- **TITLE PAGE**

PROJECT REPORT

(Project Term January-April 2022)

(HANDWRITTEN DIGITS RECOGNITION)

Submitted by

(PIYUSH VYAS) **Registration Number :…11909779…….**

Project Group Number …A04…….

Course Code ……INT247……

Under the Guidance of

(MR. SAGAR PANDE SIR)

School of Computer Science and Engineering

DECLARATION

We hereby declare that the project work entitled ("Handwritten Digits Recognition") is an authentic record of our own work carried out as requirements of Project for the award of B.Tech degree in School of Computer Science and Engineering from Lovely Professional University, Phagwara, under the guidance of Mr. Sagar Pande Sir, during January to April 2022. All the information furnished in this project report is based on our own intensive work and is genuine.

Project Group Number: …A04……

Name of Student : ……Piyush Vyas……

Registration Number: …11909779……..

piyushv

(Signature of Student)

Date: 27/03/2022

Certificate

This is to certify that the declaration statement made by this group of students is correct to the best of my knowledge and belief. They have completed this Project under my guidance and supervision. The present work is the result of their original investigation, effort and study. No part of the work has ever been submitted for any other degree at any University. The Project is fit for the submission and partial fulfillment of the conditions for the award of B.Tech degree in School of Computer science and Engineering from Lovely Professional University, Phagwara.

Signature and Name of the Mentor

Designation

School of Computer Science and Engineering,
Lovely Professional University,
Phagwara, Punjab.

Date : 27/03/2022

ACKNOWLEDGEMENT

The success and final outcome of learning, Machine Learning required a lot of guidance and assistance from many people and I am extremely privileged to have got this all along the completion of my course and few of the projects. All that I have done is only due to such supervision and assistance and I would not forget to thank them.

I respect and thank **Mr. Sagar Pande Sir** , for providing me an opportunity to do the course and project work and giving me all support and guidance, which made me complete the course duly. I am thankful to and fortunate enough to get constant encouragement, support and guidance from the faculty of Lovely Professional University, which helped us in successfully completing my course and project work.

Date :- 27/03/2022

Signature :- piyushdv

Name :- Piyush Vyas

Reg. no. :- 11909779

Abstract

Computers and phones may be more ubiquitous than ever, but many people still prefer the traditional feeling of writing with ink on paper. After all, this method served us well for hundreds of years of human history. Despite the availability of various technological writing tools, many people still choose to take their notes traditionally: with pen and paper. However, there are certain pitfalls in traditional way of handwritten text. It is difficult to store and access physical documents in an organised manner, search through them efficiently and to share them with others. Thus, handwriting recognition is the ability to interpret intelligible handwritten input from sources such as paper documents, touch-screens and other devices into digital form. A handwriting recognition system handles formatting, performs correct segmentation into characters, and finds the most plausible words. Hence, translating the handwritten characters to the digital format is gaining more popularity. With time the text on the paper will fade away but a file stored on a computer will be lost only if it is deleted. Storing any handwritten document in a digital format has gained prime importance.

Once the handwritten document is given as the input in the form of a high definition image, it segments each character in the image and identifies the letters. Further, the letters are identified and then goes on to detect the words in the image. This is performed with the aid of Machine Learning algorithms based on the training it has got from the training data. The expected output is to get a word document format of the given input image. The system can be trained by large data set of images that show the various styles and shapes in which people write. Machine Learning plays a very important role in training the system with huge data. This can be further used in organizations and companies that store important documents only in written format. It becomes easier and faster to complete the work with such a system available at hand.

The reliance of humans over machines has never been so high such that from object classification in photographs to adding sound to silent movies everything can be performed with the help of deep learning and machine learning algorithms. Likewise, Handwritten text recognition is one of the significant areas of research and development with a streaming number of

possibilities that could be attained. Handwriting recognition (HWR), also known as Handwritten Text Recognition (HTR), is the ability of a computer to receive and interpret intelligible handwritten input from sources such as paper documents, photographs, touch-screens and other devices [1]. Apparently, in this paper, we have performed handwritten digit recognition with the help of MNIST datasets using Support Vector Machines (SVM), Multi-Layer Perceptron (MLP) and Convolution Neural Network (CNN) models. Our main objective is to compare the accuracy of the models stated above along with their execution time to get the best possible model for digit recognition. Keywords: Deep Learning, Machine Learning, Handwritten Digit Recognition, MNIST datasets, Support Vector Machines (SVM), Multi-Layered Perceptron (MLP), and Convolution Neural Network (CNN).

