A PROJECT REPORT

On

Handwritten Digit Recognition System

For the partial fulfilment for the award of the degree of

BACHELOR OF TECHNOLOGY

In

Computer Science and Engineering

Submitted By

Arun Sharma(2101920100071)

Ayush Saxena(2101920100090)

Under the supervision of

Mr. Shivam Tiwari

G.L. Bajaj Institute of Technology & Management

Greater Noida

Affiliated to

Dr. APJ Abdul Kalam Technical University

Lucknow

(2022-23)

Declaration

We hereby declare that the project presented in this report entitled "**Handwritten digit Recognition System**", in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in Computer Science and Engineering, submitted to A.P.J. Abdul Kalam Technical University, Lucknow, is based on on my own work carried out at Department of Computer Science & Engineering, G.L. Bajaj Institute of Technology and Management, Greater Noida. The work contained in the report is original and project work reported in this report has not been submitted by me/us for award of any other degree or diploma.

Signature:

Name: Arun Sharma

Roll Number: 2101920100071

Signature:

Name: Ayush Saxena

Roll Number: 2101920100090

Date:

Place: Greater Noida

Certificate

This is to certify that the project report entitled **"Handwritten Digit Recognition system"** done by **Arun Sharma (2101920100071) and Ayush Saxena (2101920100090)** is an original work carried out by them in Department of Computer Science And Engineering, G.L. Bajaj Institute of Technology and Management, Greater Noida under my guidance. The matter embodied in this project has not been submitted earlier for the award of any degree or diploma to the best of my knowledge and belief.

Date:

Mr. Shivam Tiwari
Signature of the Supervisor

Dr. Sansar Singh Chauhan
Head of Department

Acknowledgement

The merciful guidance bestowed to us by the almighty made us stick out this project to a successful end. We humble pray with sincere hearts for his guidance to continue forever.

We pay thanks to our project guide **Mr. Shivam Tiwari** who has given guidance and light to us during this project. His versatile knowledge has helped us in the critical times during the span of this project.

We pay special thanks to our Head of Department **Dr. Sansar Singh Chauhan** who has been always present as a support and help us in all possible way during this project.

We also take this opportunity to express our gratitude to all those who have been directly or indirectly with us during the completion of the project.

We want to thanks our friends who have always encouraged us during this project.

At last thanks to all the faculty of CSE department who provided valuable suggestions during the period of project.

Abstract

Handwritten Digit Recognition is an important in the domain of image processing and pattern recognition. Different images have different format of writings and even writing of a single person differ from time to time which make it difficult for system to recognize and read.

Therefore, having a system that could recognize the digit will be of great use for people in different fields especially for scanning and reading handwritten digit text.

In the proposed system a prediction model will be created using machine learning algorithm of predefined dataset of digits.

This type of system will people an idea of digits that is written in an image. It can be used in search engine to recognize the digits written by a person in his usual handwriting.

Thus, this project aims to develop an application that will recognize the handwritten digit digits of a person and give correct output using machine learning model.

Table of contents

List of Figures

Chapter 1

Purpose of Study

The purpose of Handwritten digit recognition system is to understand the need of system that could recognize the handwritten digit to the best of its accuracy. Different writings styles and format of digit makes it difficult to recognize and read the digits. The study of this project helps to find optimal solution for handwritten digit recognition system. The study also aims to improve the accuracy of recognition system using machine learning concept.

The purpose of a handwritten digit recognition system is to automatically recognize and convert handwritten digit text or symbols into a digital format that can be processed by a computer, such as text or vector images. This technology can be used in various applications, such as digital handwritten digit input devices, signature verification systems, document scanning and indexing, and even historical document preservation. The main goal is to provide an efficient and accurate method of transforming handwritten digit text into machine-readable form. Image recognition can enable a computer to identify objects, people, places, and other elements within an image or video, and provide information about them. Image recognition technology is used in various applications, such as autonomous vehicles, security systems, and social media image tagging. It can also be used in retail and e-commerce for product recognition, in healthcare for medical image.

Chapter 2

Background of the Study

The study of handwritten digit recognition system has developed a lot in past years. Advancement of machine learning and image processing features has given a significant growth to text recognition system especially in search engines and various other types of document scanners. Different types of people have different style of writing and even writing of single person differs time to time especially handwritten digit texts, making it more difficult to recognize and read. This led to development of different technology like deep learning which uses neural networks to train machine and recognize the letters or digits correctly. The goal of the system is to enable recognition of blur handwritten digit text by various scanners and search engines and improve user experience. Image and text processing is widely used in search engines for better output and result.

Handwritten digit recognition technology is an active area of artificial intelligence research. Its growing popularity drives its development. Various reports predict market demand and the number of use cases will increase, spanning areas such as enterprise, field services, and healthcare. New advances in machine learning are constantly improving the accuracy of handwritten digit recognition. In this article, we'll take a closer look at the current state of this technology. Thus, handwritten digit recognition has developed a lot in past years and advancement in new technologies will further result in its improvement. Due to modification in technologies accuracy of handwritten digit recognition system has improved considerably and will keep improving.

Chapter 3

Factors Promoting to Undertake the Project

The factors to undertake this project are –

a) To apply our technical skills and knowledge to solve a real-life problem.
b) To save user time while trying to recognize and read the handwritten digit text.
c) To develop a technology that could be used in various document scanners and search engines to read handwritten digit letters or digit.
d) To find the gap in existing system and find technology that is best suited for the purpose of recognizing handwritten digit text.
e) To find the way for improving the accuracy the handwritten digit recognition system.
f) This project can help us in developing our skills in the field of machine learning and image processing field.
g) To enable a reader convert handwritten digit text into computer generated document.

Chapter 4

Literature Review

According to Jinze Li et al.[1], this paper proposes a handwritten digit recognition system based on convolutional neural networks (CNN). The system consists of two modules, a data source module and a digital identification module. The data source module provides the original handwritten digit digits and extracts the features of the digit pictures using the MNIST dataset, which contains images of handwritten digit digits from 250 different people. The system uses the OpenCV toolkit to perform image preprocessing and feature extraction. The digital identification module uses deep learning for recognition and is based on artificial neural networks (ANN). The system is trained on the MNIST dataset, which includes a training set of 30000 images and a test set of 10,000 images. The system inputs the images of handwritten digit to be recognized and outputs the recognized digit (0-9).

