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Comparative Analysis of Algorithms Used in Handwritten Digit Recognition

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Abstract - *Handwriting style differ from person to person. The handwritten digits are not always in the same width, size and orientation. In order to develop a system to understand this, includes a machine to recognize and classify the images of handwritten digits as ten digits (0 to 9). It is widely used by researchers for many applications such as computerized bank check numbers reading. Various machine learning and deep learning algorithms are used for this purpose. This paper focus on recognizing the handwritten digits i.e. 0 to 9 from the well-known MNIST dataset were 60000 samples are used for training the model and 10000 samples are used for testing the model. A comparative analysis of machine learning algorithms such as Decision tree, Logistic regression, k-nearest neighbors (KNN) and deep learning algorithm Convolutional Neural Network (CNN) is presented in this paper. In order to test the efficiency of these algorithm, the dataset is preprocessed and given as input to the algorithm and its precision, recall, f1 score and accuracy are found and compared.*

***Key Words*: *MNIST*, Decision tree, Logistic Regression, K Nearest Neighbor, CNN**.

1.INTRODUCTION

A digit recognition system is the functioning of a machine to recognize the digits from different sources like bank cheque, emails, papers, images, etc. The handwritten digit recognition is the capability of computers or machine to recognize digits that are handwritten by humans. In order to develop a system to understand handwritten digit, includes a machine to recognize and classify the images of handwritten digits as ten digits (0 to 9). The handwritten digits aren't always of equivalent size, width, orientation and justified to margins and the uniqueness and variety in the handwriting of different person also influence the formation and appearance of the digits

The idea of reading handwritten digit, characters and words by computer systems are often said to be an imitation of a human being. Artificial intelligence is used to read handwriting from any handwriting source or images. Artificial intelligence (AI) is one of the branches in computer science that deals with the simulation of intelligent behavior in computers. Machine Learning is an application of artificial intelligence which provides the system with the capability to automatically learn from the environment and use that learning to make better decisions. Deep Learning is a machine learning method that trains computers to do what easily falls into place for people: learning through examples [1]. It is a subset of machine learning. Machine learning models need human mediation in many cases to arrive at the optimal output. Deep Learning models use artificial neural networks which is inspired by the neural network of the human brain. It analyzes data with a logical structure similar to the way human would draw conclusions.

In this paper Machine Learning algorithms such as Decision Tree, Logistic Regression and K Nearest Neighbor are compared with deep learning CNN algorithm. The data set used for this is MNIST and precision and accuracy are found and compared.

2. RESEARCH METHEDOLOGY

2.1 Dataset

For this project, the dataset used is MNIST Dataset. Modified National Institute of Standards and Technology (MNIST) is a database which consist of handwritten digits. MNIST Database provides simple statics classification tasks for researchers to help them to analyze machine learning and pattern recognition techniques [2].

It consist of 60,000 examples as train set, and 10,000 examples as test set. It is a subset of a larger set that is available from NIST. The dataset is based on grey-scale images of handwritten digits where each image is of the form 28×28 pixel in height and width. Each pixel has a value associated with it where dark pixel is represented by 0 and a white pixel is represented by 255. Both the train and test dataset have 785 columns where the first column is 'label' which represents the handwritten digit (a number from 0 to 9) and the remaining 784 values represents pixel values. For testing the data is separated from labels to predict the value.

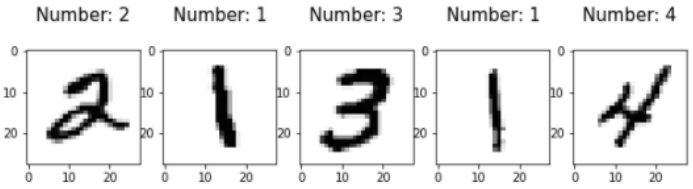

Fig -1: Sample images from MNIST test dataset

2.2 Decision tree

Decision Trees mimics the thinking ability of humans while making a decision, thus it is easy to understand. It is a supervised learning technique which is used for both regression and as well as classification problems. It is mostly used for solving classification problems. It is a tree-structured classifier, where the features of a dataset are represented by internal nodes. There are mainly two nodes, they are the leaf node and decision node. The decisions are in the leaves and the data is split in the decision nodes. Decision Tree has the following advantages: it is suitable for regression as well as classification problem, ease in interpretation, ease of handling categorical and quantitative values, capable of filling missing values in attributes with the most probable value, high performance due to efficiency of tree traversal algorithm [3].