Introduction

Handwritten digit recognition is the ability of a computer to recognize the human handwritten digits from different sources like images, papers, touch screens, etc, and classify them into 10 predefined classes (0-9). This has been a topic of boundless-research in the field of deep learning. Digit recognition has many applications like number plate recognition, postal mail sorting, bank check processing, etc. In Handwritten digit recognition, we face many challenges because of different styles of writing of different peoples as it is not an Optical character recognition. This research provides a comprehensive comparison between different machine learning and deep learning algorithms for the purpose of handwritten digit recognition. For this, we have used Support Vector Machine, Multilayer Perceptron, and Convolutional Neural Network. The comparison between these algorithms is carried out on the basis of their accuracy, errors, and testing-training time corroborated by plots and charts that have been constructed using matplotlib for visualization.

Handwritten papers are not perfect, and for one, they are difficult to read through. Handwriting recognition has been one of the challenging research areas in the field of image processing and pattern recognition in recent years. It contributes immensely to the advancement of the automation process and improves the interface between man and machine in numerous applications. Several research works have been focusing on new techniques and methods that would reduce preprocessing time while providing higher recognition accuracy[3,4]. Handwriting recognition is a challenging task because of many reasons. The primary reason is that different people have different styles of writing. The secondary reason is there are a lot of characters like Capital letters, Small.

The accuracy of any model is paramount as more accurate models make better decisions. The models with low accuracy are not suitable for real-world applications. Ex- For an automated bank cheque processing system where the system recognizes the amount and date on the check, high accuracy is very critical. If the system incorrectly recognizes a digit, it can lead to major damage which is not desirable. That’s why an algorithm with high accuracy is required in these realworld applications. Hence, we are providing a comparison of different algorithms based on their accuracy so that the most

accurate algorithm with the least chances of errors can be employed in various applications of handwritten digit recognition. This paper provides a reasonable understanding of machine learning and deep learning algorithms like SVM, CNN, and MLP for handwritten digit recognition. It furthermore gives you the information about which algorithm is efficient in performing the task of digit recognition. In further sections of this paper, we will be discussing the related work that has been done in this field followed by the methodology and implementation of all the three algorithms for the fairer understanding of them. Next, it presents the conclusion and result bolstered by the work we have done in this paper. Moreover, it will also give you some potential future enhancements that can be done in this field.

Literature Survey

Exhaustive research is being done in the field of image processing and Machine Learning towards handwritten recognition.

With the humanization of machines, there has been a substantial amount of research and development work that has given a surge to deep learning and machine learning along with artificial intelligence. With time, machines are getting more and more sophisticated, from calculating the basic sums to doing retina recognition they have made our lives more secure and manageable. Likewise, handwritten text recognition is an important application of deep learning and machine learning which is helpful in detecting forgeries and a wide range of research has already been done that encompasses a comprehensive study and implementation of various popular algorithms like works done by S M Shamim [3], Anuj Dutt [4], Norhidayu binti [5] and Hongkai Wang [8] to compare the different models of CNN with arXiv:2106.12614v1 [cs.CV] 23 Jun 2021 the fundamental machine learning algorithms on different grounds like performance rate, execution time, complexity and so on to assess each algorithm explicitly. [3] concluded that the Multilayer Perceptron classifier gave the most accurate results with minimum error rate followed by Support Vector Machine, Random Forest Algorithm, Bayes Net, Na¨ıve Bayes, j48, and Random Tree respectively while [4] presented a comparison between SVM, CNN, KNN, RFC and were able to achieve the highest accuracy of 98.72% using CNN (which took maximum execution time)

and lowest accuracy using RFC. [5] did the detailed study-comparison on SVM, KNN and MLP models to classify the handwritten text and concluded that KNN and SVM predict all the classes of dataset correctly with 99.26% accuracy but the thing process goes little complicated with MLP when it was having trouble classifying number 9, for which the authors suggested to use CNN with Keras to improve the classification. While [8] has focused on comparing deep learning methods with machine learning methods and comparing their characteristics to know which is better for classifying mediastinal lymph node metastasis of non-small cell lung cancer from 18 F-FDG PET/CT images and also to compare the discriminative power of the recently popular PET/CT texture features with the widely used diagnostic features. It concluded that the performance of CNN is not significantly different from the best classical methods and human doctors for classifying mediastinal lymph node metastasis of NSCLC from PET/CT images. However, CNN does not make use of the import diagnostic features, which have been proved more discriminative than the texture features for classifying smallsized lymph nodes. Therefore, incorporating the diagnostic features into CNN is a promising direction for future research. All we need is lots of data and information and we will be able to train a big neural net to do what we want, so a convolution can be understood as ”looking at functions surrounding to make a precise prognosis of its outcome.” [6], [7] has used a convolution neural network for handwritten digit recognition using MNIST datasets. [6] has used 7 layered CNN model with 5 hidden layers along with gradient descent and back prorogation model to find and compare the accuracy on different epochs, thereby getting maximum accuracy of 99.2% while in [7], they have briefly discussed different components of CNN, its advancement from LeNet-5 to SENet and comparisons between different model . The research outputs the LeNet-5 and LeNet-5 (with distortion) achieved test error rate of 0.95% and 0.8% respectively on MNIST data set, the architecture and accuracy rate of AlexNet is same as LeNet-5 but much bigger with around 4096000 parameters and ”Squeeze-and-Excitation network” (SENet) have become the winner of ILSVRC-2017 since they have reduced the top-5 error rate to 2.25% and by far the most sophisticated model of CNN in existence.

