit, reduce manual work and improve performance.

4. The Department of traffic enforcement needs a number plate digit recognition tool to integrate with traffic monitoring system to remove manual monitoring which is error prone and impose penalty for speeding online.

Business Model:

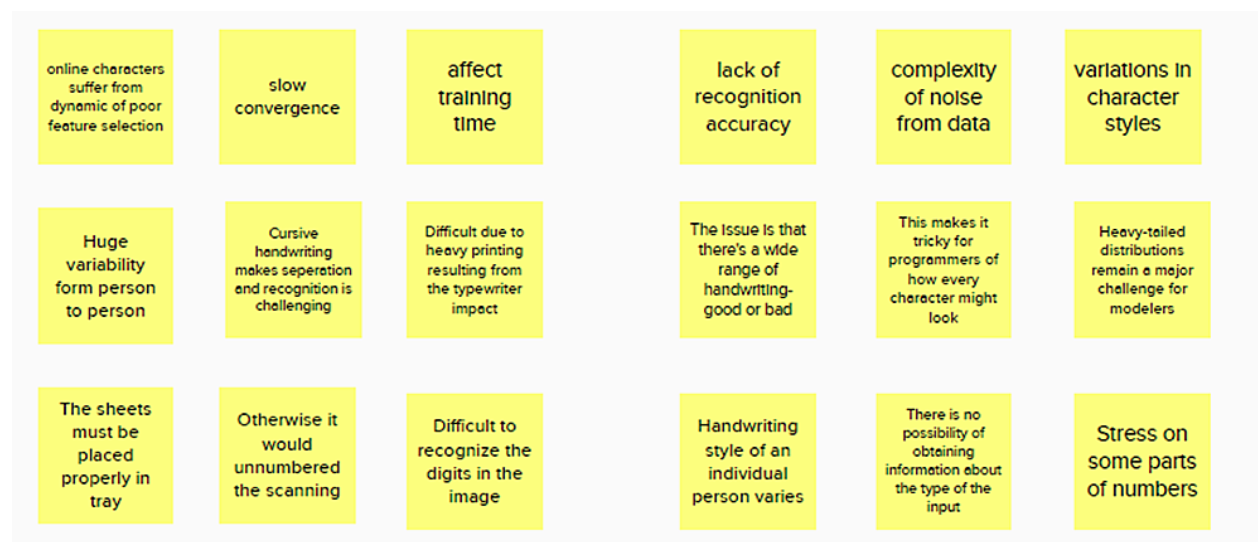
- Speed up the cheque approval process
- Store transaction records

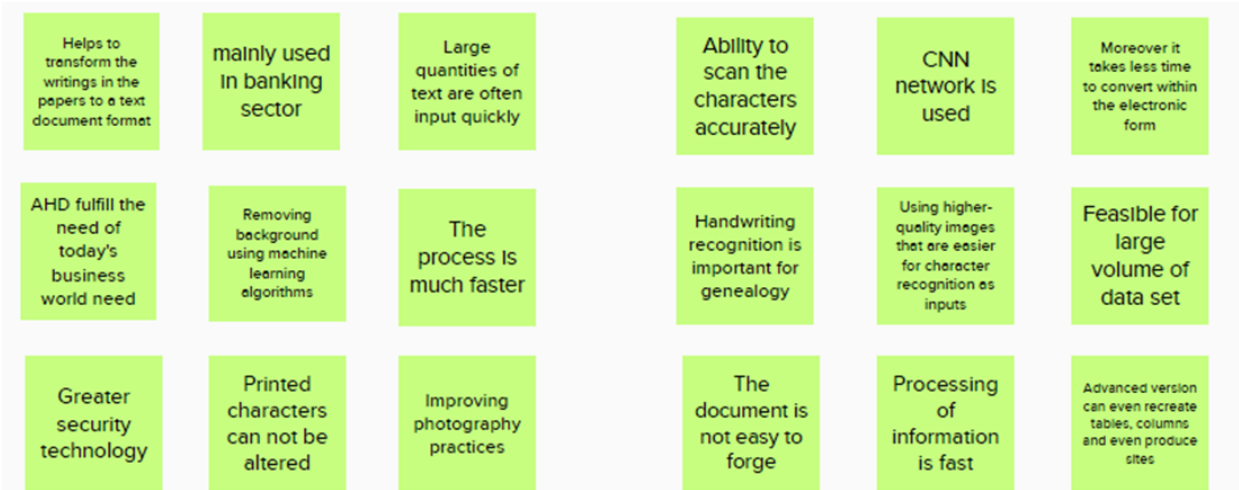
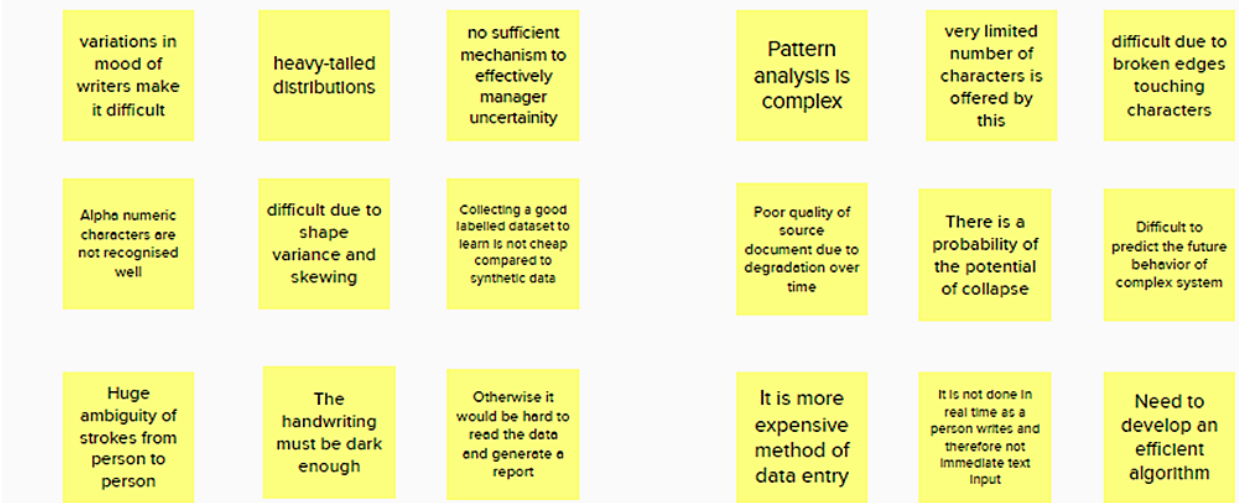
Social impact:

Ensure road safety by identifying the owner of the speeding vehicle by using the registration number of that vehicle.