The system uses the MINST dataset for training and pre-processes the images using the OpenCV toolkit. It then uses the LeNet-5 architecture in the CNN to extract features from the handwritten digit images, followed by multiple convolution-pooling layers and the result is transformed into a 1-dimensional vector. Finally, the system uses a Softmax regression model to determine the recognized digit based on the highest probability. Softmax is used finally for classification of letter or digit. This system can reduce labor costs and improve efficiency in various fields.

Handwritten digit recognition technique using various datasets like mnist, open CV and advanced technology like CNN. ANN, etc and softmax tool can reduce human effort to large extent. But still it needs human reviews and technology to improve the accuracy of system.

According to S. Aniket et al.[2], research paper explains how Gujarati script can be recognized and read easily using handwritten digit recognition system. It has become challenge to recognize the different scripts and words of Gujarati for various researchers using technologies like machine learning with full accuracy.

First the dataset is required to train the system and test its accuracy on Gujarati characters. Classification and recognition of characters depends on this training and testing. Major problem

is during offline handwritten digit recognition of Gujarati script due to various types of characters with different posture, shape and way of writing.

In the first step image of Gujarati script is taken as input from image, scanner, camera or other input sources. Then preprocessing is done on his data in order to filter the data and remove distractions or unwanted details from this text. Here, image is converted to grayscale whereby it's pixels are changed in range from 0 to 255 between black and white where black pixels range is 0 to white pixel range is 255.

In next step thresholding is performed in the data which removes noise from the data and improves the accuracy of recognition. Now segmentation is performed on the data that cluster the data into various segments. After pre-processing, segmentation and clustering classification is performed on the data using advanced technology like deep neural network.

Finally, data is analyzed for the recognition of characters according the dataset. The aim of this research and technology is to digitize the ancient script and preserve it for future generations.

According to Taihei Hayashi et al.[3], the paper proposes a method for augmenting training data for handwritten digit character recognition using data augmentation. Handwritten digit recognition has gained a lot of advancement in field of research and technology but a large of data is required for training the machine and system. However, it is difficult to generate realistic data due to difference and writing method of different persons. Thus, gathering the data using conventional data augmentation method is required. This paper proposes a method for gathering probability distribution of various features related to characters and using this probability distribution for gathering image data for training the system. The method involves creating statistical character structure models from a small number of handwritten digit character images and generating new character images based on the probability distributions of the strokes. This approach can reduce the risk of over fitting caused by the lack of training data and can generate various handwritten digit styles of characters that are less correlated to the original ones. Thus, various techniques and technology and help in data in data acquisition which will increase the overall accuracy of the system to recognize the characters. However, the structure of generated character cannot be controlled completely which result in unstable image of data augmentation. The proposed method was evaluated on various handwritten digit recognition systems and good

results were obtained when used in conjunction with conventional data augmentation methods. However more researchers will propose different methods and technologies for collecting more data for training and testing that could improve handwritten digit character recognition system.

According to Mr. Narendrasing et al.[4], the article discusses the progress made in Character Recognition (CR) systems, which are enabled by continuously evolving information technologies. A character recognition system is a type of technology that can automatically recognize and interpret handwritten or printed characters, such as those found in documents, forms, and digital images. The system can be used to extract text from images or documents and convert it into machine-readable formats, such as ASCII or Unicode. Character recognition systems typically use a combination of hardware and software to perform the recognition process. The hardware component may include scanners or cameras that capture the images or documents containing the characters, while the software component performs the recognition and interpretation of the characters. The CR systems are classified into two categories: online and offline. Online recognition is a real-time process that captures the temporal and dynamic information of the pen trajectory, while offline recognition is the conversion of the image of writing into bit pattern data by an optically digitizing device such as optical scanner or camera. Handwritten digit and machine-printed character recognition systems are two main areas of interest in the CR field. The article further explains the methodologies of CR systems, which vary greatly depending on the type of system and the methodology used, and are grouped into stages of pre-processing, segmentation, representation, training and recognition, and post-processing.

The passage goes on to describe the three ages of CR systems. The early ages, from 1900 to 1980, were characterized by the development of the first character recognizers and the use of low-level image processing techniques for extracting feature vectors from handwritten digit text. In the period from 1980 to 1990, there was rapid growth in CR system development due to the explosion in information technology. Structural approaches were initiated in many systems in addition to statistical methods, but the focus was on shape recognition techniques without using any semantic information. In the third period after 1990, the real progress in CR systems was achieved using new development tools and methodologies, such as Image Processing and Pattern Recognition techniques combined with Artificial Intelligence methodologies. Researchers

developed complex CR algorithms, which receive high-resolution input data and require extensive number crunching in the implementation phase. However, the author notes that there is still a long way to go in order to reach the ultimate goal of machine simulation of fluent human reading, especially for unconstrained on-line and off-line handwriting.

According to Mondher Frikha et al.[5], handwritten digit recognition has received considerable attention in last few years. It is because of its demand and usage in various regions like search engine or pilgrims identification.

This research paper mainly dealt with various steps that are followed in training and recognizing the text in image recognition system.

These steps involve- Image acquisition, pre-processing, Segmentation, Feature extraction and Classification & Recognition.

a) Image Acquisition

Image acquisition is the first and most basic steps involved in text and handwritten digit recognition. It involves collecting and gathering data from various resources like camera, scanner, saved files, touch pad, keyboard or other input method from where data could be collected.

b) Pre processing

This step involves the applying various technique on the collected data to pre-process it and make it ready for the next step. It involves removing of distortion from data like noise, different height of words, bending of words, jitters and irregular spaces. This step is basically used to filter the words or image.

c) Segmentation

Image recognition is the process of parting the whole text into various segments which makes it easy to read and recognize by the system. It involves division of text into lines, words and then words into character.