To train the classifier, the preprocessed training dataset is fed as input to the Decision tree model. The guessed label or value is matched with the original label to obtain the accuracy of the classifier. After the training, the testing dataset is given to the classifier in order predict the labels and then the testing accuracy is obtained. The probability between the original data and the predicted data is represented with the help of confusion matrix. It is found that digit 1 has more successful predict rate and digit 5 has least successful predict rate. Accuracy, precision, recall and f1 score of each class (0-9) is found out with the help of classification matrix. The test dataset obtained about 86.6% accuracy using Decision tree classifier. Below fig 2 shows the confusion matrix obtained on test dataset using Decision tree model.

Fig -2: Confusion matrix using Decision tree on test dataset

The below table 1 shows the weighted average of precision, recall and f1 score obtained for the test data set using the Decision tree classifier.

Table -1: weighted average of precision, recall and f1 score using decision tree.

	Precision	Recall	f1 score
Weighed avg	0.87	0.87	0.87

2.2 Logistic regression

Logistic regression is mainly used to deal with classification problem. It is one of the most popular Machine Learning algorithms, which is a Supervised Learning technique. Using a given set of independent variables we can predict the categorical dependent variable with the help of this algorithm. It can be used to classify the observations using different types of data and can easily determine the most effective variables used for the classification [4]. Logistic Regression has the following advantages: simplicity of implementation, computational efficiency, efficiency from training perspective, ease of regularization [3].

Here also, the preprocessed training dataset is fed as input to the Decision tree model and train accuracy of the classifier is obtained. After the training, the testing dataset is given to the classifier and then the testing accuracy is obtained. Classification report is used to represent measures like precision, recall and f1 score of

each class (0-9). The algorithm obtained about 92.6% test accuracy.

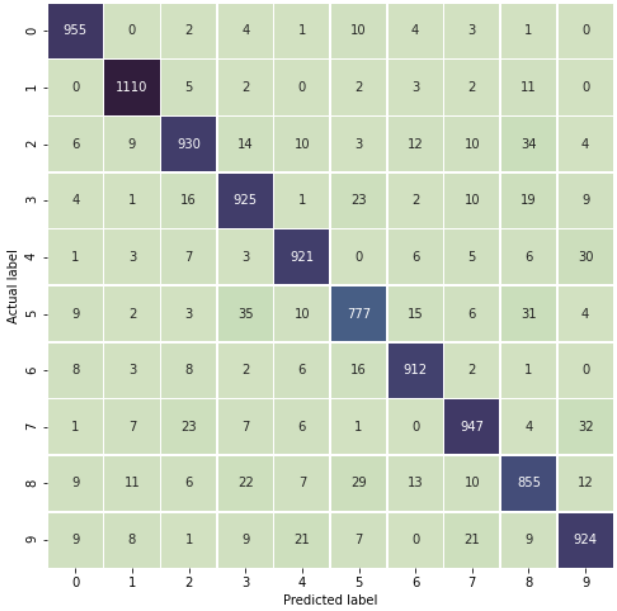

Fig -3: Confusion matrix using Logistic regression on test dataset

The below table 2 shows the weighted average of precision, recall and f1 score obtained for the test data set using the Logistic regression.

Table -2: weighted average of precision, recall and f1 score using Logistic regression.

	Precision	Recall	f1 score
Weighed avg	0.93	0.93	0.93

2.4 K Nearest Neighbor

K-Nearest Neighbor is one of the simplest Machine Learning algorithms which assumes the similarity between the new data and available data and put the new data into the category that is most similar to the available categories. During the training phase, it stores the dataset and when new data is added, it classifies that data into a category that is much similar to the new data. There are two main benefits of using KNN algorithm, that is, it is robust to noisy training data and it is very efficient if the data is very large in size [1]. KNN is a lazy learning algorithm, which means that it does not have specialized training phase and it uses all the data available for training. It is a non-parametric learning algorithm as it does not assume anything about the data. The algorithm is trained with train dataset and obtained about 96.89% test accuracy.

