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M Surekha, Riya Goyal, Ritika Sahu and Sumeet Singh

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Recognition of Handwritten Numbers Using Machine Learning and Deep Learning

Surekha M[1], Riya Goyal[2], Ritika Sahu[3], Sumeet Singh[4]
Department of Computer Science and Engineering, JSS Academy of Technical Education, Noida, Uttar Pradesh, India

[1]surekha@jssaten.ac.in
[2]goyalriya781@gmail.com
[3]ritikasahu535@gmail.com
[4]singhsumeet898@gmail.com

ABSTRACT: People are striving to use computers to complete the majority of their work as technology is improving daily. The process may involve classifying objects in pictures or giving silent movies sound. Deep learning and machine learning algorithms are able to do any of the above tasks. Similarly, recognizing handwritten text is a significant area of research and development with several potential applications. Handwriting recognition is the capacity of a system to identify & decode comprehensible handwritten input from various types of sources. Evidently, utilizing the MNIST datasets and the K Nearest Neighbor Algorithm(KNN), Support Vector Machines(SVM) Algorithm, Random Forest Classifier(RFC) Algorithm, and Convolution Neural Network models(CNN), we have provided an outline of handwritten digit recognition in this research. The accuracy of the models mentioned above, as well as how well they were implemented, will be compared in order to obtain the most reliable results.

1 INTRODUCTION

The capability of a computer to recognize human handwriting on numerous objects, including photos, documents, touch screens, etc. and sort them into the 10 distinct categories, I.e, from 0 to 9, is referred as handwritten digit recognition(HDR)[18]. Numerous studies in the area of DL have been centred on this. Processing bank checks, recognizing license plates, and sorting mail at the post office are a few of the applications for digit recognition. This document serves as an introduction to the models we'll be creating and the resources we'll need to use them. Additionally, it offers a literature review of earlier studies on handwritten digit recognition. Several ML techniques, such as KNN, SVM, and RFC will be compared to CNN. Using plots and charts created using the visualization tool matplotlib, these algorithms will be contrasted based on their precision, errors, and testing-training time. The accuracy of any model is vital since more precise models yield superior results. Low accuracy models are inappropriate for application in real-world circumstances.

In order to detect handwritten numerals, deep convolutional neural networks now exhibit accuracy comparable to that of humans. CNN has recently been one of the most appealing techniques, and it is the secret to current achievements as well as some challenging machine learning applications [19]. We chose CNN to solve the difficult problem of image classification based on all these considerations. The ability to read handwritten numbers can be applied to both business operations and higher education. Handwritten digit recognition can be used for a variety of purposes in our everyday lives. So, we will be comparing the Convolution Neural Network (CNN) with other machine learning methods. This work provides a decent grasp of ML and DL strategies such as CNN, RFC, SVM, & KNN for HDR. We will address similar research conducted in this area, methodology, and work flow in later portions of this

study. It then presents the verdict. It will also suggest some potential improvements that may be made in this area in the future.

2 RELATED WORK

The humanization of machine-related advancement and research has had a substantial positive impact on deep learning, machine learning, and artificial intelligence. Machines have improved the safety and management of human lives by becoming more advanced over time, from conducting basic math operations to retinal recognition. A lot of research has already been done on Handwritten Digit Recognition, and it involves a detailed examination and use of many well-known methods. The information in the table below will give us an overview of current studies in the area of handwritten digit recognition.

Table 1. Literature Survey.

