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Intelligent Handwritten Digit Recognition Based on Multiple Parameters using CNN

Vidushi[1*], Manisha Agarwal[2]

[1,2]Banasthali Vidyapith, Rajasthan, India

Corresponding Author: vidushi_vidushi.mtech@gmail.com, Tel.: +91-8700409410

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***Abstract*—** In the computer vision, pattern recognition is a wide area to study. Handwritten digit recognition is an important research topic of pattern recognition. There are various ways to write any digit. To recognize it is a challenging task. This paper shows the effective results of handwritten digit recognition on well-known, reliable handwritten digit database using CNN (Convolutional Neural Network). In the current scenario, the convolution neural network (CNN) shows a remarkable success in most of the computer vision and recognition tasks. CNN is well-known feed-forward architecture important for object recognition. We have tested our work on MNIST database. In this paper we analyzed the accuracy using CNN depending on different parameters like Number of hidden layers, Number of CNN layers, Number of neurons in each layer, Number of iterations and on the optimizer that we are using optimize the result. Aim of this paper is to know how the accuracy varies due to changes in these parameters. Increasing or decreasing the number of parameters leads to change in the performance. These results demonstrate the advantage or effect of different parameters on the result.

***Keywords*—** CNN(Convolution Neural Network), MNIST(Modified National Institute of Standards and Technology), Deep learning, ANN(Artificial Neural Network).

I. INTRODUCTION

Researchers are doing their research work in handwritten digit recognition [15,41]. This is a very vital and plays crucial role in the field of pattern recognition [10,14,16,20]. Every person has different handwriting style means handwriting changes from person to person. Due to the variation in the writing style, writing recognition becomes wide and important area for researchers. The style of writing digits from 0 to 9 also varies from person to person and a number of writing style are available. In this paper emphasis is on recognising the hand written digit recognition. There are number of techniques are available to recognize this task such as k-Nearest Neighbor (k-NN) [9,10] Support Vector Machine (SVM) [20] Principal-Component-Analysis (PCA) [3,34] or Gabor wavelets [21,35] Deep learning [1,19,26] etc. Deep learning is the latest technique to accomplish this task. It is one of the fields of Machine Learning [4,37] which is base on how to learn data, as we learn from our childhood. The inspiration of deep learning is biological nervous system. How are brain works? How different neurons are connected to each other? How the information flow? Of course these are very complicated questions but Artificial Neural Network (ANN) [7,15,22] is trying to solve these questions and also trying to make machine to think as a human brain. Deep learning models are based on the ANN [7,15,28]. ANN works on number of layers and each layer consists of number of artificial neurons. These artificial neurons are connected with the edges and each edge has weight to adjust the learning process. A number of tasks can be done by using ANN. These are as follows:

1. Machine Translation[6]
2. Speech Recognition[13]
3. Computer Vision[10,20]
4. Pattern Recognition[8]
5. Forecasting[14,18]
6. Social Networks[16]
7. Medical Diagnosis[17]
8. Games, etc[19]

There are number of uses or areas where we can apply the concept of ANN. Depending on the type of work and desired output there are number of ANN. Different ANNs are implemented by using different mathematical operations and a number of different parameters to get the desired result. Widely used different ANNs are as follows:

1. Feed-forward Neural Network [21.39]
2. Radial basis function Neural Network [7,22]
3. Kohonen Self organising Neural Network [15,22]
4. Recurrent Neural Network(RNN) – Long Short Term Memory [29]
5. Convolutional Neural Network(CNN) [11,12,26]
6. Modular Neural Network [5,36]
7. Multilayer Perceptron [15,22]

All these Neural Network have their respective advantages and disadvantages. The basic neural network [7,21,23] work basically depends on input, weight, bias and the activation function used. Following figure 1 depicts their relationship:

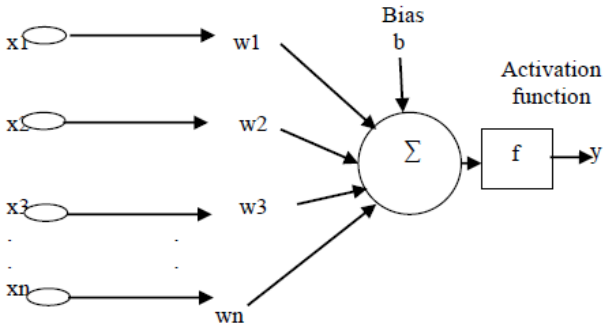

Figure 1. A Simple Neural Network

The equation of the Simple Neural Network [2] is

$$Y=f(\sum_{i=1}^{i=n} x_i w_i + b) \quad (1)$$

Where,
Y is the output of neural Network.
f is the Activation function
x_i is the set of input (x1, x2, … xn)
w_i is the weight corresponding to each input x_i
b is Bias.

Actually in Neural Network we apply the Activation function on the sum of products of inputs and their corresponding weights. There are a number of Activation functions that can be used on different layers according to the need. These functions affect the output. Some of them are as follows:

1. Sigmoid or Logistic function[24]
2. Tanh – Hyperbolic tangent[25,26]
3. ReLu – Rectified linear units[26,27]

All these functions are used according to the need or requirement of output.

To get the desired output we need to adjust the weight and bias. This technique of weight adjustment is called optimization. To train the neural network there are number of optimizers. Some of these are:

1. Gradient Descent[28,39]
2. Adam[29,39]
3. AdamDelta[30,39]

The basis function of all the mentioned optimizers is to optimize the result. This paper used 3 different optimizers one by one on well-known dataset MNIST using CNN model [7,31,32]to recognize the accuracy of handwritten digit.

A number of different parameters can affect the result. These are:

1. Optimizer used,
2. Number of hidden layers,
3. Number of CNN layer,
4. Number of iteration, etc

There are many other parameters that can affect the result but we concentrate on above mentioned only.

A. CNN (Convolutional Neural Network)

CNN is similar to normal neural network [28,33]. Like the normal neural CNN also made up of neurons, can have multiple hidden layers, and adjust weight and biases to achieve the max possible accuracy and use the cost function. To optimize the result it uses optimizer. Apart from this, CNN can have one or more CNN layers [28,34,35]. CNN has taken the biological inspiration through visual cortex. Basic steps of CNN are:

1. Take the input (image)
2. Pass it through one or more convolutional layer/s (convolutional + nonlinearity)
3. Pooling
4. Then through fully connected layers
5. Output

The main task of CNN is the image/object/digit/pattern classification or recognition. CNN can be used for single feature and multi feature extraction. CNN [28,39,40] is able to recognize more than one object in a single picture. It is very beneficial approach to work on the pattern recognition field.

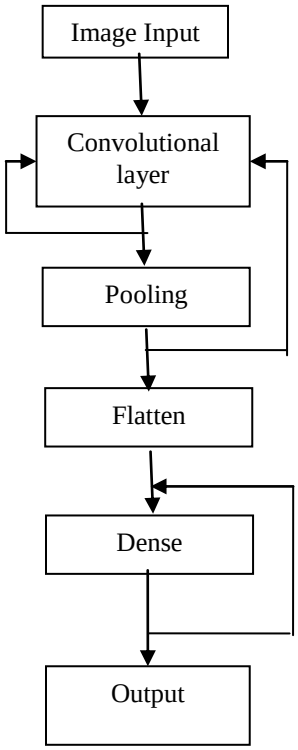

Figure 2. Working steps of CNN

1. Convolutional Layer: It is a first layer of CNN. Feature extraction from the images starts from this

layer. Any image or digit is made up of collection of pixels. These pixels have relationship with each other. CNN decrease the image size but the relationship between the pixels not loose. It means it decreases the complexity of image without losing relationship between the pixels.