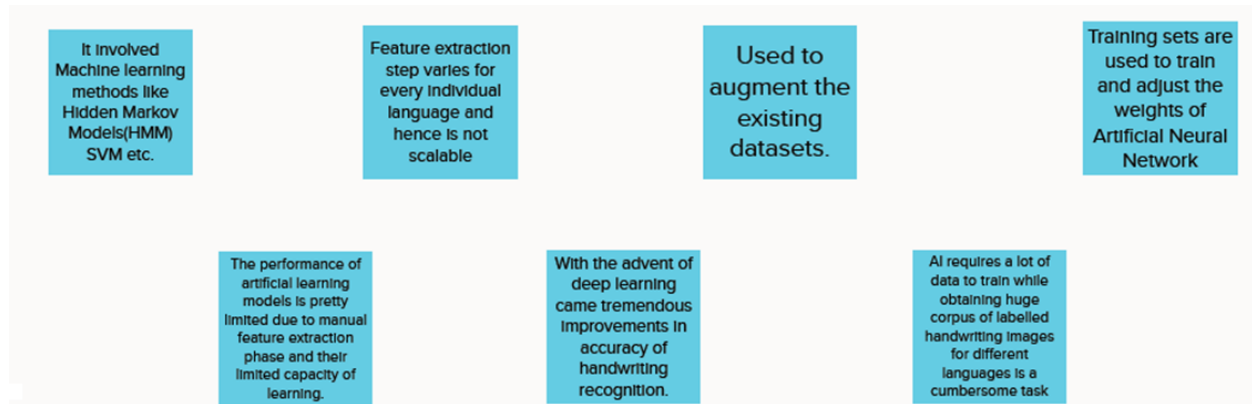
3.4 BRAINSTORMING AND IDEA PRIORITIZATION

Brainstorming:

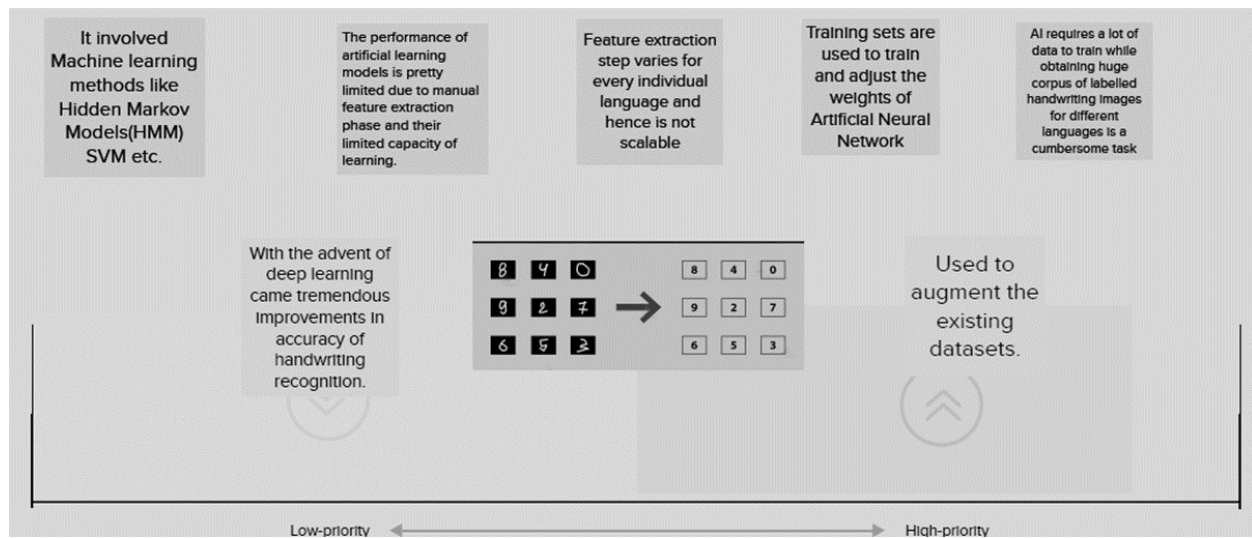




Group Ideas



Idea Prioritization



CHAPTER 4

PROJECT DESIGN PHASE I

4.1 PROPOSED SOLUTION

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	<p>Digit recognition is essential in the modern world.</p> <p>It has the capacity to resolve problems that are getting harder and easier while facilitating human work.</p> <p>One instance is the recognition of handwritten digits.</p> <p>This is a technique that is used globally to identify zip codes or postal codes for mail sorting.</p> <p>A variety of methods can be used to recognise handwritten digits.</p> <p>Because handwritten digits are not always accurate and can be produced in a variety of ways, the machine has a challenging task.</p> <p>Handwritten digit identification, which uses an image of a digit to identify the digit represented in the image, offers a solution to this problem.</p>

2.	Idea / Solution description	<p>The MNIST dataset, which includes 10,000 test images and 60,000 training images of handwritten digits from zero to nine, is used to perform handwritten digit recognition. Thus, there are 10 separate classes in the MNIST dataset.</p> <p>In this project, we'll put into practise a Convolutional Neural Networks model-trained application for handwritten digit recognition.</p> <p>In the end, a GUI is created in which the user enters a handwritten digit, which is then identified, and the answer is shown right away.</p>