It plays a significant role in accuracy of recognition of the text as a whole. Thus segmenting the text into sub units influence the accuracy of the whole system.

d) Feature Extraction

It involves gathering the important feature from the text. These features are useful in training and testing the data. It involves extracting features like statical characteristics, structural pattern of words, size and distribution of pixels. Thus gathering significant features from text plays a important role in accuracy of the system.

e) Classification and Recognition

This is the final step of recognition process whose accuracy depends on the previous steps. It involves identifying the image or text by comparing git previously collected training data. It tries to match the feature of image with training data and make decision based on features and recognizes the image or text. The above explained process when executed sequentially results in image or letter or digit recognition.

According to Sung-Hyuk et al.[6], this research paper basically focuses on the finding the similarities between different character images. Let's suppose there are more than one images (let say templates) comprising the differently styled characters. Now situation demands to figure out whether these images have the similar texts.

So, normally there is not any appropriate universal definition for figuring out the similarities considering the wide range of characteristics such as invariant constraints, deformed shape and size of texts, slants etc.

However various researchers proposed different methodologies to fulfil this demand. Out of them, one of the most famous and appreciated approach is "Approximate Stroke Sequence String Matching Algorithm". This proposed method especially helped a lot in various applications. Some of them are "Handwritten digit analysis", Online optical character recognition", Offline optical character recognition". This algorithm works by breaking down the stroke sequence into smaller sub-sequences and comparing each sub-sequence to a database of known stroke sequences. The algorithm considers the similarity between the sub-sequence and each of the

stroke sequences in the database and calculates a similarity score for each comparison. The stroke sequence with the highest similarity score is considered the best match

This approach firstly converts a two-dimensional image into a one-dimensional string. Same procedure is being done with the other images too. After converting all images into the one-dimensional strings, it's time to compare all these resultants strings. It is done by computing the edit-distance between the resultant stroke sequence strings. The similarity of the different strings is inversely proportional to the edit-distance between them that means the

smaller the edit-distance between any two strings, the more similar their characters look to each other.

So, as discussed earlier, one of the applications of this approach is "Handwritten digit recognition Analysis". This approach helps us in analyzing the similarities and differences of the written texts or characters in the string. This can lead us to the conclusion that whether these texts are written by same author.

According to Michael R. et al.[7], in this fastmoving world, there is a huge demand of image recognition technology. One of those technologies include Optical character recognition (OCR). It is meant to analyze and processes an image document to recognize the characters present int that images efficiently. For this application software, the inputs can be hand-written or printed texts, PDF documents or a scanned photo. It translates these input texts into a recognizable machine encoded editable text. It recognizes only those characters for which the system has been trained for using specific classification algorithms.

Following are the algorithmic steps to implement Optical character recognition (OCR).

a) Reading and processing the training image, converting it into a greyscale, blurred, threshold and flattened image to make it easier for the system to understand the features of the characters and differentiate them from the background.
b) Extracting features of each character from the contours and storing them in an array. The array and a label array are combined and stored in a text file.
c) Loading the text files, creating a KNN classifier object, and training the classifier using the text file.

d) Reading and processing the image to be tested, extracting the features from the contours with valid data.
e) Checking and storing the contours with valid data in a list.
f) Marking the contours with green rectangles on the testing image and showing it.
g) Cropping, resizing, thresholding, and flattening the green marked rectangles.

then using find nearest function KNN object the character label with most matching features are obtained and displayed as string.

According to Dhirendra Pratap Singh et al.[8], Input documents for this application software contains merged characters which are the major cause of character recognition errors. For fixing this problem, many researchers proposed a well efficient technique.

Generally, there are three merging relationships between two involved characters viz; “linear”, ”non-linear” and “overlapped”. Most of the segmentation methods has the capability to handle first type effectively. However, they are not able to grapple with the other two types of complexities. So, this all incapabilities leads to the development of this method.

Basically, this method works on the basis of three processes namely; Forepart prediction, character-adaptive masking and Necessity -sufficiency algorithm (NSM).

This paper proposes an effective merged-character recognition method, which consists of a novel segmentation scheme based on forepart prediction (FP), character-adaptive masking (CAM), and a necessity-sufficiency matching (NSM) algorithm for single character recognition. First, the method predicts the candidates for the foremost (for horizontally aligned text, “foremost” equals “leftmost”) character of merged characters based on a set of forepart features and then cuts it from the image using its individual mask, namely, character-adaptive masking. Next, the recognizer determines the probability of each candidate and decides which candidates are acceptable, and each accepted candidate will start a new processing branch for the latter segmentation; consequently, there will be multiple segmentation solutions. Finally, the solution with the highest holistic recognition probability will be accepted. Compared with existing merged character recognition approaches, the advantages of the proposed method are the following:

a) Forepart prediction is verified by reliable character matching.
b) NSM algorithm utilizes a concise feature-row-based character model to distinguish similar characters efficiently.
c) Character masks for the segmentation are adaptive to character shapes so as to avoid damaging the character image.

According to Anshul Gupta, et al.[9], Offline character recognition (OCR) is one of the applications of handwritten digit recognition techniques. The main approaches for offline character recognition are mainly of two types; first one is holistic and second one is segmentation-based analysis.

OCR technology involves several stages, including image preprocessing, character segmentation, feature extraction, and classification. In the image preprocessing stage, the image is cleaned and enhanced to improve the quality of the character images. In the character segmentation stage, individual characters are isolated from the image, which can be challenging for handwritten characters. In the feature extraction stage, relevant features of the characters are extracted to represent the character. Finally, in the classification stage, a machine learning algorithm is used to recognize the characters based on their features.

Talking about the first approach that is holistic based algorithm, it works on the principle that it tries to recognize limited size vocabulary that is in this approach global features are extracted from the entire word image which is the input of the system. But as the size of the vocabulary increases, it becomes more complex, hence this drawback of holistic approach led to the second approach which is segmentation based which works on the principle that it starts analyzing from the stroke or the character level and gradually after analyzing each character, it led to the meaningful word. So, this is the working of the second approach.

