Handwritten Digit Recognition Based on Convolution Neural network

M. Gopikrishna[1] , B. Samatha[2]
[1,2]Department of Computer Science and Systems Engineering
Andhra University College of Engineering, Andhra University, Visakhapatnam, AP, India

Abstract: Human perception is much more robust than the machine's in dealing with rotated and noisy patterns. Recognizing the handwritten digits is the most difficult task in computer vision. Handwritten digit recognition is gaining more and more fame because of its potential range of applications like bank cheque analysis, recognizing postal addresses on postal cards, etc. Handwritten digit recognition plays a prominent role in day to day life, like in a form of recording of information and style of communication even with the addition of new emerging techniques. This paper proposing convolutional neural networks to recognize handwritten digits. Furthermore, data augmentation technique with a stacked architecture is proposed to improve the accuracy of the digit recognition. The main aim of the proposed system is to improve the accuracy of the prediction by decreasing the loss percentages.

***Keywords*:- Artificial Neural networks, Deep Learning, Convolution Neural network, Data Augmentation.**

I. Introduction

Handwritten digit recognition is one of the most challenging tasks in image processing and pattern recognition. digits which are written in various formats are easy to understand by the human but it is hard to understand by the machines as the written style changes from person to person. Handwritten digit recognition is gaining popularity because many potential application areas which it's being used such as to recognize zip code or postal code, mail sorting, bank cheque processing, vehicle license plate recognition. Handwritten digital recognition mainly identifies 10 characters(0-9), and the classification category is much less than optical character recognition. Digit recognition is a process of detecting and recognition digits from the input image and convert it into appropriate machine editable forms. Constructing a system for digit recognition is a challenging task for the researchers due to the various shapes of digits that includes a large set with curves, loops, thickness, orientation size. There are many digit pairs which are similar in shape but some digits are having similarity between them such as 1 and 7, 8 and 9, 5 and 6. Based on the input to the system, handwritten digit recognition can be categorized into online and offline recognition. The movements of a pen on a pen-based software screen surface were used to provide input into the system designed to predict the handwritten Digits in online recognition. Meanwhile, the offline mode uses an interface such as a scanner or camera as input to the system. Offline mode uses an interface such as a scanner or camera as input to the system. Although there are various image processing techniques designed, the fact that the handwritten digits do not follow any fixed image recognition pattern in each of its digits makes it a challenging task to design an optimal recognition system. The neural network has been widely used in character recognition because of its strong self-learning ability, adaptive ability, classification ability, fault tolerance, and fast recognition. With the development of deep learning, convolutional neural network has been widely used in image processing. In this paper, convolution neural network with Data Augmentation is studied and verified on the MNIST dataset.

II. Literature Review

Yawei Hou and Huailin Zhao proposed multi-layer feedforward neural network to obtain higher recognize rate of the digits. The main feature of the network is the forward signal transmission and error backpropagation[1]. Mahmoud M. Abu Ghosh and Ashraf Y. Maghari implemented Different deep learning

models to compare the accuracy of the algorithms. This paper concluded that among the implemented algorithms DNN has given more accuracy with 98.08%[2]. Caiyun Ma and Hong Zhang proposed an effective handwritten digit recognition approach based on specific multi-feature extraction and deep analysis. This paper fuse multiple features into the deep neural networks for semantics recognition[3].The aim of Saeed AL-Mansoori is to implement a Multilayer Perceptron to recognize and predict handwritten digits from 0 to 9. The dataset was trained using gradient descent back-propagation algorithm and further tested using the feed-forward algorithm. The system performance is observed by varying the number of hidden units and the number of iterations[4]. Single layer neural network classifier with Principal Component Analysis (PCA) is used by the Vineet Singh for digit recognition.

The Principal Component Analysis (PCA) is used for feature extraction to curtail the computational and training time and at the same time produce high accuracy[5]. A pattern recognition system based on the n-tuple technique is developed and evaluated for use in classifying non-deterministic data with particular reference to unconstrained hand-written numerals[6]. Juan Manuel Alonso-Weber and M. Paz Sesmero presented work based on a relatively modest sized Neural Network trained with standard Back Propagation and combined with a set of input pattern transformations. Applying ensemble averaging on the trained Neural Networks gives an encouraging error rate of 0.34% measured on the MNIST dataset[7]. In this work, Adriano Mendes Gil, Cícero Ferreira Fernandes Costa Filho2 use SVM binary classifiers coupled with a binary classifier architecture, an unbalanced decision tree, for handwritten digit recognition. Two classifiers were trained and tested. One using digit characteristics and the other using the whole image as input variables[8].