2. Pooling: This layer is inserted after convolutional layer but this is not a compulsory layer. The paper used it to reduce the computational complexity and to solve the over fitting problem.
3. Flatten: It converts the Matrix (2D array) into 1Darray and send it as an input to dense layer.
4. Dense: It is a set of fully connected layers. It is fully connected to know the actual effect.

B. MNIST Dataset

MNIST dataset is very famous and widely used in Machine Learning. It stands for Modified National Institute of Standards and Technology database [8,33]. It is used to train and test the data. It has 60,000 training and 10,000 testing images. It is a reliable resource and used by many scientists in their research work. Each sample image size is 28X28 and vector size is 1X784.

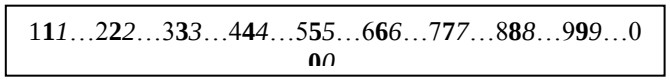

Figure 3. MNIST Dataset image [38,41]

C. Optimization

This helps us to get the optimized result. It uses some function to adjust the Weight (w) and Bias (b) with some learning parameters (Ƞ). Optimizing solution means to minimize the loss. Some of the important Optimizers are:

1. Gradient Descent [34],[35]: It uses the following formula:

$$\theta = \theta - \text{Ƞ}.\nabla J(\theta) \quad (2)$$

formula for updating parameters
Where,
Ƞ is learning rate,
$\nabla J(\theta)$ is Loss function wrt θ.

2. AdamDelta [36][40]:

$$\theta(t+1) = \theta(t) + \Delta\theta(t) \quad (3)$$

Where,

$$\Delta\theta(t) = -\text{Ƞ} \cdot g(t,i) \quad (4)$$

Where,
g (t,i) is the partial derivative wrt parameter θ (i) at time step t.

3. Adam [36],[35]:

$$\theta(t+1) = \theta(t) - (\text{Ƞ} / ((v(t)^{1/2} + \varepsilon))*m(t) \quad (5)$$

Where,
m (t) is mean

$$m(t) = mt/(1-\beta_1(t)), \quad (6)$$

v (t) is uncertain variance

$$v(t) = v(t)/(1-\beta_2(t)) \quad (7)$$

β_1 is 0.9,
β_2 is 0.999,
ε is $(10)^{-8}$

There are so optimizers present that we can use like Adagrad, RMSprop, Nadam, AMSGrad, AdaMax, etc. All these use some mathematical formula. This research concentrates on only 3 optimizers i.e. Gradient Descent, AdamDelta, Adam. This research emphasised on how these optimizers with some other change in parameters shows difference in desired output.

II. EXPERIMENTAL RESULT

This paper analysed the effect of different parameters on the result. How the accuracy of our desired result varies wrt these parameters. The experiment is done using Python language, which is the most effective language in machine learning. How the handwritten digits can be recognised efficiently depends on various parameters that are shown through the experiment performed in this paper.

A. Optimizer used:

This paper is done using 3 optimizers Gradient Descent, Adam and AdamDelta. In this we fixed other parameters like number of CNN layers, Number of hidden layers, number of iterations/epocs. We have used:
Number of Hidden Layers: 01,
Number of CNN layers: 02,
Number of Iterations: 12, and
Number of Neurons/dense layer: 128.

Table 1. Analysing using Optimizer

Optimizers	Gradient Descent	Adam	AdamDelta
Accuracy	0.9903	0.9939	0.9913
Test loss	0.0304	0.0246	0.0266

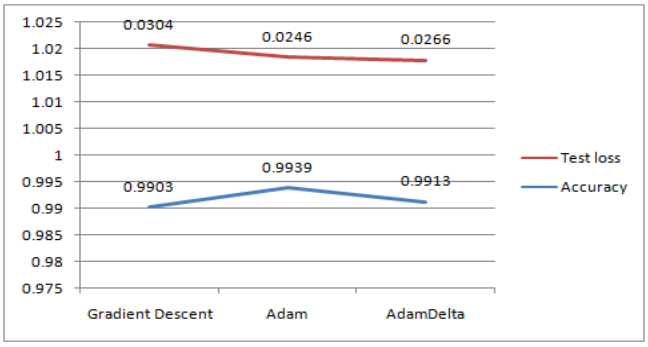

Figure 4. Optimizers v/s Accuracy/Test loss

B. Number of Hidden or Dense Layer used:

Here this paper analysing the result by changing number of hidden layers and keeping other parameters constant.
Number of CNN layers: 02,
Number of Iterations: 12, and
Number of Neurons/dense layer: 128.