Methodology

The comparison of the algorithms (Support vector machines, Multi-layered perceptron and Convolutional neural network) is based on the characteristic chart of each algorithm on common grounds like dataset, the number of epochs, complexity of the algorithm, accuracy of each algorithm, specification of the device used to execute the program and runtime of the algorithm, under ideal condition.

Implementation

In this project we aim at building a mechanism that would recognize handwritten digits from the MNIST dataset. We have opted for the Image Correlation technique, also referred to as Matrix Matching. The goal of this project is to use the basic and simple concepts of this methods and see how good can we make the accuracy rate without using complex techniques such as machine learning. We have started the implementation of the program using a very simple and basic method, which is explained in further details under the section Version 1, then we have calculated its error rate. Afterwards, we have tried to spot the problems in the mechanism and find the limitations of the technique in order to improve it, and that is how we ended up with a second version of the program. We kept doing the same thing, each time trying to improve the previous version, which enabled us to keep improving the program and reach a higher accuracy and performance.

Machine Learning is a data analytics technique that teaches com-puters to do what comes naturally to humans and animals that learn from experience. Machine Learning algorithms use computational methods to learn information directly from data without relying on a predetermined equation as a model. The algorithms adaptively improve their performance as the number of samples available forlearning increases. Machine Learning has become a key technique for solving problems in areas, such asComputational finance : credit scoring and algorithmic trading Image processing and computer vision : face recognition, motion detection, and object detection Computationalbiology: tumor detection, drug discovery, and DNA sequencing Energy production: price and load forecastingAutomotive, aerospace, and manufacturing: predictive main-tenanceNatural language processing: voice recognition applications.

Machine Learning algorithms find natural patterns in data that generate insight and help to make better decisions and predictions. They are used every day to make critical decisions in medical diagnosis, stock trading, energy load forecasting, image processing and more.

Thus, it is needed to harness the power of Machine Learning to use data to make better decisions. MATLAB makes Machine Learning easy with tools and functions for handling big data, as well as apps to make Machine Learning accessible. MATLAB is an ideal environment for applying Machine Learning to data analytics. With MATLAB, engineers and data scientists have immediate access to pre-built functions, extensive toolboxes, and specialized apps for classification, regression, and clustering.

MATLAB lets us Extract features from signals and images using established manual and automated methods Compare approaches such as logistic regression, classification trees, support vector machines, nsemble methods, and deep learning. Apply AutoML and other model refinement and reduction techniques to create optimized models Integrate Machine Learning models into enterprise systems, clusters, and clouds, and target models to real-time embedded hardware. Perform automatic code generation for embedded sensor analytics.

The MatLab toolbox provides supervised and unsupervised Ma-chine Learning algorithms, including Support Vector Machines (SVMs), boosted and bagged decision trees, k-nearest neighbor, k-means, k- medoids, hierarchical clustering, Gaussian mixture mod-els, and hidden Markov models. Many of the statistics and Machine Learning algorithms can be used for computations on data sets that are too big to be stored in memory.

Data:

It is very necessary to know the kind of data we are using before we start the design and the implementation of the program. That is why we had to have a look at its format to understand how it is represented before creating the reference and the test set.

Dataset Format

The dataset that I have downloaded from the MNIST database contains 60,000 images of handwritten digits, from zero to nine, all grouped in one file. Each of the images is of size 28 by 28 pixels and represents a digit. I have noticed that there is no pattern or order to the way the images were organized in the file. The images are represented as matrices, of which the elements represent the pixels. Also, each image has a label that indicates the digit represented. This label was very helpful later on in order to be able to create the test set. Furthermore, the data did not contain noise or any major problems to deal with, that is why it was used without preprocessing it.

Test set

The program to be developed needs to be tested against some images that contain handwritten digits so as to be able to assess its performance and calculate its success rate. That is why it is very necessary to create a test set. The test set represents an example of the images containing the handwritten digits which will have to be compared to the images in the reference set so as to identify them.

