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Handwritten Digit Recognition Using Deep Learning

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Abstract: In order to meet the needs of paperless offices and greatly improve word efficiency, it is necessary to research and implement a handwritten digit recognition system. Handwritten digit recognition plays and important role in large-scale data statistics and the financial business, such as industry annual inspection, population census, tax statements and checks, etc. This project proposes a new type of handwritten digit recognition system based on convolutional neural network (CNN). In order to improve the recognition performance, the network was trained with a large number of standardized pictures to automatically learn the spatial characteristics of handwritten digits. For model training, according to the loss function, the convolutional neural continuously updates the network parameters with the data set in MNIST, which contains 60,000 examples. For model test, the system uses the camera to capture the pictures composed of the images generated by the test data set of MNIST and the samples written by different people, then continuously processes the captured graphics and refreshes the output every 0.5 seconds. With the trained deep learning model, we got a recognition accuracy of 99.3% in test process. Good performance in this experiment shows that our system can automatically recognize the handwritten digital content appearing in the target area and output the content label in real time.

Keywords: Digit Recognition, Deep Learning, Convolutional Neural Network (CNN), MNIST data set, Real-time recognition, Image processing, Machine learning

I. INTRODUCTION

In Character recognition is one of the traditional research fields of pattern recognition. Since the middle if the last century, many experts and scholars have continuously studied and developed this subject in this field. In particular, one of the problems with very high application value is the recognition of handwritten digits discussed in this article. For the recognition of numbers, everyone hopes that the higher the recognition accuracy, the better, because the recognition of numbers is slightly deviated, which may cause a big mistake, and the error cannot be detected through the context. So in some occasion, it may cause great losses, such as filling in checks and accounts in the financial industry. Handwritten digit recognition system plays an important role in large scale data statistics and the financial business, such as industry annual inspection, population census, etc. The main problems that affect the accuracy of recognition most are the various personal writing habits and no logical connection in the digital context. In recent years, with the development of artificial intelligence technology, handwritten digit recognition system based on deep learning can achieve higher accuracy than traditional feature extraction methods, such as Scale-Invariant Feature Transform (SIFT), Histogram of Oriented Gradient (HOG), Speeded - Up Robust Features (SURF) and 13-point feature extraction method etc. Those traditional feature extraction is based on hand-crafted methods. Generally, the extracted feature vector has a high dimensionality, so it needs to discard some unimportant dimensions through some dimensionality reduction method, such as principal components analysis(PCA).

Dimensionality reduction is often followed by pattern classification. There are many classification methods, the most common ones are SVM, nearest neighbour algorithm and so on. Obviously, traditional methods are very complicated and inefficient. With the development of neural network theory, many new methods that perform better have emerged, e.g., the Semantic Segmentation - Aware CNN Model. After realizing the powerful capability of CNN in target recognition, researchers widely utilize CNN in the sub-area of target recognition, e.g., image classification and text detection. This paper proposes a new type of handwritten digit recognition system based on convolutional neural network (CNN).In order to improve the recognition performance, the network was trained with a large number of standardized pictures to automatically learn the spatial characteristics of handwritten digits. For model training, according to the loss function, the

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convolutional neural network continuously updates the network parameters with the data set in MNIST, which contains 60,000 examples. For model test, the system uses the camera to capture the pictures composed of the images generated by the test data set of MNIST and the samples written by different people, the continuously processes the captured graphics and refreshes the output every 0.5 seconds.

II. RELATED WORKS

Handwriting recognition of characters has been around since the 1980s. The task of handwritten digit recognition, using a classifier, has extraordinary significance and use such as – online digit recognition on PC tablets, recognize zip codes on mail, processing bank check amounts, numeric sections in structures filled up by hand (for example - tax forms) and so on. There are diverse challenges faced while attempting to solve this problem. The handwritten digits are not always of the same size, thickness, or orientation and position relative to the margins. The main objective was to actualize a pattern characterization method to perceive the handwritten digits provided in the MNIST data set of images of handwritten digits (0-9).

Digit Recognition is a noteworthy and important issue. As the manually written digits are not of a similar size, thickness, position and direction, in this manner, various difficulties must be considered to determine the issue of handwritten digit recognition. The uniqueness and assortment in the composition styles of various individuals additionally influence the example andpresence of the digits. It is the strategy for perceiving and arranging transcribed digits. It has a wide range of applications, for example, programmed bankchecks, postal locations and tax documents and so on.