The accuracy of any software is heavily dependent on the type of quality of input document of that software. As, in handwritten digit text, there is a great possibility that their adjacent characters tend to be touched or overlapped. This fact makes this approach worth it as such irregular arrangement of characters needs to be segmented correctly into their character components.

After segmentation step, it requires to be represented and classified into character classes by features.

The different representation methods are discussed below:

a) Global transformation and series expansion: includes Fourier transform, Gabor transform, wavelet, movements and Expansion.
b) Statistical representation: Zoning, crossing and distances, projections.
c) Geometrical and topological representation: Extracting and counting topological structures, geometrical properties, coding, graphs and trees etc.

According to Prof. Rohan Vaidya et al.[10], as we know, in this fastmoving world, there are various advancements which are expanding their significance all around the technology world. Out of which, Artificial Intelligence (A.I) and deep-learning are one of the prominent technologies. There are many fields where these domains find their applications, out of which "Handwritten digit recognition" is one of the active areas of research where deep neural networks concepts are used.

Deep learning is a subset of machine learning that involves training artificial neural networks to perform specific tasks, such as digit recognition. Convolutional neural networks (CNNs) are a type of deep learning algorithm that have shown great success in digit recognition tasks.

Handwritten digit recognition is somewhat easy task for the humans but a daunting task for computers as there can be different handwritings for different individual as each have different handwritten digit style. So, it is a very daunting task to develop such a technology which can help in handwritten digit recognition analysis.

Various developers after years of research, have proposed various methodologies. One of which is analysis of handwritten digit on the basis of deep neural networks.

This system comprises of two main steps:

a) An android application: It works as the frontend of this software. It works on the principle that the user will have to click a picture of text which is to be recognized. Now

this input image will be passed to the written python script which is embedded in the software, where it will be processed to extract the relevant information.

b) A server: It is the backend of our system. It is basically a computer which will help to execute the embedded python script. Now the question arises why it is needed, as we know an ordinary android phone don't have such computational power for running neural networks and performing image processing operations. For all this, we used Convolutional Neural network model in our system. Int this software, we used NIST dataset which is having samples of various handwritten digit texts written by lakhs of writers.

Chapter 5

Aims & Objective of the Study

The aim and objective of this project is to develop a system that could recognize the handwritten digit text. It aims to learn about various types of technology that could help improve the accuracy of system and give correct output. It would improve user experience of scanning and reading the handwritten digit text that is difficult to recognize and read normally.

We aim to develop a system that could accurately and efficiently convert handwritten digit text or symbols into a digital format that can be processed by a computer. It would enable a reader to easily recognize the handwritten digit text in computer generated document format and read it easily.

The objective of this project is to recognize the handwritten digit characters of the user with the help of neural networks. We have to build suitable neural network and aim it properly. The program should be able to take out the characters one by one and plan the target output for training purpose. After automatic processing of the image, the training dataset has to be used to train "classification engine" for identification purpose. The main objective is to understand the handwritten digit and convert it into readable text, which includes characters, words, lines, paragraphs etc. In this project, the challenge is classifying the image of any handwritten digit word, which might be of the form of cursive or block writing. Along with this, Text-to-Speech is used to help people who have trouble reading on-screen text.

Chapter 6

Research Gap

There are various research gaps available in the field of Handwritten digit recognition using machine leaning:

a) **Limited data acquisition:** The quantity and variety of the dataset available for training and testing the recognition system if not sufficient. Increasing data collection that could be used for training and testing the system will further improve accuracy of system.
b) **Few machines learning technology:** Technology and technique of machine learning used for training the system are complete accurate. Further research on machine learning technologies could help improve accuracy on output.
c) **Variation in technique:** Due to large variations and difference in technique for testing the machine accuracy makes it difficult to check the accuracy of system properly and improve its functioning.
d) **Difficulty in distinguishing between similar text:** Due to difficult in difference in writing of different people and even handwritten digit of single person differ from time to time so it becomes difficult to give correct output. To predict correct output this problem calls for more sophisticated feature extraction and learning algorithms.

Chapter 7

Scope of the study

The scope of this system refers to the range of tasks and applications of this system. It includes various operations such as identifying individual characters by segmentation approach, recognizing words and phrases, changing the handwritten digit texts into the machine encoded text and after that analyzing handwritten digit for various characteristics such as the speed of writing of the user, mood of the writer while writing.

Some of the areas where handwritten digit recognition technology is used include:

a) Data entry: Automating the process of data entry by converting handwritten digit information into a digital format.
b) Document scanning: Digitizing handwritten digit documents for preservation, analysis, and distribution.
c) Signature verification: Verifying the authenticity of signatures on legal and financial documents.
d) Education: Facilitating the digitization of handwritten digit notes, exams, and other materials.
e) Healthcare: Converting handwritten digit medical records into digital format for analysis and record-keeping purposes.
f) Retail and e-commerce: Recognizing handwritten digit product information on labels, invoices, and other materials.
g) Handheld devices: Enabling handwritten digit input on mobile devices and digital pens.
h) Historical document preservation: Digitizing historical handwritten digit documents for preservation and analysis.

This is just a partial list, and the scope of handwritten digit recognition technology is continually expanding as new applications are developed and new industries adopt the technology.

So, conclusively, if we talk about the specific scope of this software, it depends on the various factors such as the type of trained data, type of algorithm, it's accuracy and efficiency.

Chapter 8

Methodology

8.1: Implementation

This project uses the concept of the convolutional Neural networks and deep learning to recognize the handwritten digit texts using the various methods such as segmentation, feature extraction etc. Deep Learning self-extracts features with a deep neural network and classify itself. Comparing to traditional Algorithms, its performance increase with Amount of Data.

System takes text image as input data and divide it into different segments after recognizing it's features. Then it analyzes the features and tries to classify the data based on it training. And finally, it recognizes the text data based on features and classification.