This set was formed using the file from the MNIST database. The original file contained 60,000 images representing different digits. This made it difficult to look for each number using the label for the testing of the program. In order to make it easier to access each digit we want, we have decided to store a number of images from each digit in a separate file. That is why we have stored 20 images of each digit in ten different files. That is to say, the resulting test set was in the form of ten files, each one of them represents a digit and contains 20 images of it. These images were extracted from the initial file by reading them and their labels using Octave.

In order to make the manipulation of the matrices/images easier, we had to make some modifications in the elements of all the matrices representing the test set as well. The black pixels were originally represented as zeros, so they were left the same. As for the white ones, each of them had a different non zero number, so we turned them all into ones.

Software Tools:

Import the libraries and load the dataset:

First, we are going to import all the modules that we are going to need for training our model. The Keras library already contains some datasets and MNIST is one of them. So we can easily import the dataset and start working with it.
The **mnist.load_data()** method returns us the training data, its labels and also the testing data and its labels.

Preprocess the Data:

The image data cannot be fed directly into the model so we need to **perform some operations and process the data** to make it ready for our neural network. The dimension of the training data is (60000,28,28). The CNN model will require one more dimension so we reshape the matrix to shape (60000,28,28,1).

Train the model:

The **model.fit() function** of Keras will start the training of the model. It **takes the training data, validation data, epochs, and batch size.**
It takes some time to train the model. After training, we save the weights and model definition in the 'mnist' file.

Evaluate the Model:

We have 10,000 images in our dataset which will be used to **evaluate how good our model works**. The testing data was not involved in the training of the data therefore, it is new data for our model. The MNIST dataset is well balanced so we can get around 99% accuracy.

Result

After implementing all the three algorithms that are SVM, MLP and CNN we have compared their accuracies and execution time with the help of experimental graphs for perspicuous understanding. We have taken into account the Training and Testing Accuracy of all the models stated above. After executing all the models, we found that SVM has the highest accuracy on training data while on testing dataset CNN accomplishes the utmost accuracy. Additionally, we have compared the execution time to gain more insight into the working of the algorithms. Generally, the running time of an algorithm depends on the number of operations it has performed. So, we have trained our deep learning model up to 30 epochs and SVM models according to norms to get the apt outcome. SVM took the minimum time for execution while CNN accounts for the maximum running time.

This table represents the overall performance for each model. The table contains 5 columns, the 2nd column represents model name, 3rd and 4th column represents the training and testing accuracy of models, and 5th column represents execution time of model.

Furthermore, we visualized the performance measure of deep learning models and how they ameliorated their accuracy and reduced the error rate concerning the number of epochs. The significance of sketching the graph is to know where we should apply early stop so that we can avoid the problem of overfitting as after some epochs, change in accuracy becomes constant.

Conclusion

In this work, we have implemented three models for handwritten digit recognition using MNIST datasets, based on deep and machine learning algorithms. We compared them based on their characteristics to appraise the most accurate model among them. Support vector machines are one of the basic classifiers that's why it's faster than most algorithms and in this case, gives the maximum training accuracy rate but due to its simplicity, it's not possible to classify complex and ambiguous images as accurately as achieved with MLP and CNN algorithms. We have found that CNN gave the most accurate results for handwritten digit recognition. So, this makes us conclude that CNN is best suitable for any type of

prediction problem including image data as an input. Next, by comparing execution time of the algorithms we have concluded that increasing the number of epochs without changing the configuration of the algorithm is useless because of the limitation of a certain model and we have noticed that after a certain number of epochs the model starts overfitting the dataset and give us the biased prediction.

Future scope

The future development of the applications based on algorithms of deep and machine learning is practically boundless. In the future, we can work on a denser or hybrid algorithm than the current set of algorithms with more manifold data to achieve the solutions to many problems. In future, the application of these algorithms lies from the public to high-level authorities, as from the differentiation of the algorithms above and with future development we can attain high-level functioning applications which can be used in the classified or government agencies as well as for the common people, we can use these algorithms in hospitals application for detailed medical diagnosis, treatment and monitoring the patients, we can use it in surveillances system to keep tracks of the suspicious activity under the system, in fingerprint and retinal scanners, database filtering applications, Equipment checking for national forces and many more problems of both major and minor category. The advancement in this field can help us create an environment of safety, awareness and comfort by using these algorithms in day to day application and high-level application (i.e. Corporate level or Government level). Application-based on artificial intelligence and deep learning is the future of the technological world because of their absolute accuracy and advantages over many major problems.