3.	Novelty / Uniqueness	<p>In this study, a practical method for addressing novelty in the field of handwriting visual recognition is introduced.</p> <p>A flawless transcription agent would be able to recognise recognised and unrecognised characters in a picture as well as any aesthetic differences that might exist within or across texts.</p> <p>Novelty has shown to be a significant roadblock for even the bestrobust techniques based on machine learning for these tasks.</p> <p>Novelty in handwritten documents can take many different forms, such as a change in the author, character traits, writing skills, or overall document appearance.</p> <p>We think that an integrated agent that can handle well-known characters and innovations simultaneously is a better approach than looking at each aspect separately.</p> <p>The optical character recognition (OCR) problem includes the handwritten digit recognition problem as a subtask.</p>
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4.	Social Impact / Customer Satisfaction	<p>The handwriting recognition system offers a wide range of advantages. It is helpful for reading forms in addition to reading postal addresses and bank check amounts. Additionally, it is employed in the detection of fraud since it makes it simple to compare two texts and identify which is a copy. Because it employs an innovative technique for identifying handwritten digits, this system ensures high accuracy for the model and meets all customer expectations. If the system offers a variety of synonyms for the words recognised, users will save a great deal of time and work.</p> <p>This proposed system should be able to recognise those digits because users in rural areas will speak their own regional language.</p> <p>The method must be quick and dependable because it will be utilised in socially populated settings like banks to check quantities.</p> <p>It should be extremely dependable and trustworthy in every manner, and users all over the world should be able to use it efficiently because it is made to address real-life issues</p>
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5.	Business Model (Revenue Model)	Given that it is intended to address real-life issues, it must be completely trustworthy and extremely reliable in all respects, and it must be used by users all over the world.
6.	Scalability of the Solution	<p>Making use of cloud-native techniques is one way to scale the handwritten digit recognition system.</p> <p>IBM Cloud, for instance, is one of the cloud-based AI scalability options. Run and manage AI models, as well as optimise decisions at scale across any cloud, with the aid of IBM Cloud Build.</p> <p>The benefit of using the cloud to scale solutions is that we can install our AI</p>

		<p>programme there. the particular cloud setting that best meets our company's demands.</p> <p>We can benefit from AI model monitoring and built-in security features.</p> <p>With ModelOps pipelines, we can automate the AI lifecycles, deploy and run models with one-click integration, and prepare and create models visually and programmatically.</p> <p>Considering these benefits, we can improve business outcomes by making the best decisions possible and scaling our solution via the cloud.</p>
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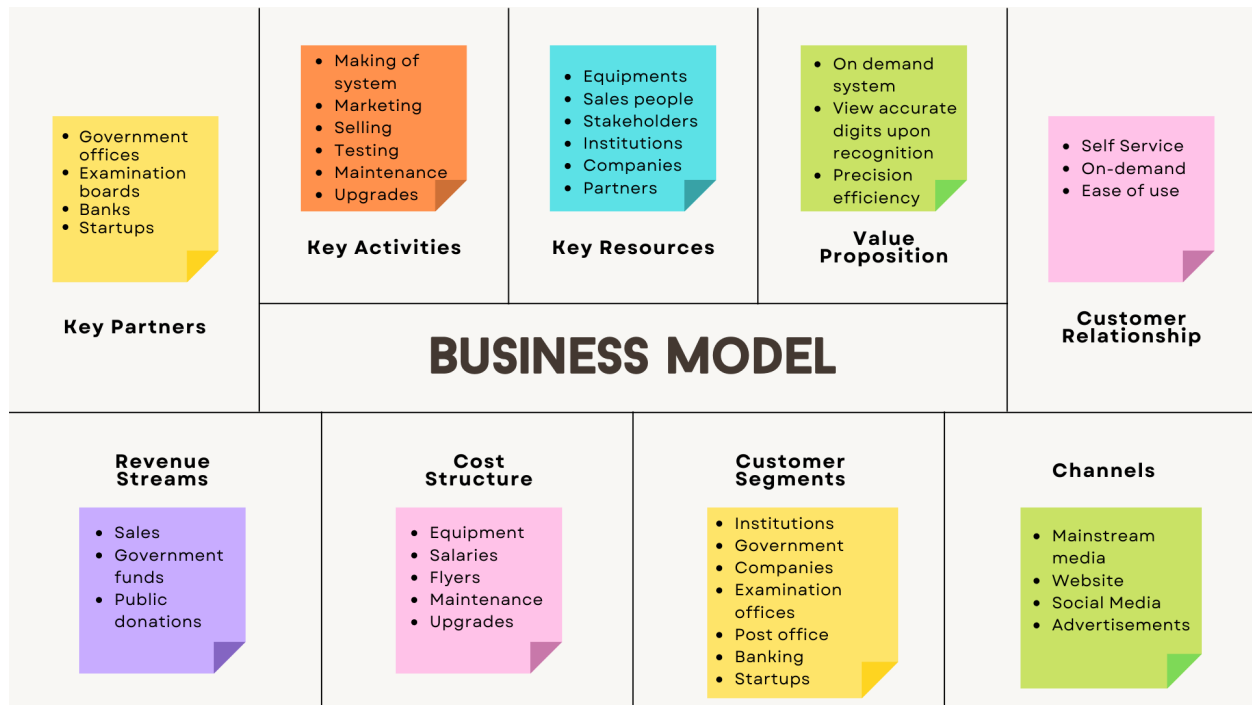
4.2 PROBLEM SOLUTION FIT

1.CUSTOMER SEGMENT(S):	5. AVAILABLE SOLUTIONS	8. CHANNELS OF BEHAVIOUR
<p>Customers who work with handwritten numbers include businesses, schools, railroads, and banking institutions.</p>	<p>Since handwriting cannot be read by most software, the numbers are verified by other individuals rather than using commonly utilised software.</p>	<p>utilising online-accessible applications. enlisting the aid of surrounding neighbours in order to identify the numbers that their clients have scribbled.</p>