Handwritten digit recognition systems are a type of artificial intelligence (AI) technology that enable machines to recognize and interpret handwritten digit text or characters. Some of the implementation steps are Data collection, Data preprocessing, Feature Extraction, Testing and evaluation and the last step is Deployment.

The performance of a handwritten digit recognition system depends on various factors, such as the quality and quantity of the data, the preprocessing techniques used, the feature extraction methods employed, and the choice of machine learning algorithms.

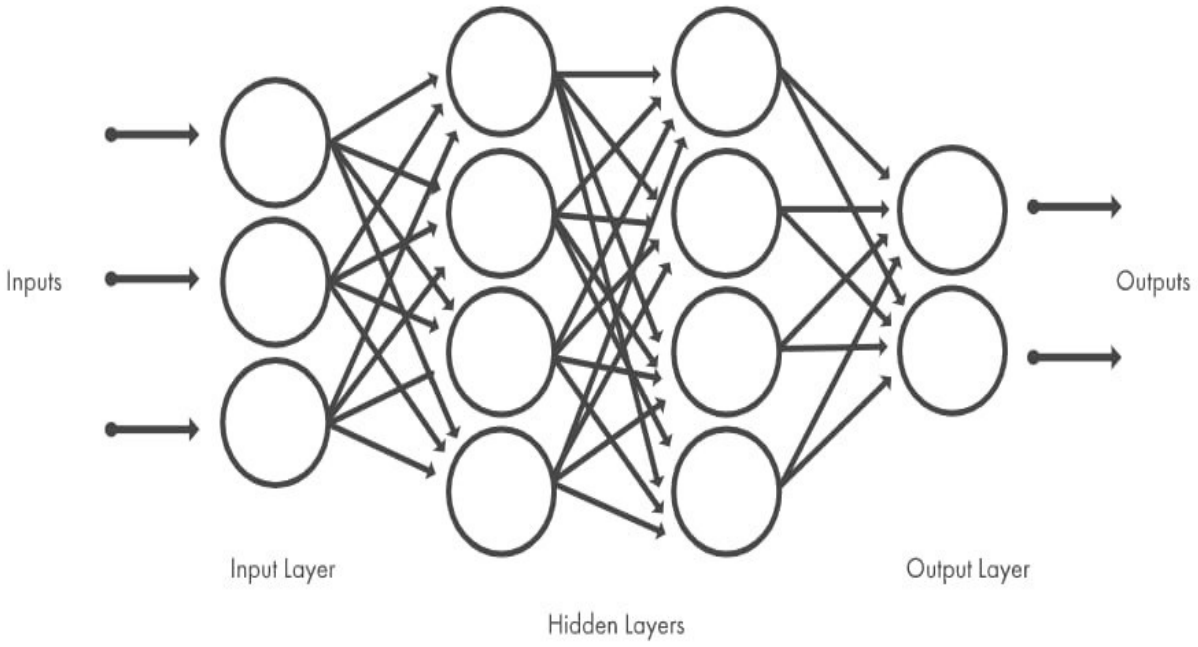

Figure 8.1.1: Deep Learning Network

First Use Convolutional Recurrent Neural Network to extract the important features from the handwritten digit line text Image.

The output before CNN FC layer (512x1x100) is passed to the BLSTM which is for sequence dependency and time-sequence operations.

Then CTC Loss Alex Graves is used to train the RNN which eliminate the Alignment problem in Handwritten digit, since handwritten digit have different alignment of every writer. We just gave the what is written in the image (Ground Truth Text) and BLSTM output, then it calculates loss simply as -log("text"); aim to minimize negative maximum likelihood path.

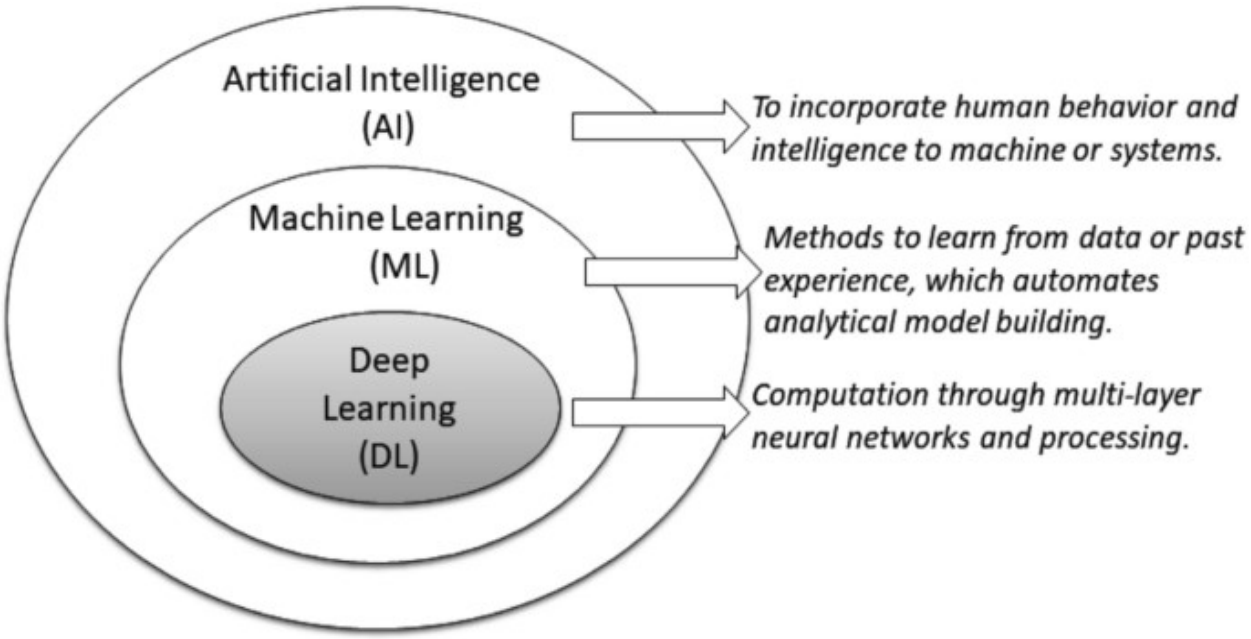

Figure 8.1.2: Difference Between AI, ML and Deep Learning

Artificial Intelligence (AI): AI is the broader concept of creating machines that can perform tasks that normally require human intelligence, such as perception, reasoning, learning, and problem-solving. AI is the ability of machines to simulate human intelligence and perform tasks that would normally require human intelligence.