Reference Number	Methodology	Advantages	Disadvantages
[1]	An input layer, an output layer, & five hidden layers make up the author's seven-layered convolutional neural network.	The highest training accuracy and highest verification accuracy were both 100% at epoch 15. Overall, the network was operational 99.21% of the time.	CNN does not factor the object's orientation or position into its estimates. They transfer all the data to a single neuron, which might not be equipped to handle it.
[2]	The authors compared SVM, MLP, and CNN.	Execution time is also calculated so that more accurate results in less time could be achieved.	SVM is faster algorithm but could not classify complex images accurately.
[3]	In order to make the real-world images more similar to MNIST raster images, the author presented a CNN model that was created to operate on real-world data.	The suggested approach has a 98% accuracy rate and could recognize actual photographs as well. The loss percentage is low, being less than 0.1 in both training and evaluation.	The noise that was present in the real-world photographs was the difficult aspect. After reaching training accuracy of 98.21% and validation accuracy of 98.51% with a 5% training loss and 4% validation loss, the model stopped learning at the second epoch.
[4]	WEKA has been used to recognize digits using MLP, SVM, Naive Bayes, Bayes Net, Random Forest, J48, and Random Tree.	They addressed both the feature extraction and correct classification approaches well in terms of time complexity and accuracy.	They achieved a Maximum accuracy only upto 90.37%.
[5]	CNN, OpenCV, Gaussian blur, CNN with some libraries like Keras, Matplotlib, CV2, Tensorflow.	CNN has high accuracy as compared to other algorithms. It makes the model very simple by reducing the number of variables.	It takes a lot of training data to be effective.
[6]	Multilayer perception (MLP) Neural Network.	It can handles large amount of input data.It makes quick prediction after training.	This is sometime inefficient because there is redundancy in such high dimension.

[7]	KNN, SVM, Neural Network, CNN, Object Character Recognition.	It has superior data security and it helps in increasing storage space.	There is chance of loosing the quality of the image during the process.
[8]	Quantum Computing, Grover Algorithm, K nearest Algorithm, CNN, Double Q learning Algorithm.	Machine learning algorithm and models are particularly effective in identifying or detecting patterns in various writing styles.	Any dataset other than the MATLAB dataset cannot provide good accuracy from the double Q learning technique.
[9]	The CNN model was used by the authors, who then adjusted the hidden layers and enhanced and regularized the picture data over the period of 20 epochs to track changes in accuracy.	They achieved the highest accuracy of 99.33% in training and the highest accuracy of 98.82% in testing when employing 3 dense layers.	They toggled only 2 parameters for variation observation. They used an image data augmentation technique that is incapable of handling pictures that have been rotated by more than 10 degrees.
[10]	A multi-layer, fully connected neural network (NN) with 10 and 12 hidden layers was created by the authors. The usage of automatically generated features rather than manually developed features is also highlighted by this paradigm.	An overall accuracy of 99.10%, 99.34%, and 99.70%, respectively, is attained by the multi-layer ANN (10), ANN (12), and CNN.	The authors could use some optimization techniques to improve performance of classification.

3 METHODOLOGY

The diagram of our suggested model was created to provide a summary of our investigation. Dataset is collected from the internet[11]. We shall first pre-process the data. The first phase in ML and DL is pre-processing, that aims to optimize the input data by removing undesired impurities and redundancies. All of the images in the dataset will be reshaped into 2-D images to make it simpler and decompose the input data (28,28,1). The input features will be normalized by modifying the dataset to a "float32" format and then divide it by 255.0 to make them range from 0.0 to 1.0 because the picture pixel values vary from 0 to 255. Then, each number will be classified using the one-hot encoding of the y values into 0s and1s. For instance, the output value 3 will be encoded as an array of 0 & 1 values, [0, 0, 1, 0, 0, 0, 0, 0, 0, 0]. The image dataset will then be split into training and testing groups. The remaining data will be chosen for testing after 60,000 updated data have been trained. On the MNIST dataset, machine learning and deep learning techniques including KNN, RFC, SVM, and CNN will be examined in order to evaluate our working scenarios for the suggested model. The working flow is illustrated below with the help of following diagram.

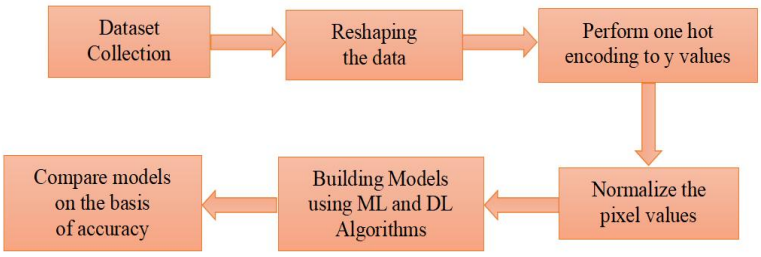

Figure 1. The working flow of our proposed system

3.1 *Dataset*

For the large research area of handwritten character recognition, detailed implementation strategies, such as enormous learning datasets, well-known techniques, scaling of characteristics, and methods for feature extraction are now accessible. We have chosen the MNIST dataset for our investigation. A lot of image processing algorithms are trained using this dataset of handwritten numbers. In the domain of machine learning, it is mostly utilized for training and testing. It is a big dataset with 60,000 training examples and 10,000 testing instances. The size of every image is always fixed at 28 by 28 pixels.