Ankita Mishra and D.S.Singh focused on different methods of handwritten digit recognition that uses both feature extraction techniques and neural network approaches and presented a comparative analysis while discussing the pros and cons of each method[9]. Selection of classifiers plays a very important role in achieving the best possible accuracy of classification. Gauri Katiyar developed an efficient Support Vector Machine based off-line handwritten character recognition system. Experiments have been performed using well known standard database acquired from CEDAR[10]. Anka Ignat and Bogdan proposed a method that combines basic image processing techniques such as rotations and edge filtering in order to extract digit characteristics[11]. This paper implemented the model using K-NN and SVM classifiers[11][12].

III. Methodology

Data collection

The MNIST dataset of the handwritten digit was used for training and testing. The dataset contains 60000 training set and 10000 test set images. Each image is of size 28 x 28 pixel grayscale image. The handwriting of individual personnel can influence the prediction as a digit can be written in different ways. The training set and the test set were kept distinct to help the network learn from the training dataset and thereafter predict the test set. The count by each digit in the training dataset is shown in the Fig.1.

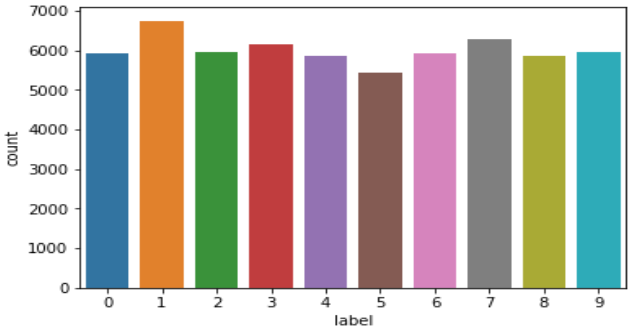

Fig.1. Count of digits in the training dataset

Data Preprocessing

Dataset needs to be normalized to eliminate noise in the data and to get all the dataset in a fixed format. After normalization, each sample is normalized and centered in 28 x 28 pixel grayscale image resulting in a total of 784 pixels per image. The images were further normalized by simply dividing each pixel by 255 resulted in pixel between 0 to 1. The sample preprocessed digit is shown in Fig 2.

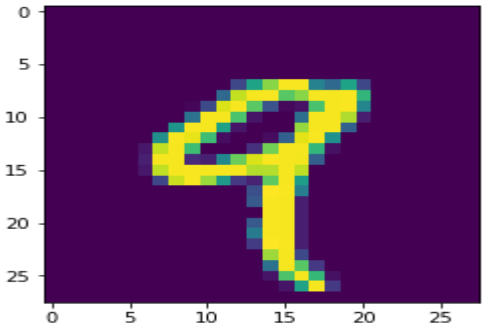

Fig.2 Sample digit

Neural Network

A neural network is an information processing unit which is inspired by the biological nervous system such as a brain. It consists of a huge number of highly interconnected processing elements called as neurons working in coordination to solve specific problems. The main objective of the neural network is to process information and solve the problem in the same way as the human brain does. This paper proposing the Convolution neural network classifier in combination with Data Augmentation for handwritten digits recognition. It consists of an input layer, a hidden layer, and an output layer. The network propagates from layer to layer until output pattern is obtained in the output layer. If the actual output and desired pattern are different, then the error is calculated. CNN extracts features from the image using convolution layer, pooling layer, and dense layer. The architecture of the proposed model is given in Fig3.