Machine Learning (ML): Machine learning is a subset of AI that focuses on enabling machines to learn from data, without being explicitly programmed. ML algorithms can recognize patterns and relationships in data and use this knowledge to make predictions or take actions.

Deep Learning (DL): Deep Learning is a type of ML that is based on neural networks. DL involves training artificial neural networks to recognize patterns in data, similar to the way the human brain does. DL is particularly useful for tasks such as image and speech recognition.

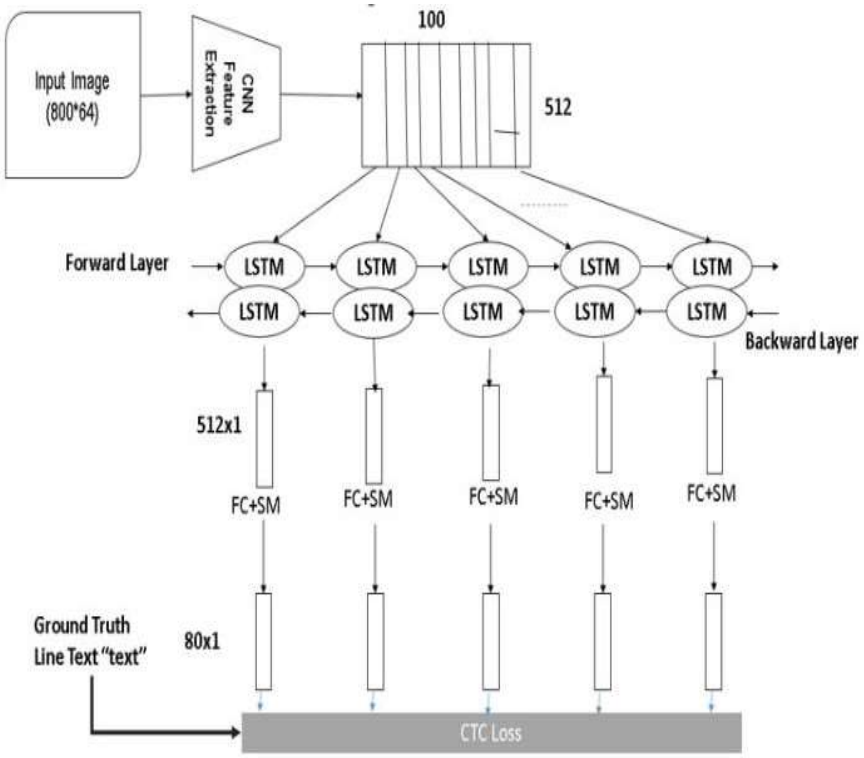

Figure 8.1.3: Detail project Overflow

The proposed method comprises of 4 phases:

a) Pre-processing: The pre-processing is a series of operations performed on scanned input image.
b) Segmentation: In this step, an image of sequence of characters id decomposed into sub-images of individual character.
c) Feature extraction: It extracts different line types that form a particular character. It also concentrates on the positional features of the same.
d) Classification and Recognition: Classification is the process of assigning a class label to an input sample based on certain features. It is a supervised learning task where the model is trained on a labeled dataset to predict the class label of a new sample.

Recognition, on the other hand, is a broader term that encompasses various tasks such as classification, detection, segmentation, etc. It refers to the ability of a machine to identify objects, people, patterns, etc. from an input image, audio, or any other type of data.

8.2: Source code

```
import numpy as np

import matplotlib.pyplot as plt

from keras.datasets import mnist

from keras.models import Sequential

from keras.layers import Dense, Flatten

from keras.utils import to_categorical


# Load the MNIST dataset

(set1_train, set2_train), (set1_test, set2_test) = mnist.load_data()


# Preprocess the data

set1_train = set1_train.reshape(set1_train.shape[0], 28, 28, 1).astype('float32') / 255

set1_test = set1_test.reshape(set1_test.shape[0], 28, 28, 1).astype('float32') / 255

set2_train = to_categorical(set2_train)

set2_test = to_categorical(set2_test)


# Define the model

model = Sequential()

model.add(Flatten(input_shape=(28, 28, 1)))

model.add(Dense(128, activation='relu'))
```

```
model.add(Dense(10, activation='softmax'))

# Compile the model
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])

# Train the model
history = model.fit(set1_train, set2_train, validation_split=0.2, epochs=10, batch_size=128)

# Evaluate the model on the test set
test_loss, test_acc = model.evaluate(set1_test, set2_test)
print('Test accuracy:', test_acc)

# Display some of the digit images from the test set along with their predicted labels
predictions = model.predict(set1_test)
fig, axes = plt.subplots(nrows=5, ncols=5, figsize=(8, 8))
for i, ax in enumerate(axes.flat):
    ax.imshow(set1_test[i].reshape(28, 28), cmap='gray')
    ax.set(title = f"Prediction: {np.argmax(predictions[i])}")
    ax.axis('off')
plt.show()
```