If anyone wishes to test learning and model recognition techniques on real-world data with minimal possible formatting and preparation work, MNIST is a great dataset. We take different techniques to use this MNIST database for various purposes. As previously mentioned, it is a reasonably straightforward database for quick testing of ideas and algorithms. Making less efforts for preprocessing and formatting will be a good place to start for us as the MNIST dataset already contains handwritten digits.

Figure 2. Visualization of the MNIST Test Dataset[20]

3.2 *K Nearest Neighbour*

A supervised machine learning approach for identifying unknown items is called K-nearest neighbour. It achieves this by examining the value k of its neighbouring item, which is already categorized. KNN is a form of image recognition system that divides an image into smaller parts that represent each character individually. It can recognize special characters as well. You can use this technique to differentiate the characters of different oral languages. It can also outperform NNs at situations involving stage order. A network type known as a NN learns and retains a specific pattern. It can also decide whether or not the input has a specific amount of digits. Finding the numerous input characteristics required for the KNN algorithm to function is the process of feature extraction. This action can increase the HCR recognition rate. Additionally, it can lessen misclassification. The major goal of this stage is to extract a set of features that can boost recognition rates.[17]

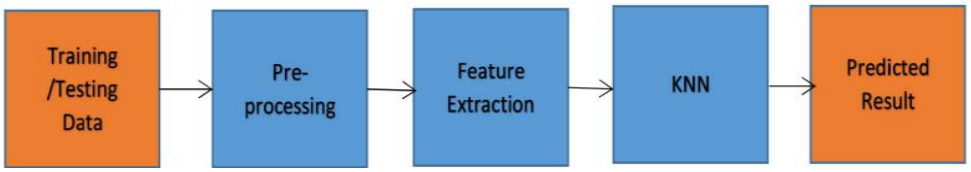

Figure 3. This figure shows the working of KNN.

3.3 *Support Vector Machine*

SVM is a ML algorithm for the supervised learning. The data points are frequently shown in n-D space, where n represents the number of attributes, and a particular position designates a feature's value. Obtaining the hyperplane that separates the two categories allows for classification to be completed.

Hyperplane will be chosen such that it divides the classes appropriately. SVM chooses the extreme vectors(referred to as support vectors) that help create the hyperplane. For the purpose of reading handwritten digits, we'll employ Linear SVM, which is one of the two types of SVM.[15]

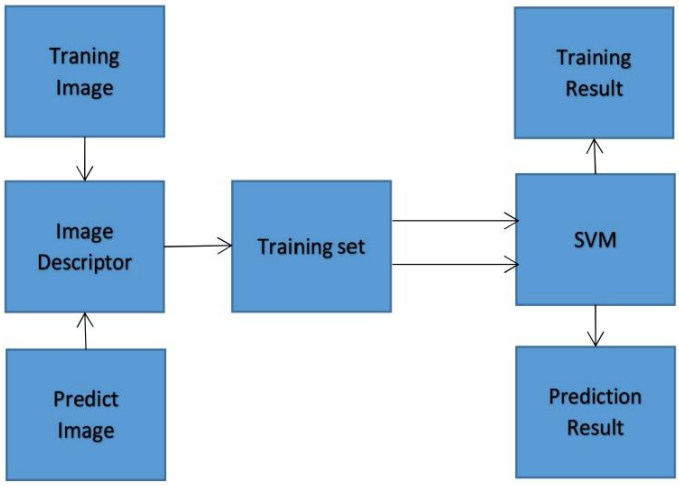

Figure 4. This figure represents the working of SVM.