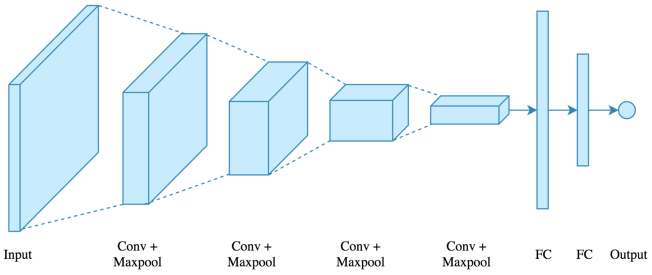

Fig.3 CNN architecture

The convolutional layer is the main building block of CNN it is a mathematical operation to merge two sets of information. The proposed system applies the convolution on the input data using a convolution filter to produce a feature map. The system performs multiple convolutions on the input, each using a different filter and resulting in a distinct feature map. The pooling operation reduces the number of parameters, which both shortens the training time and combats overfitting. Pooling layers downsample each feature map independently, reducing the height and width, keeping the depth intact. The system uses the Dropout to prevent overfitting. During training time, at each iteration, a neuron is temporarily "dropped" or disabled with probability p. This means all the inputs and outputs to this neuron will be disabled at the current iteration. The dropped-out neurons are resampled with probability p at every training step, so a dropped out neuron at one step can be active at the next one.

Experimental Setup

- Windows 10
- Python 3.6
- Jupyter notebook
- I5 processor
- Ram 12gb

IV. Results

The proposed algorithm is trained and tested against the data from the MNIST database and the accuracy and errors of the model are shown in bellow tables.

Table.1 Performance of the algorithm

Epochs	Train Accuracy	Test Accuracy
20	99.34	99.12
100	99.87	99.52

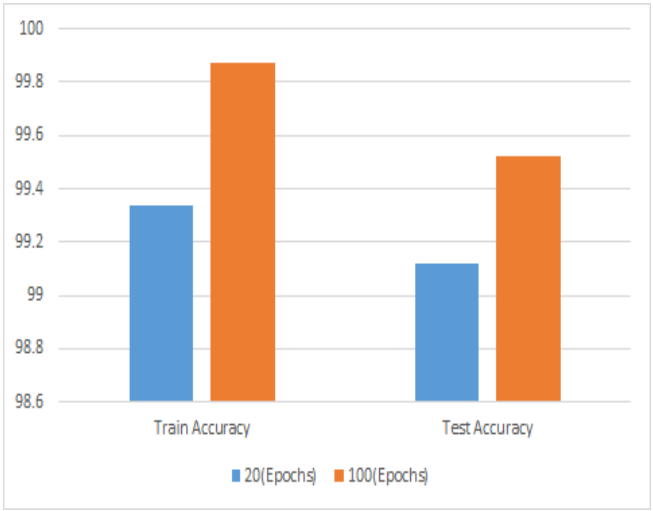

Fig.4 Performance of the model with different epochs

From the above figure, it is seen that the Convolution neural network improving its performance by increasing the number of epochs. The model can achieve 100 percent if we can increase the no of epochs. The no of failures by the model to detect digits is given in Table2.

Table.2 No of failures by the model

Epochs	CNN without Data Augmentation	CNN with Data Augmentation
20	57	47
50	50	38
100	35	29

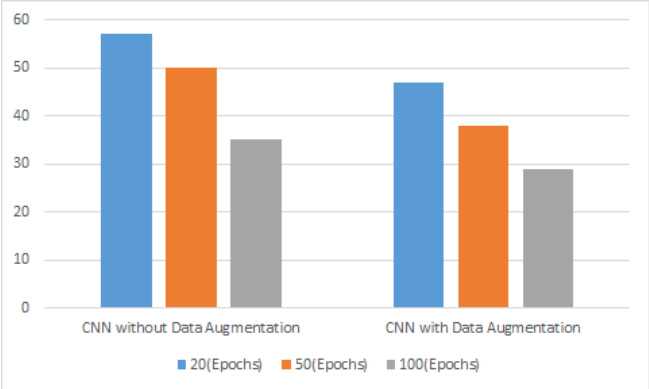

Fig.5 no of errors with different epochs

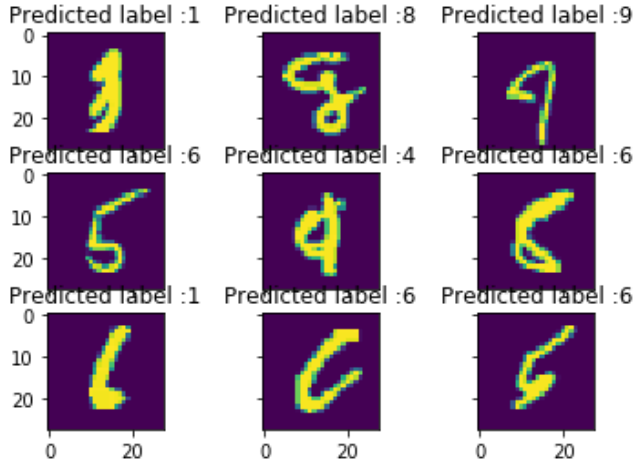

Fig.6 Sample errors

The above fig.6 referencing true and predicted digits of the dataset. Further errors can be reduced if we can increase the number of epochs. Train and Test Loss values of the model are given in below figure 7 and 8.