8.3: Flow Chart

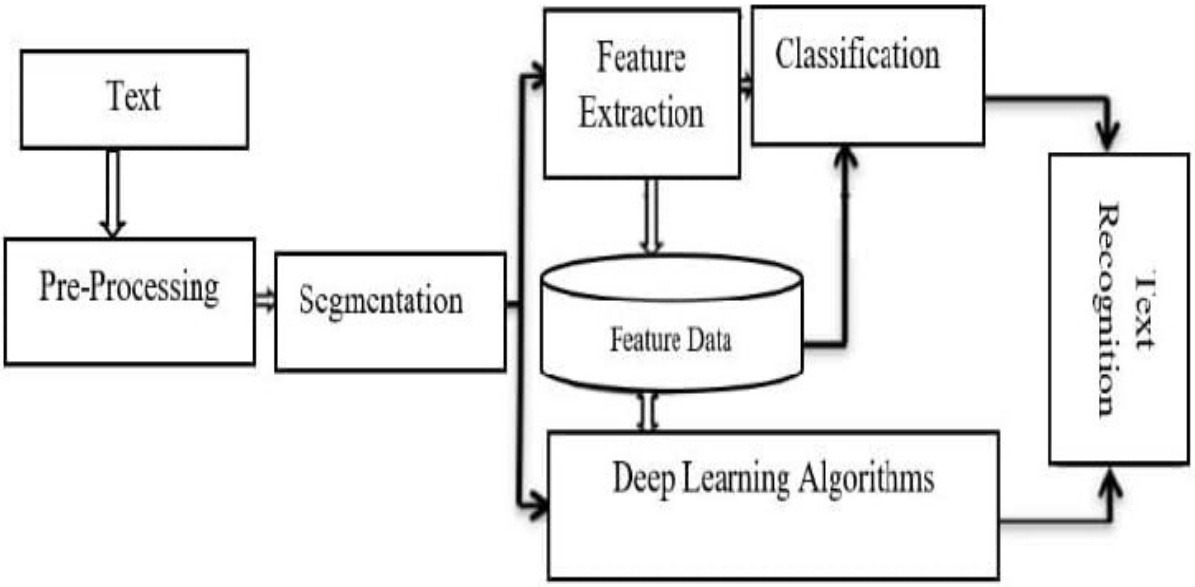

Figure 8.3.1: Flow Chart

The flowchart for a handwritten digit recognition system involves a series of steps that work together to convert handwritten digit text into digital format through image acquisition, pre-processing, segmentation, feature extraction, classification, post-processing, and output.

a) Image Acquisition: The system captures an image which works as an input to the system.
b) Pre-Processing: The captured image is pre-processed to remove noise and distortion.
c) Segmentation: The pre-processed image is segmented to isolate individual words.
d) Feature Extraction: The segmented parts are analyzed to extract features like their shape, size.
e) Classification: The extracted features are used to classify the segmented words into categories.
f) Post-Processing: After classification, it is again processed to improve accuracy.
g) Output: After all above steps, the recognized text is the result and output of the above system.

8.4: Data Flow Diagram

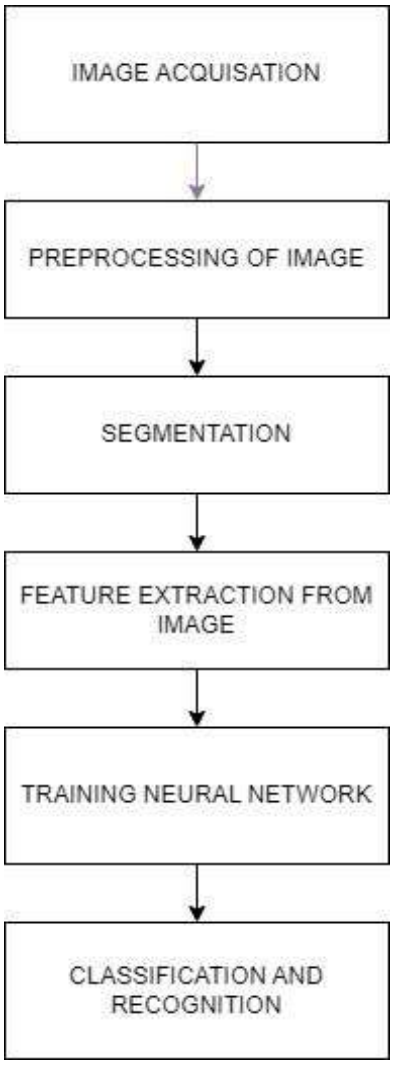

Figure 8.4.1: Data Flow Diagram

8.5: Use Cases

Handwritten digit recognition systems are used in a wide range of applications, some of which include:

a) Digital Document Processing: Handwritten digit recognition systems can convert handwritten digit notes, forms, and other documents into digital text, making them easier to edit, search, and store. This can be useful in various industries, such as healthcare, education, and finance.
b) Postal Services: Handwritten digit recognition systems can be used in postal services to recognize addresses and postal codes on envelopes and packages, which helps with sorting and delivery.
c) Banking and Finance: Handwritten digit recognition systems can be used for check processing, signature verification, and other financial transactions.
d) Interactive Whiteboards: Handwritten digit recognition systems can be used in interactive whiteboards to recognize and digitize notes and diagrams made on the board.
e) Mobile Devices: Handwritten digit recognition systems can be used on mobile devices to recognize handwritten digit input, allowing users to enter text and commands using a stylus or their finger.
f) Accessibility: Handwritten digit recognition systems can be used to help people with physical disabilities, such as those who are unable to use a keyboard, to input text into a computer or other electronic device.
g) Investigation: Handwritten digit recognition system can plays a vital role in various types of frauds and scams investigation where it can help in figuring out the fake passwords, in understanding the crumbled digits which is a hard task to understand.

Overall, handwritten digit recognition systems can be used in any application where handwritten digit needs to be converted to digital text or used for recognition and verification purposes.

Chapter 9

Result and Discussion

9.1: Assessment of Project

Once the system is trained and tested, following input are provided to the system and output obtained are validated.