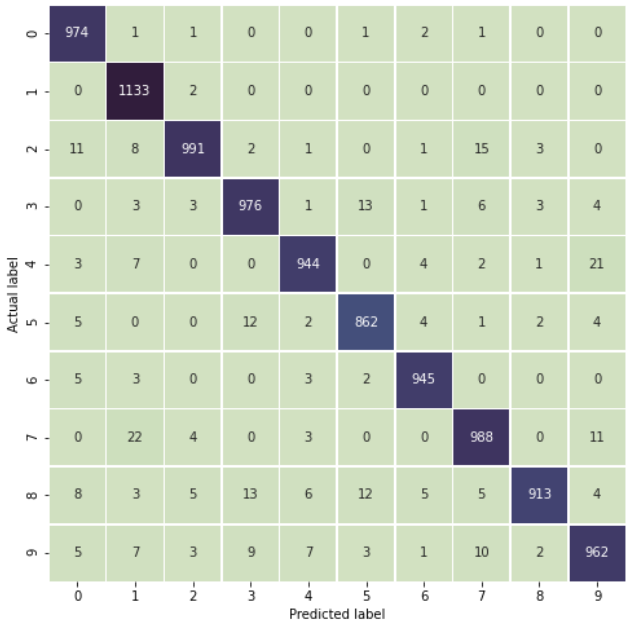

Fig -4: Confusion matrix using KNN on test dataset

The below table 3 shows the weighted average of precision, recall and f1 score obtained for the test data set using the K Nearest Neighbor.

Table -3: weighted average of precision, recall and f1 score using K Nearest Neighbor.

	Precision	Recall	f1 score
Weighed avg	0.97	0.97	0.97

2.4 Convolutional Neural Network

The convolutional neural network (CNN), is a specialized type of neural network model designed for working with two-dimensional image data, but also they can be used with both one-dimensional and three-dimensional data. The main idea of convolutional neural networks is to use alternating convolutional and subsampling layers and a multilayer perceptron at the output [5]. It takes an image as input, which is classified and process under a certain category. CNN is consist of an input layer, hidden layers, and an output layer. The hidden layers include a convolutional layer, dense layer etc.

In this project we have used about 8 hidden layers. These includes convolution, pooling, flatten and dropout layer. Two dropout layers are used to reduce over fitting of

data. We use batch size of 128 and 12 epochs. First epoch obtained training accuracy about 81.48% and then increased on next epoch. The model obtained about 99.9% training accuracy and 99% testing accuracy.

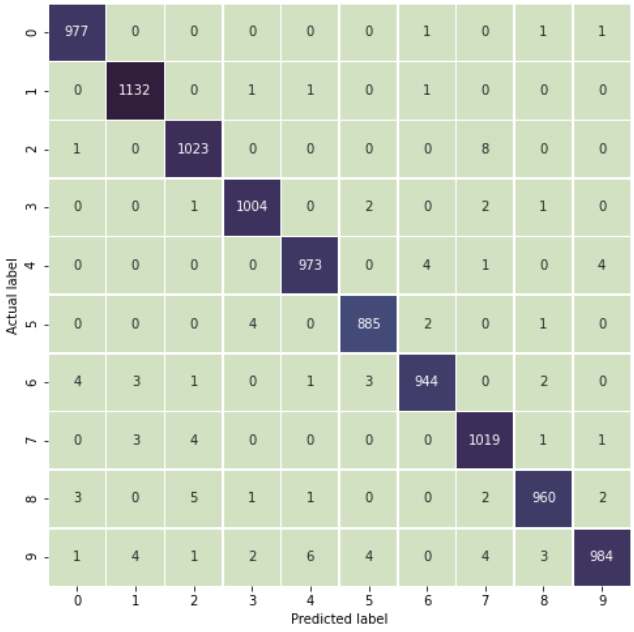

Fig -5: Confusion matrix using CNN on test dataset

The below table 4 shows the weighted average of precision, recall and f1 score obtained for the test data set using the CNN.

Table -4: weighted average of precision, recall and f1 score using CNN.

	Precision	Recall	f1 score
Weighed avg	0.99	0.99	0.99

3. CONCLUSIONS

In this paper handwritten digits from MNIST database are trained and tested using various Machine Learning algorithms such as Decision Tree, Logistic Regression, K Nearest Neighbor and deep learning CNN algorithm. 60000 samples are used for training the model and 10000 samples are used for testing the model. The models are compared based on their accuracy, precision, recall and f1 score.

For CNN we run about 12 epochs for training and at epoch 1 training accuracy was found to be 81.48% which increased to 99.9% on epoch 12. Table-5 shows the comparison of testing accuracies of the models. It is observed that CNN model took more time for training than machine learning models but gave better testing accuracy i.e. 99% compared to the other models. Considering the value predictions from all class (0-9) from confusion matrix, CNN predicts the value more accurately than other models. In Machine Learning Algorithms, K Nearest Neighbor turns out to give better model accuracy i.e. 96.8% and Decision tree algorithm showed poor performance with 86.8% test accuracy.

Table -5: Test accuracy of different model

Algorithm	Accuracy
Decision Tree	86.6%
Logistic Regression	92.6%
K Nearest Neighbor	96.89%
CNN	99%

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