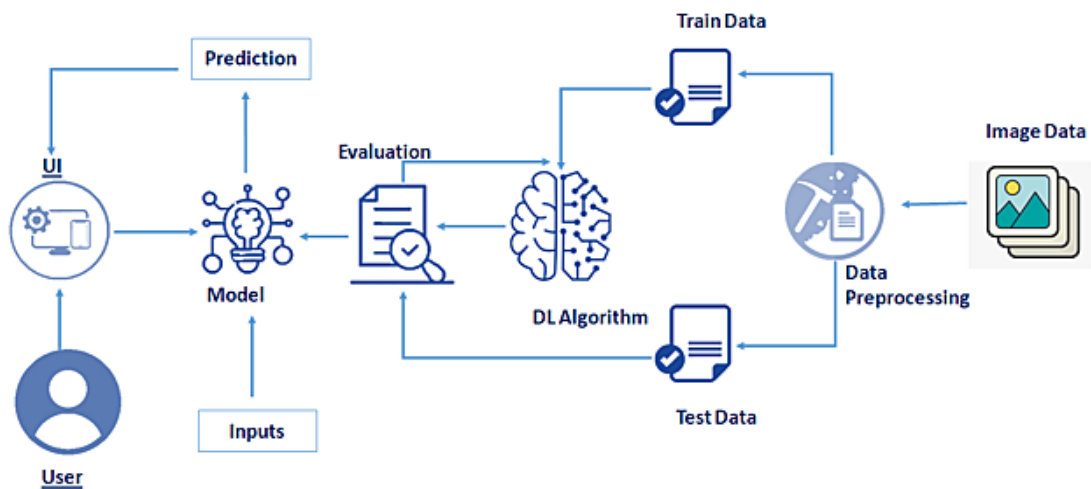
<p>2. JOBS-TO-BE-DONE/PROBLEM S:</p> <p>It can occasionally be challenging to read and understand handwritten numerals.</p> <p>When working with sloppy handwriting, mistakes may occur.</p>	<p>6.CUSTOMER CONSTRAINT(S):</p> <p>They think that the alternatives will lead to inconveniences, mistakes, and errors.</p>	<p>9. PROBLEM ROOT CAUSE</p> <p>In order to recognise handwritten numbers, we must overcome many obstacles.</p> <p>due to varying writing habits and a lack of Optic character recognition</p> <p>This study provides a thorough comparison of several machine literacy and deep literacy approaches.</p>
<p>1. TRIGGERS</p> <p>to quickly and accurately gather the statistics.</p> <p>2. EMOTIONS :BEFORE/AFTER</p> <p>When numbers are not entered, one feels angry and depressed.</p>	<p>7. BEHAVIOUR</p> <p>Finding the finest software to more quickly and accurately recognise digits</p>	<p>10. YOUR SOLUTION</p> <p>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.</p> <p>To recognise handwritten numbers, a convolutional neural network model created using PyTorch was deployed to the MNIST dataset.</p>

4.3 SOLUTION ARCHITECTURE

Our Business Model :



Technical Architecture:



Dataset Description :

A dataset that is frequently used for handwritten digit recognition is MNIST. 10,000 test photos and 60,000 training images make up the dataset.

Artificial neural networks, which are a crucial component in the field of image processing, can most closely resemble the human brain.

Using the MNIST dataset, handwritten digit recognition is a significant effort that was created with the use of neural networks. In essence, it recognises the scanned copies of handwritten numbers.

Our handwritten digit recognition technology goes a step further by allowing you to write numbers on the screen and have them recognised using an integrated GUI in addition to recognising scanned photos of handwritten numbers. 10,000 test handwritten digit images and 60,000 training handwritten digit images make up the MNIST Handwritten Digit Recognition Dataset.

The total number of pixels in each image is 784 (28x28), with a height of 28 pixels and a width of 28 pixels. A single pixel value connects every pixel. It displays the brightness or darkness of that pixel (larger numbers indicates darker pixel). The integer for this pixel value ranges from 0 to 255.



Procedure:

1. Install the latest TensorFlow library.
2. Prepare the dataset for the model.

3. Develop Single Layer Perceptron model for classifying the handwritten digits.
4. Plot the change in accuracy per epochs.
5. Evaluate the model on the testing data.
6. Analyse the model summary.
7. Add hidden layer to the model to make it Multi-Layer Perceptron.
8. Add Dropout to prevent overfitting and check its effect on accuracy.
9. Increasing the number of Hidden Layer neuron and check its effect on accuracy.
10. Use different optimizers and check its effect on accuracy.
11. Increase the hidden layers and check its effect on accuracy.
12. Manipulate the batch size and epochs and check its effect on accuracy.

This project will be approached utilising a three-layered neural network.

- The input layer: It transfers the characteristics from our example layers to the following layer so that the subsequent layer's activations can be calculated.
- The hidden layer: These ties for the network are built up of hidden units known as activations.
- Depending on our needs, there can be a variety of concealed layers.

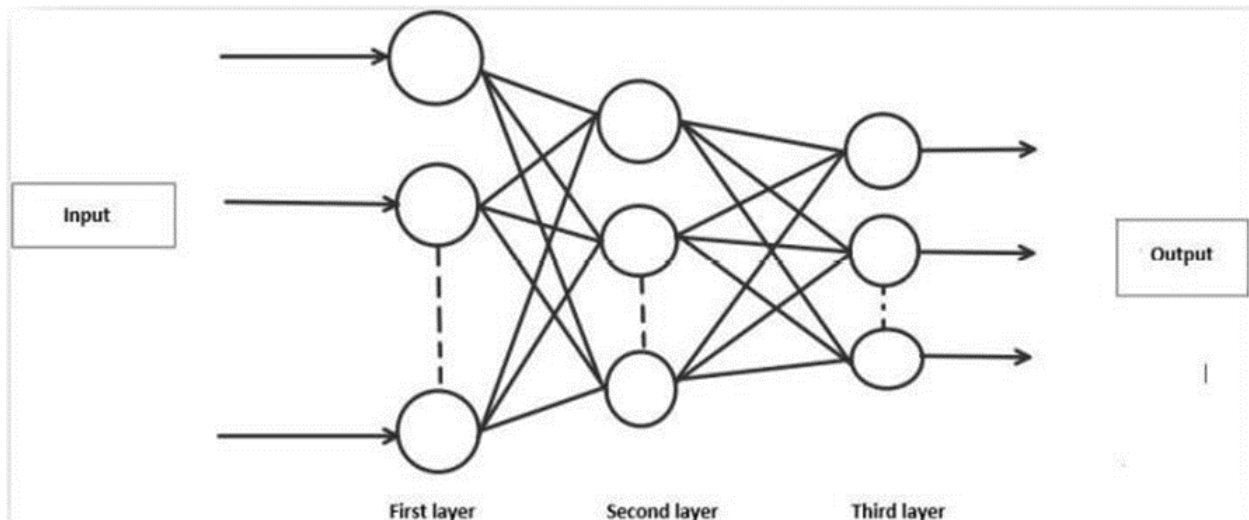
The nodes in this layer are referred to as output units. It gives us access to the neural network's final prediction, which may be used to make final predictions.