3.4 *Random Forest Classifier*

Activated by bootstrap samples of the training data, random forest is an ensemble of un-pruned classification or regression trees that adopts random feature selection during the tree imitation process. By adding together the ensemble's predictions for classification via superiority voting, the forecast is formed. It provides generalization error rate and has a higher noise tolerance. However, just like most classifiers, RF could be plagued by the drawback of having to learn from a severely unbalanced training set. Since it is designed to reduce overall inaccuracy rates, it will typically place more emphasis on the accuracy of the majority class's predictions, which consistently leads to subpar performance for the minority class.[16]

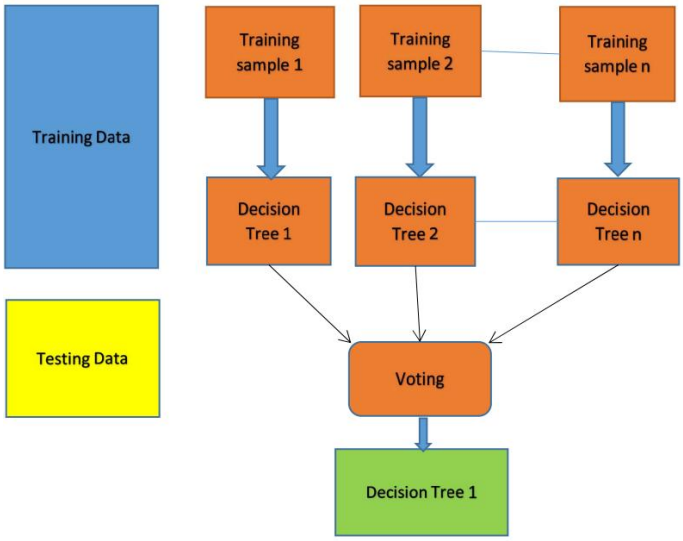

Figure 5. This figure shows the working of RFC algorithm.

3.5 *Convolutional Neural Networks*

A popular DL algorithm for classifying and recognizing images is CNN. A class of deep neural networks in this category need less pre-processing. Instead of entering an image one pixel at a time, it inputs the image in small pieces, which helps the network recognize ambiguous patterns (edges) in the image more

effectively. The three layers that make up CNN include an input layer, an output layer, and a number of hidden layers[12]. An array of weights serves as the filter (kernel) employed by CNN for extracting the data characteristics from the input picture. CNN employs a number of activation functions at each layer to introduce some non linearity [13]. As we enter CNN, we see that the dimensions are getting smaller while the number of channels is getting bigger. The output is predicted using the created column matrix [14].

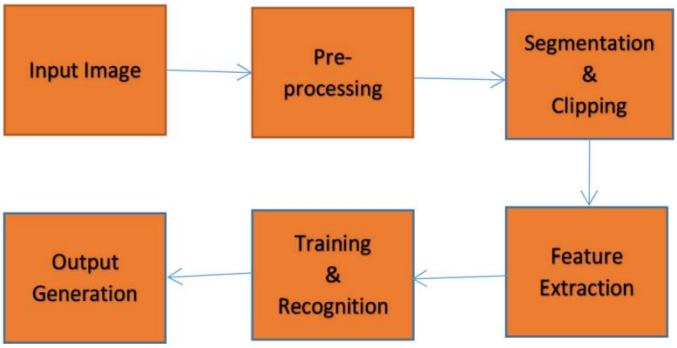

Figure 6. This figure shows the working of CNN

4 CONCLUSION

Considerable progress has been made in this area of research in the past. Our aim is to construct a model using the typical neural network that has been trained and tested on a substantial quantity of data having MNIST as the dataset. Obtaining a representation of individual handwritten digits that enables efficient detection is the major goal of this work. We will be using the MNIST datasets and develop a variety of ML and DL based models for HDR. To decide which model is the most precise among them, we will compare them on the basis of their individual qualities. Among the 70000 samples of digits in the MNIST dataset, we will use 60000 for training the model and the remaining 20,000 for testing to get the best results.

5 FUTURE SCOPE

Applications based on DL and ML algorithms have virtually infinite potential for future growth. In the future, we can develop a hybrid or denser algorithm with a wider range of data than the current algorithms to address a number of problems. This research intends to create a system for the categorization and identification of digits, but it might be used for handwriting. We may also extend it to produce more accurate results on colored images given that colored images may contain a range of border conditions. We may also attempt to build our models on databases with double-digit and letters to broaden their use and extend our implementation.

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