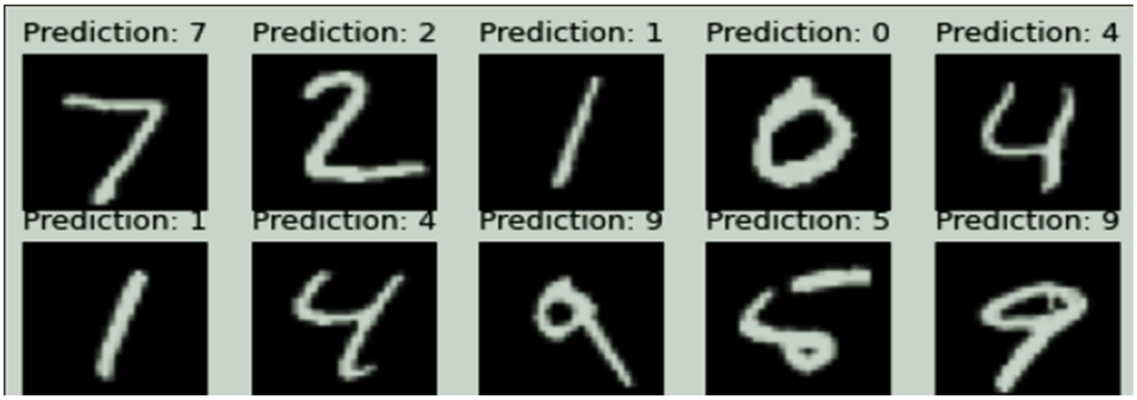

Figure 9.1.1: Output of Image 1

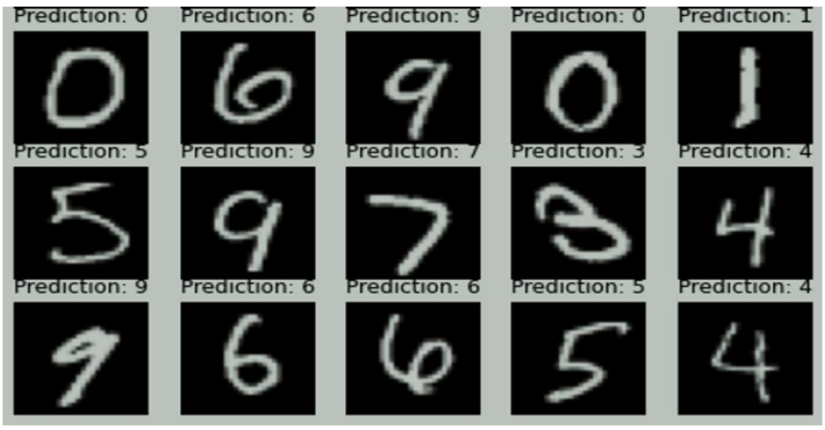

Figure 9.1.2: Output of Image 2

The accuracy of the system can be improved by-

Data Augmentation - Collecting more dataset and training the system to improve accuracy.

Better Filtration- Performing better pre-processing and filtration on collected data to improve classification and recognition.

Chapter 10

Conclusion

This project has helped us in learning lot of new concepts about python libraries, machine learning, image processing, data acquisition, data filtration and classification & recognition of data. Handwritten digit recognition system has gained a lot of development through usage of various types of technologies like deep learning, Convolutional Neural Network, RNN, image processing, etc. These technologies are significantly important for relevant and accurate output of recognized text. As a result, recognition system gives high quality output to user. However, there is still room for improvement. Future work can focus on more data acquisition and training of machine on this large set of data that could help improve the accuracy of handwritten digit text recognition. Overall handwritten digit recognition system is an example of developed technology that has potential to enhance the quality of handwritten digit text scanners and help it's user in easily scanning and reading the blur text.

References

[1] J. Li, G. Sun, L. Yi, Q. Cao, F. Liang and Y. Sun, (2020), "Handwritten digit Digit Recognition System Based on Convolutional Neural Network", IEEE International Conference on Advances in Electrical Engineering and Computer Applications(AEECA), pp. 739-742, doi: 10.1109/AEECA49918.2020.9213619.

[2] S. Aniket, R. Atharva, C. Prabha, D. Rupali and P. Shubham, (2019), "Handwritten digit Gujarati script recognition with image processing and deep learning technology", International Conference on the Nascent Technologies in Engineering (ICNTE), pp. 1-4, doi: 10.1109/ICNTE44896.2019.8946074.

[3] T. Hayashi, K. Gyohten, H. Ohki and T. Takami, (2018), "A Study of Data Augmentation for Handwritten digit Character Recognition using Deep Learning", 16th International Conference on Frontiers in Handwritten digit recognition (ICFHR), pp. 552-557, doi: 10.1109/ICFHR-2018.2018.00102.

[4] MR. Narendrasing, Prof. S.M. Rajput, Prof S.M. Badave, (2012), "Handwritten digit Character Recognition -A Review", International Journal of Engineering & Technology, vol. 1.

[5] M. M. Al-Taee, S. B. H. Neji and M. Frikha, (2020),"Handwritten digit Recognition: A survey", IEEE 4th International Conference on Image Processing, Applications and Systems, pp. 199-205, doi: 10.1109/IPAS50080.2020.9334936.

[6] Sung-Hyuk Cha, Yong-Chul Shin and S. N. Srihari, (1999),"Approximate stroke sequence string matching algorithm for character recognition and analysis", Proceedings of the Fifth International Conference on Document Analysis and Recognition. ICDAR '99, pp. 53-56, doi: 10.1109/ICDAR.1999.791723.

[7] Jiqiang Song, Zuo Li, M. R. Lyu and Shijie Cai, (2005), "Recognition of merged characters based on forepart prediction, necessity-sufficiency matching, and character-adaptive masking", IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), vol. 35, no. 1, pp. 2-11, doi: 10.1109/TSMCB.2004.837588.

[8] T. K. Hazra, D. P. Singh and N. Daga, (2017),"Optical character recognition using KNN on custom image dataset", 8th Annual Industrial Automation and Electromechanical Engineering Conference, pp.110-114, doi: 10.1109/IEMECON.2017.8079572.

[9] A. Gupta, M. Srivastava and C. Mahanta, (2011), "Offline handwritten digit character recognition using neural network", IEEE International Conference on Computer Applications and Industrial Electronics,pp.102-107, doi: 10.1109/ICCAIE.2011.6162113.

[10] R. Vaidya, D. Trivedi, S. Satra and P. M. Pimpale, (2018), "Handwritten digit Character Recognition Using Deep-Learning", Second International Conference on Inventive Communication and Computational Technologies (ICICCT), pp. 772-775, doi: 10.1109/ICICCT.2018.8473291.