A neural network is a representation of the way the brain works. It has many layers and various activations, which resemble the neurons in our brain. An attempt by a neural network to learn a set of parameters from a batch of data may help identify underlying connections. Without needing to reconsider the output criteria, neural networks can offer the greatest outcomes since they can adjust to changing input.

Methodology:

We built a neural network with 100 activation units and one hidden layer (excluding bias units). The characteristics are then scaled down to a range of $[0,1]$ and split by 255 to prevent calculation overflow. 10,000 testing cases and 60,000 training examples make up the data.

The training set is used to derive the hypothesis, and backpropagation is then utilised to lessen the error between the layers. The regularisation parameter λ is changed to 0.1 to combat overfitting. To choose the model with the best fit, the optimizer is run 70 times.



The Forward Propagation Architecture algorithm:

This is a succinct explanation of how the CNN module will extract features

from the image and categorise it using those features. The design shows the input layer, hidden layers, and output layer of the network. Convolution and resampling are two of the many layers that are used in the network's feature extraction stage.

Explaining the specified system:

- The User layer is the top layer of the architecture. The users who engage with the programme and get the desired outcomes makeup the user layer. The frontend architecture of the application is made up of the following three levels. The application will be created on the open-source JavaScript, CSS, and HTML platform. The localhost, which is displayed in the browser, is where the programme is deployed. The user will be able to upload images of the handwritten numbers to the app to have them digitalized.
- The business layer, which consists of logical calculations based on the client's request, sits between the database and view layers. The service interface is also included.
- Training Data and Test Data make up the backend layer's two datasets. The training set, which consists of 60,000 cases, and the test set, which consists of 10,000 examples, have already been separated into the MNIST database.
- Convolution neural network training is the employed training algorithm. By doing this, the trained model will be ready to be used to categorise the digits found in the test data. As a result, the digits in the photos can be categorised as Class 0,1,2,3,4,5,6,7,8,9.

Working :

Neural networks process input through a number of secret layers after receiving it.

- Each group of neurons in a hidden layer is completely connected to every other neuron in the layer below it.
- Each layer of neurons functions entirely separately.
- The "output layer" is the final layer to be fully connected.

Convolution Layer:

The foundational component of a CNN is the convolutional layer. The parameters of the layer are a set of learnable filters (or kernels) that cover the entire depth of the input volume but have a narrow receptive field. Each filter is convolved across the width and height of the input volume during the forward pass, computing the dot product between each filter entry and the input to create a two-dimensional activation map of the filter. As a result, the network picks up filters that turn on when they spot a certain kind of feature at a particular location in the input.

Feature extraction:

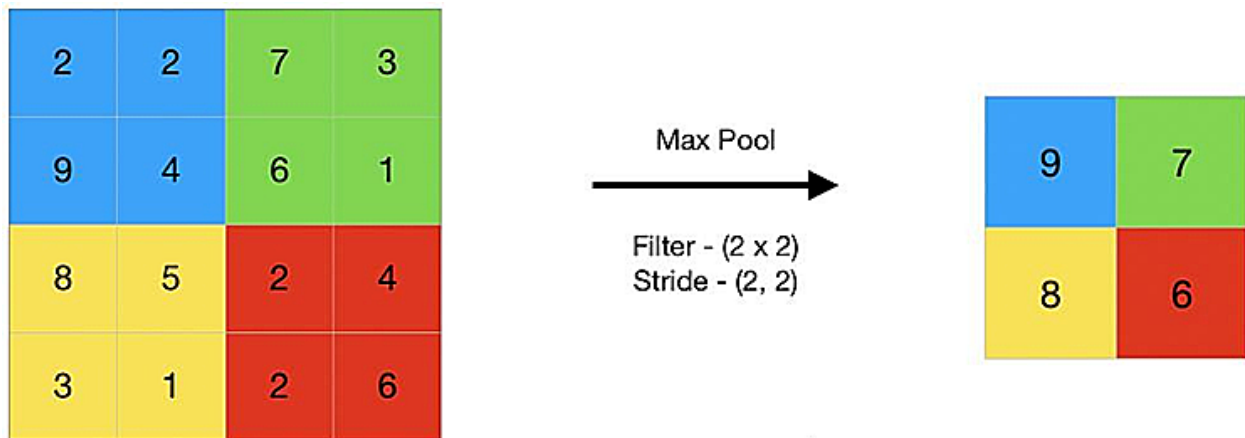
Each neuron in a feature has the same weights during feature extraction. In this manner, the same feature is recognised by all neurons at various locations in the input image. Limit the number of unrestricted parameters.

Subsampling:

Reducing a signal's total size is referred to as subsampling, sometimes known as down sampling. Each feature map's spatial resolution is decreased by the subsampling layers. Shift or distortion invariance is attained, and the impact of sounds is

Pooling layer:

In a Convnet architecture, it is typical to sporadically introduce a Pooling layer between subsequent Conv layers. In order to decrease the number of parameters and computation in the network and, as a result, control overfitting, it gradually shrinks the spatial size of the representation. Every depth slice of the input is independently processed by the Pooling Layer, which then applies the MAX operation to resize each slice spatially.



TensorFlow:

An opensource machine learning library for both research and production is called TensorFlow. TensorFlow provides developers of all skill levels with APIs for desktop, mobile, web, and cloud applications. To get started, refer to the sections below. We can achieve text output and sound output by scanning the number digit and converting it to png format using the python3 command in terminal.