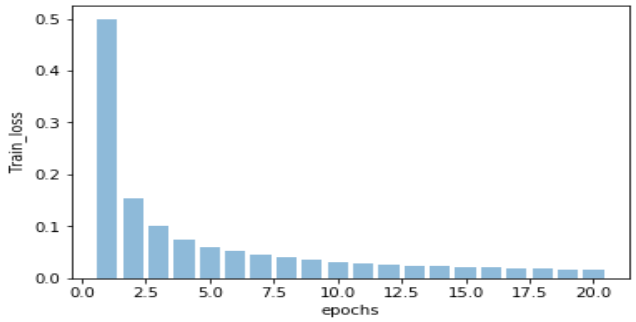

Fig.7 Train loss

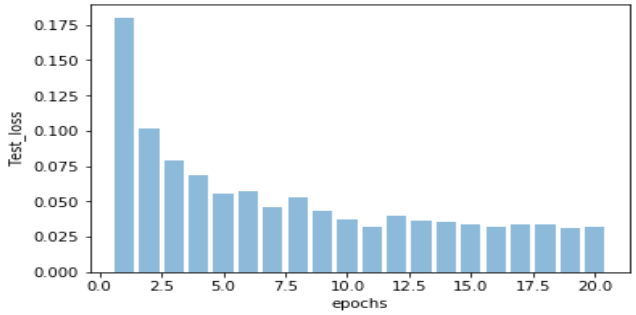

Fig.8 Test loss

V. Conclusion

In this paper, we implemented the Convolution neural network algorithm to recognize the digits. To improve the accuracy of the algorithm and to reduce the error rate we proposed the data augmentation technique. The results showed that CNN has improved its accuracy of the recognition with data augmentation technique.

References

[1] Yawei Hou, Huailin Zhao, "Handwritten Digit Recognition Based on Depth Neural Network, " in International Conference on Intelligent informatics and Biomedical Sciences, 2017.

[2] Mahmoud M. Abu Ghosh, Ashraf Y. Maghari, "A Comparative Study on Handwriting Digit Recognition Using Neural Networks, " in International Conference on Promising Electronic Technologies, 2017.

[3] Caiyun Ma, Hong Zhang, "Effective Handwritten Digit Recognition Based on Multi-feature Extraction and Deep Analysis," in 12th International Conference on Fuzzy Systems and Knowledge Discovery, 2015.

[4] Saeed AL-Mansoori, “Intelligent Handwritten Digit Recognition using Artificial Neural, ” 2015.

[5] Vineet Singh, and Sunil Pranit Lal, “Digit Recognition Using Single Layer Neural Network with Principal Component Analysis, ” 2014.

[6] Mazin Al Hadidi, Rami Salim Rzouq, “Handwritten digits recognition using digital learning networks, ” in International Future Computer Supported Education,2012.

[7] Juan Manuel Alonso-Weber, M. Paz Sesmero, “Handwritten Digit Recognition with Pattern Transformations and Neural Network Averaging, ”in International Conference on Artificial Neural Networks, 2013.

[8] Adriano Mendes Gil, Cícero Ferreira Fernandes Costa Filho2, “Handwritten Digit Recognition Using SVM Binary Classifiers and Unbalanced Decision Trees, ” in International Conference on Image analysis and REcognition, 2014.

[9] Ankita Mishra, D.S.Singh, “Handwritten Digit Recognition Using Neural Network Approaches and Feature Techniques: A Survey” 2016.

[10] Gauri Katiyar, Shabana Mehfuz, “SVM based off-line handwritten digit recognition, ” in IEEE annual India Conference, 2015.

[11] Anka Ignat, Bogdan Aciobanitei, “Handwritten Digit Recognition Using Rotations, ” in 18th International Symposium onSumbolic and Numeric Algorithms for Scientific Computing, 2016.

[12] Eva Tuba, Nebojsa bacanin, “An algorithm for handwritten digit recognition using projection histograms and SVM classifier, ” in 23rd telecommunications Forum Telfor, 2015.