III. EXISTING SYSTEM

These days, an ever-increasing number of individuals use pictures totransmit data. It is additionally main stream to separate critical data from pictures. Image Recognition is an imperative research area for its generally used applications. In general, the field of pattern recognition, one of the difficult undertakings is the precise computerized recognition of human handwriting. Without a doubt, this is a very difficult issue because there is an extensive diversity in handwriting from an individual to another individual. In spite of the fact that, this difference does not make any issues to people, yet, anyway it is increasingly hard to instruct computers to interpret general handwriting. For the image recognition issue, for example, handwritten classification, it is essential tomake out how information is depicted onto images.

IV. PROPOSED SYSTEM

Proposed concept deals with providing data set in MNIST, which contains 60,000 examples. And we used Deep Learning calculation like multilayer CNN utilizing Keras with Theano and Tensorflow which can analyse with no limitation of data and simply calculates the data and get the results with less time, great accuracy. The Convolutional Neural Network algorithm is a supervised deep learning algorithm used for both classification and regression.

V. IMPLEMENTATION

The proposed Handwritten digit recognition using Deep Learning has different modules for working its efficient functionality. These modules help the systemto work efficient and also well in performance as well as in accuracy.

In this model we will have to import the dependencies that are required for the creation of this system and such will be numpy, Pandas, Matplotlib, Train_test_split, Conv2D, Tensorflow, Statistics, keras. Only byimporting these domains we will be able to train the data.

The dataset that is being used here is the MNIST digits classification dataset. Keras is a deep learning API written in Python and MNIST is a dataset provided by this API. This dataset consists of 60,000training images and 10,000 testing images. It is a decent dataset for individuals who need to have a go at pattern recognition as we will perform in just a minute. When the Keras API is called, there are four values returned namely- x_train, y_train, x_test, and y_test.

The language used here is python. I am going to use google colab for writing and executing the python code. You may choose a jupyter notebook as well. I choose google colab because it provides easy access to notebooks anytime and anywhere. It is also possible to connect a colab notebook to a GitHub repository.Also, the code used in this tutorial is available on this Github repository. So if you find yourself stuck someplace, do check that repository. To keep this tutorial relevant for all, we will understand the most critical code. In this we Use train_test_split() to get training and test sets which can control the size of the subsets with the correct parameters train_size and test_size.

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Data has to be processed, cleaned, rectified in order to improve its quality. CNN will learn best from a dataset that does not contain any null values, has all numeric data, and is scaled. So, here we will perform some steps to ensure that our dataset is perfectly suitable for a CNN model to learn from. From here onwards till we create CNN model, we will work only on the training dataset.

In the CNN model created above, there is an input layer followed by two hidden layers and finally an output layer. In the most simpler terms, activation functions are responsible for making decisions of whether or not to move forward. In a deep neural network like CNN, there are many neurons, and based on activation functions, neurons fire up and the network moves forward. If you do not understand much about activation functions use 'relu' as it is used most popularly.

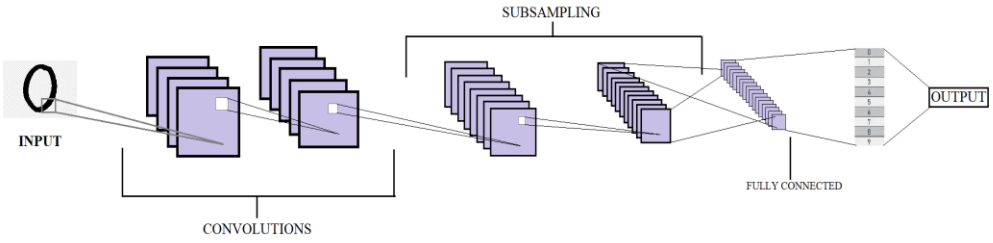

Fig. 1 Architecture diagram

Once the model has been created, it is time to compile it and *fit themodel*. During the process of fitting, the model will go through the dataset and understand the relations. It will learn throughout the process as many times as has been defined. In our example, we have defined 10 epochs. During the process, the CNN model will learn and also make mistakes. For every mistake (i.e., wrong predictions) the model makes, there is a penalty and that is represented in the loss value for each epoch. In short, the model should generate as little loss and as high accuracy as possible at the end of the last epoch.