CHAPTER 5

PROJECT DESIGN PHASE II

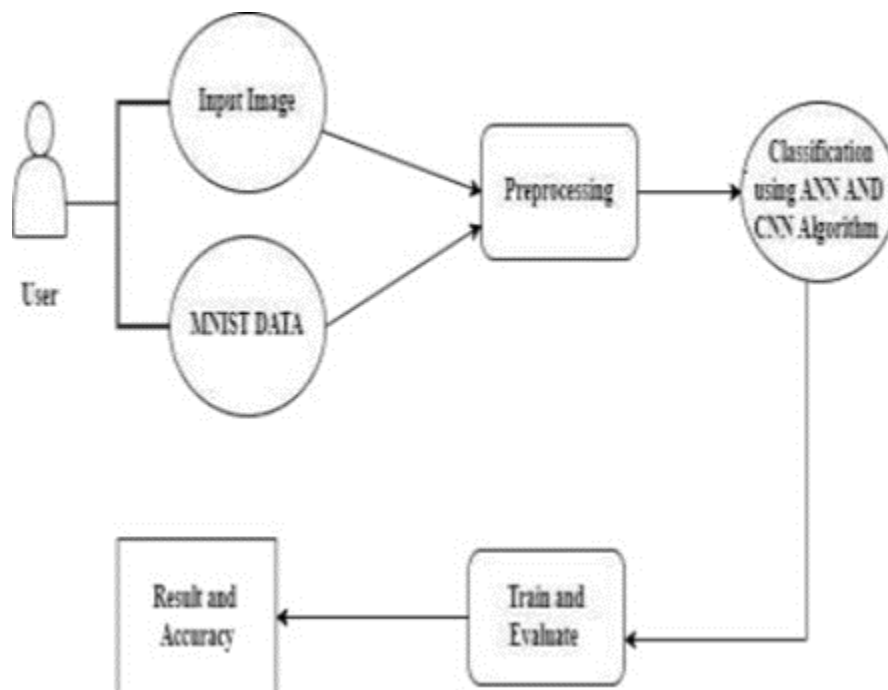
5.1 CUSTOMER JOURNEY

5.2 FUNCTIONAL REQUIREMENTS

FR No.	Sub Requirement (Story / Sub-Task)
FR-1	<p>Image Data: Handwritten digit recognition is the ability of a computer to recognise human handwritten digits from a number of sources, including pictures, papers, touch screens, etc., and classify them into ten predetermined categories (0-9).</p> <p>This has been the focus of innumerable studies in the field of deep learning.</p>
FR-2	<p>Website: Web hosting enables online access to the HTML, graphics, and other components of a website.</p> <p>Every website you've ever visited is hosted by a server.</p> <p>The amount of server space provided to a website depends on the hosting type.</p> <p>The four primary types of hosting are shared, dedicated, VPS, and reseller.</p>
FR-3	<p>Use the MNIST database of handwritten digits to train a neural network to predict the digit from a picture.</p> <p>assemble the data for training and validation first.</p>

FR-4	<p>Cloud: The cloud provides a variety of IT services, such as server, database, virtual storage, networking, and servers.</p> <p>Cloud computing is defined as an internet-based virtual platform that allows for limitless data storage and access.</p>
FR-5	<p>modified dataset from the National Institute of Standards and Technology</p> <p>The MNIST dataset is referred to by the acronym MNIST.</p> <p>It is a collection of 60,000 extremely small square grayscale photos, each measuring 28 by 28, with handwritten single numerals from 0 to 9.</p>

5.3 DATA FLOW DIAGRAM



User Stories:

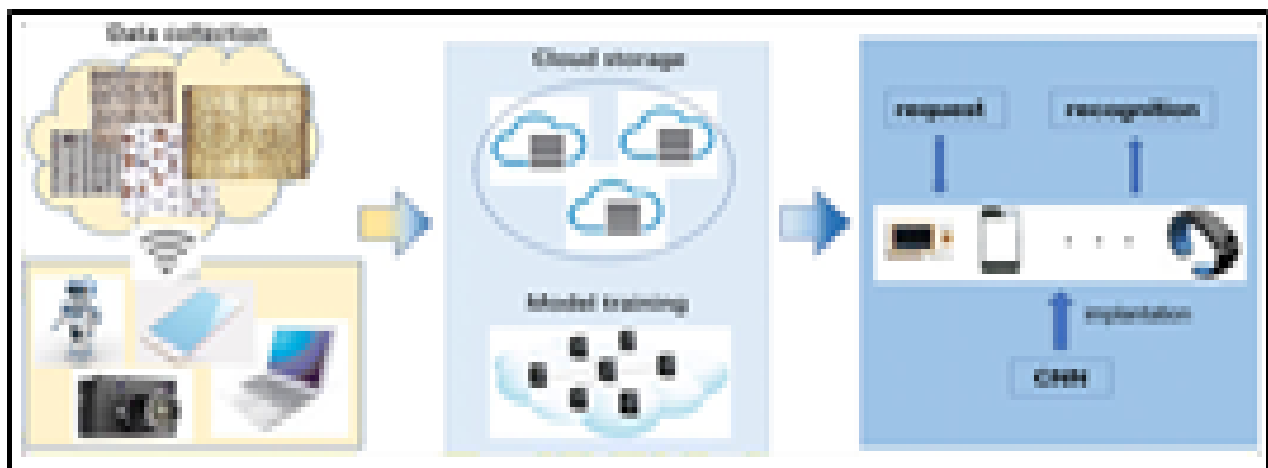
User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Customer (Mobileuser)	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	I can access my account / dashboard	High	Sprint-1
		USN-2	As a user, I will receive confirmation email once I have registered for the application	I can receive confirmation email & click confirm	High	Sprint-1
		USN-3	As a user, I can register for the application through Facebook	I can register & access the dashboard with Facebook Login	Low	Sprint-2
	Login	USN-4	As a user, I can register for the application through Gmail	I can register the application with Gmail	Medium	Sprint-2
		USN-5	As a user, I can log into the application by entering email & password	I can login to the application	High	Sprint-1

	Home	USN-6	As a user, I can view the application's home page where I can read the instructions to use this application	I can read instructions also and the home page is user-friendly.	Low	Sprint-1
	Upload Image	USN-7	As a user, I can able to input the images of digital documents to the application	As a user, I can able to input the images of digital documents to the application	High	Sprint-3
	Predict	USN-8	As a user I can able to get the recognised digit as output from the images of digital documents or images	I can access the recognized digits from digital document or images	High	Sprint-3
		USN-9	As a user, I will train and test the input to get the maximum accuracy of output.	I can able to train and test the application until it gets maximum accuracy of the result.	Medium	Sprint-4

Customer (Webuser)	Accessibility	USN-10	As a user, I can use the web application virtually anywhere.	I can use the application in any device with a browser	Medium	Sprint-4
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5.4 TECHNOLOGY ARCHITECTURE

Technical Architecture:



Components and Technologies:

S.No	Component	Description	Technology
1.	User Interface	How user interacts with application e.g. WebUI, Mobile App, Chatbot etc.	HTML, CSS, JavaScript
2.	Application Logic-1	Logic for a process in the application	Python
3.	Application Logic-2	Logic for a process in the	IBM Watson STT

		application	service
4.	Application Logic-3	Logic for a process in the application	IBM Watson Assistant
5.	Database	Data Type, Configurations etc.	MySQL, NoSQL, etc.
6.	Cloud Database	Database Service on Cloud	IBM DB2, IBM Cloudant
7.	File Storage	File storage requirements	IBM Block Storage
8.	External API-1	Purpose of External API used in the application	IBM WeatherAPI
9.	External API-2	Purpose of External API used in the application	Aadhar API
10.	Machine Learning Model	Purpose of Machine Learning Model	Object Recognition Model
11.	Infrastructure (Server/ Cloud)	Application Deployment on Local System / Cloud LocalServer Configuration Cloud Server Configuration	Local, Cloud Foundry

Application Characteristics:

S.No	Characteristics	Description	Technology
1.	Open-Source Frameworks	The open-source frameworks used are listed.	The technology of Opensourceframework
2.	Security Implementations	Listing all the security / access controlsimplemented, use of firewalls etc.	SHA-256, Encryptions, IAM Controls,OWASP
3.	Scalable Architecture	To justify the scalability of architecture used in system. User friendly and highly	3 – tier, Micro-services

		flexible.	
4.	Availability	Figures and abstract. The capabilities for recognizing handwritten digits have been implemented. These characteristics extract slope or slant information from the digit image based on shape analysis. They are successful in achieving high recognition accuracy.	Distributed servers, IBM cloud
5.	Performance	The handwritten digits are accurately classified with an accuracy of (98-99) percent using the typical neural network implementations.	number of requests per sec, use of Cache, use of CDN's

CHAPTER 6

PROJECT PLANNING PHASE

6.1 PROJECT MILESTONES AND ACTIVITY LIST

Title	Description	Date
Literature Survey and Information Gathering	Gathering Information by referring to the technical papers, research publications ,etc.,	20OCTOBER 2022
Prepare Empathy Map	To capture userpain and gains Prepare a List of ProblemStatement.	20OCTOBER 2022
Ideation	Prioritise a top 3 ideas basedon feasibility and Importance	20OCTOBER 2022
Proposed Solution	Solution include novelty, feasibility, business model, social impactand scalability of solution.	20OCTOBER 2022
Problem Solution Fit	Solution fit document	20OCTOBER 2022
Solution Architecture	Solution Architecture	20 OCTOBER 2022
Customer Journey	To Understand UserInteractions and experiences with application.	21OCTOBER 2022
Functional Requirement	Prepare functional Requirement	20OCTOBER 2022

Data flow Diagrams	Data flow diagram	20OCTOBER 2022
Technology Architecture	Technology Architecture diagram	20 OCTOBER 2022
Milestone & sprintdelivery plan	Activity what we done&further plans	31 October2022
Project Development Deliveryof sprint 1,2,3& 4	Develop and submit the developed code by testing it	26 October 2022 – 19 November 2022

6.2 SPRINT DELIVERY PLAN

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	RAVIKANT VIMAL RAAJ M VIGNESHWAR C KUMARAN S
Sprint-1	Login	USN-2	As a user, I can log into the application by entering email & password.	1	High	RAVIKANT VIMAL RAAJ M VIGNESHWAR C KUMARAN S

Sprint-2	Upload Image of digital document	USN-3	As a user, I can able to input the images of digital documents to the application	2	Medium	RAVIKANT VIMAL RAAJ M VIGNESHW AR C KUMARAN S
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Sprint-2	Prediction	USN-4	As a user, I can predict the word	1	Medium	RAVIKANT VIMAL RAAJ M VIGNESHW AR C KUMARAN S
Sprint-3	Upload Image of Handwritten document	USN-5	As a user, I can able to input the images of the handwritten documents or images to the application	2	High	RAVIKANT VIMAL RAAJ M VIGNESHW AR C KUMARAN S
Sprint-3	Recognize text	USN-6	As a user, I can able to choose the font of the text to be displayed	1	Medium	RAVIKANT VIMAL RAAJ M VIGNESHW AR C KUMARAN S
Sprint-4	Recognize digit	USN-7	As a user I canable to get the recognised digit as output from the images of digital documents or images	1	Medium	RAVIKANT VIMAL RAAJ M VIGNESHW AR C KUMARAN S

Sprint-4	Recognize digit	USN-8	As a user I can able to get the recognised digit as output from the images of handwritten documents or images	2	High	RAVIKANT VIMAL RAAJ M VIGNESHWAR C KUMARAN S
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Product Tracker:

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	2	6 Days	24 Oct 2022	29 Oct 2022	2	29 Oct 2022
Sprint-2	2	6 Days	31 Oct 2022	05 Nov 2022	2	05 Nov 2022
Sprint-3	2	6 Days	07 Nov 2022	12 Nov 2022	2	12 Nov 2022
Sprint-4	2	6 Days	14 Nov 2022	19 Nov 2022	2	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).

$$AV = \frac{\text{sprint duration}}{\text{velocity}} = \frac{20}{10} = 2$$

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.

CHAPTER 7

PROJECT DEVELOPMENT PHASE

7.1 DELIVERY OF SPRINT - 1,2

Feature 1: Model Building Using CNN Model in Our Project: CNN is a model known as Convolutional NeuralNetwork, andit has recently gained a lot of popularity due to its utility. CNN performs computational tasks by employing multilayer perceptrons. When compared to other image classification techniques, CNN requires very little pre-processing. This means that the network learns through filters that were hand-engineered in traditional algorithms. As a result, CNNs are the ideal alternative for image processing tasks.

7.2 DELIVERY OF SPRINT - 3,4

Feature 2: Application Building In our project, we are use the Flask application: Flask is a Python-based micro web framework. It is characterised as a microframework because it does not necessitate the usage of any specific tools or libraries. It lacks a database abstraction layer, form validation, and other components where third-party libraries provide common functionalities. Flask, on the other hand, enables extensions that can add application functionalities as if they were built into Flask itself. There are extensions for object-relational mappers, form validation, upload handling, different open authentication protocols, and other framework-related tools.

CHAPTER 8

TESTING

Functional Testing

This type of testing is performed to determine whether or not the functional components or functionality required from the system have been obtained. It truly falls under the purview of Software Engineering's Black Box testing. This section includes feeding inputs into the system or project and determining whether or not the system or project is returning the expected value; if not, calculate the error and look for more. This project's functional testing consists primarily of the following items. All of these are successfully tested, and errors are calculated.

- i)Checking the input image
- ii)Checking the work flow
- iii)Correct recognition and error calculation

Testing for Integration:

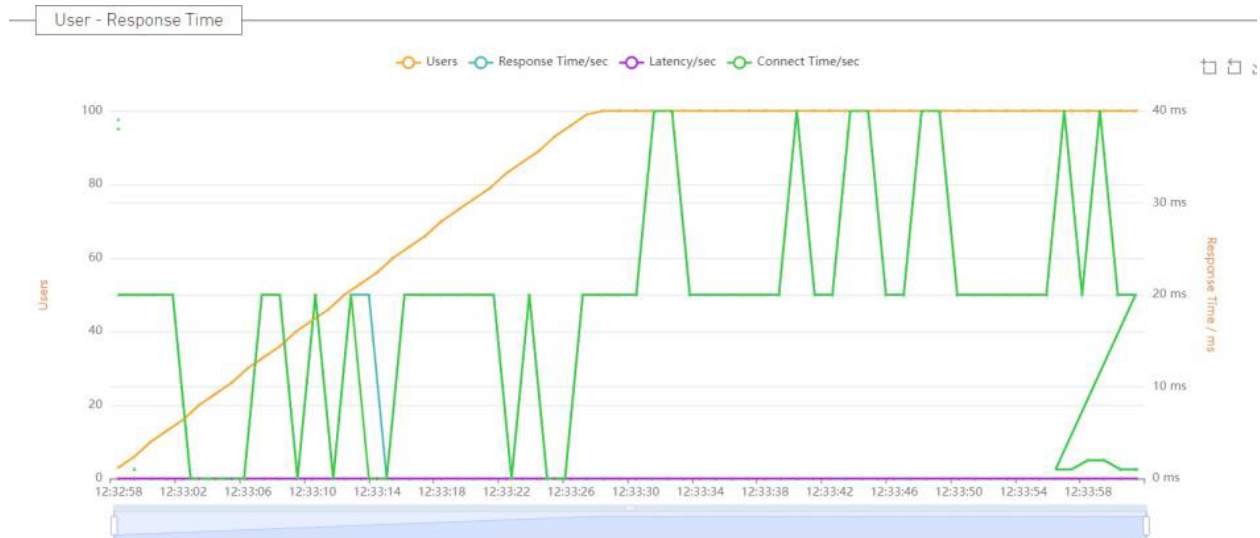
Many groupings of components are added or summed up in the objective of the project query in a comprehensive project or system. Integration testing involves examining the interplay of several project or system modules. This module also provides the project's hardware and software requirements.

All of the separate modules are combined and evaluated. All of the best and worst instances in which the modules interact or do not interact are correctly tested and passed, and mistakes are calculated for the deep learning platforms.

System Testing:

This type of testing is intended for the system or project, as well as the platform, integrated softwares and tools, and technologies. The goal or purpose of system testing is to check all of the requirements that the system will provide. This project's application, as well as the tools and technologies, have been tested in both Windows and Linux. It passed with flying colors.

8.2 User Acceptance Testing



CHAPTER 9

CONCLUSION

Using the MNIST dataset, a deep learning model for Handwritten Digit Recognition based on Convolutional Neural Network was successfully trained, tested and implemented. The CNNbased digit classifier model was trained using keras and tensorflow libraries. The model is deployed in a Flask webpage interface which consists of a homepage entailing introduction to handwritten digit recognition system and a prediction page where the user is prompted to select a digit image for prediction and the predicted result is displayed in the interface. The accuracy of our model gives around 92.2% which outperforms many other models used for handwritten digit recognition systems. Also our model resulted in good performance metrics as well giving a score of precision, recall and F1 measures also as 92.2%.

CHAPTER 10

APPENDIX

a. Python: Developed by Guido Van Rossum and initially released in 1991, Python is an interpreted, high-level, general-purpose programming language. Python's design philosophy stresses code Readability through the prominent use of significant White space. Its language constructs and object-oriented methodology are designed to aid programmers in creating clean, comprehensible code for both little and big projects. Python has garbage collection and dynamic typing. Programming paradigms like procedural, object-oriented, and functional programming are all supported.

b. Keras is a robust and user-friendly deep learning model development and evaluation Python library that is available for free and open source. It covers Theano and TensorFlow, two efficient frameworks for numerical computation, and enables you to define and train neural network models with just a few lines of code. It makes use of standalone machine learning toolkits, C#, Python, and C++ libraries. Although they are incredibly powerful libraries for building neural networks, Theano and TensorFlow are also challenging to grasp.

c. TensorFlow:

Google developed and released TensorFlow, a Python library for quick numerical computations. It is a foundation library that may be used to build Deep Learning models directly or indirectly using wrapper libraries created on top of TensorFlow to make the process easier. The TensorFlow tutorial is intended for both novices and experts. Deep neural networks, image processing, and sentiment analysis are just a few of the deep learning techniques covered in this tutorial. TensorFlow is one of the most well-known deep learning frameworks, and it was created by the Google Team. This tutorial is set up so that we can easily implement a deep learning project using a free and open source software library that was created in the Python programming language.

d. JupyterLab, a web-based interactive development environment for Jupyter notebooks, code, and data, provides a complement to Jupyter. JupyterLab can be configured and organized to accommodate a variety of data science, scientific computing, and machine learning workflows. JupyterLab is modular and expandable; you may create plugins that connect new components with those already in use.

e. Machine learning is a technique for data analysis that automates the creation of analytical models. It is a subfield of artificial intelligence founded on the notion that machines are capable of learning from data, spotting patterns, and making judgments with little assistance from humans.

f. Deep Learning: Deep learning is a feature of artificial intelligence (AI) that mimics how the human brain processes information and builds patterns to aid in decision-making. In artificial intelligence, deep learning is a subclass of machine learning that enables networks to learn unsupervised from unstructured or unlabeled data. also referred to as a deep neural network or deep learning.

g. Neural Networks: Using a technique that resembles how the human brain functions, a neural network is a collection of algorithms that aims to identify underlying relationships in a set of data. In this context, neural networks are systems of neurons that can be either organic or synthetic in origin.

CHAPTER 11

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