The convolutional_neural_network model to make predictions for the test dataset and store it in the y_predicted_by_model dataframe. For each of the 10 possible digits, a probability score will be calculated. The class with the highest probability score is the prediction made by the model.

VI. RESULTS

An epoch is one complete forward and backward passage of data in the neural network. With the change in the number of epochs, the difference in the accuracies can be observed in the below table 1.

Number of epochs	Trained Data Accuracy (%)	Test Data Accuracy (%)
1	93.6	97.7
2	97.4	98.0
3	98.1	97.9
4	98.6	98.0
5	98.9	98.4
6	99.1	98.3
7	99.1	98.3
8	99.2	98.5
9	99.3	98.3
10	99.4	98.4

Table 1: Difference in the accuracies

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From the below figure 2, it can be clearly observed and stated that the increase in the number of epochs increases the Trained Data Accuracy. It can benoticed that for epoch=1, the accuracy is about 93.6% and as the number of the epochs is increased to 10 the accuracy is also increasedto 99.4%.

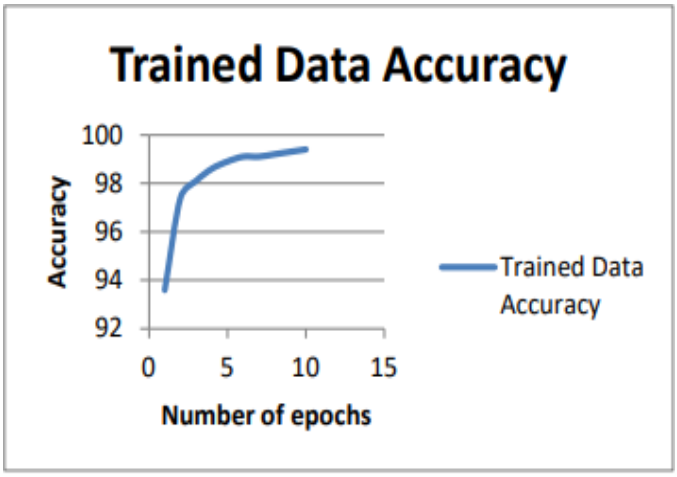

Fig. 2 Trained Data Accuracy

In CNN, the change in the number of epochs also impacts the cross- entropy loss and it can be seen in the below figure 8. As the number of epochs isbeing increased there is a gradual reduction in the cross-entropy loss. Initially, for epoch=1 that is the input data is passed only once then there is a loss ofabout 0.2 and for epoch=10 it can be seen that the loss is reduced to 0.01.

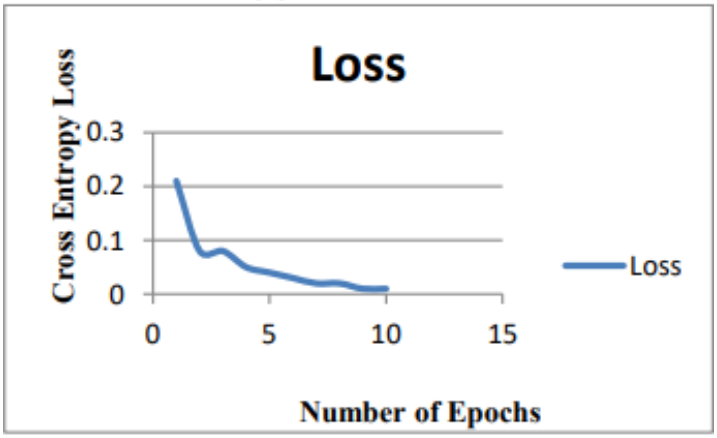

Fig. 3 Cross Entropy Loss

VII. CONCLUSION

In this paper, the performances of the algorithms like SVM, KNN, and CNN are analyzed and compared. Using Tensorflow, CNN has achieved an accuracy of 99.4% on trained set whereas 98.4% on test data. Similarly, it is observed that KNN has yielded the least accuracy of about 97.1% on the trained data and 96.7% on the test data.

The SVM classifier has achieved 97.9% trained data accuracy and 97.6% test data accuracy. Therefore, it can be concluded that CNN tends to give better performance for this handwritten digit recognition process.

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