Table 2. Number of Hidden Layers effecting Result

Optimizers	Number of Hidden Layers	Accuracy	Test loss
Gradient Descent	1	0.9903	0.0304
	2	0.9905	0.0303
	3	0.9907	0.0308
Adam	1	0.9939	0.0246
	2	0.9896	0.0443
	3	0.9908	0.0471
AdamDelta	1	0.9913	0.0266
	2	0.9913	0.3205
	3	0.9891	0.0419

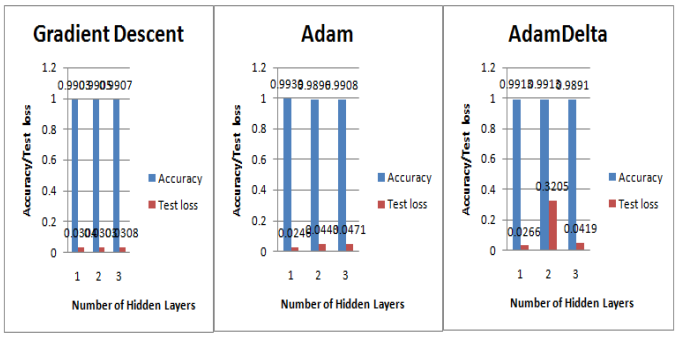

Figure 5. Number of Hidden layers v/s Accuracy/Test loss

C. Number of CNN Layers used:

By changing the number of CNN layers, this research analysed the results. The other parameters are kept constant.
Number of Hidden/Dense layers: 01,
Number of Iterations: 12, and
Number of Neurons /dense layer: 128.

Table 3. Number of CNN layers effecting Result

Optimizers	Number of CNN Layers	Accuracy	Test loss
Gradient Descent	1	0.983	0.0462
	2	0.9918	0.0262
	3	0.9917	0.0254
Adam	1	0.9881	0.0386
	2	0.9919	0.0277
	3	0.9942	0.0239
AdamDelta	1	0.9871	0.0382
	2	0.9926	0.0231
	3	0.9924	0.0258

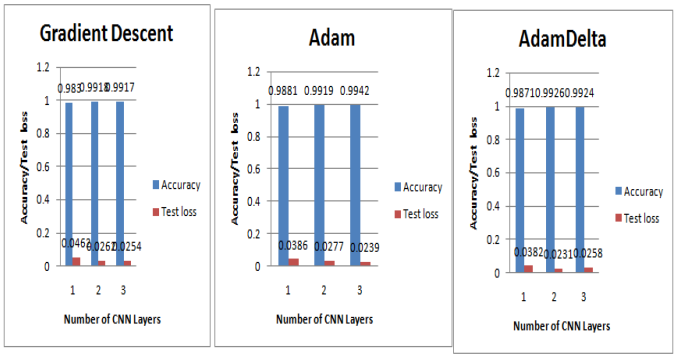

Figure 6. Number of CNN layers v/s Accuracy/Test loss

D. Number of Neurons/Dense layer:

This research experiment for analysing the result by changing in number of Neurons per Dense Layer and rest of the factors are kept constant.
Number of CNN layers: 02,
Number of Hidden/Dense layers: 01, and
Number of Iterations: 12

Table 4. Number of Neurons/Dense layer effecting Result

Optimizers	Number of Neurons/Dense layer	Accuracy	Test loss
Gradient Descent	128	0.9903	0.0304
	256	0.9918	0.0262
AdamDelta	128	0.9913	0.0266
	256	0.9926	0.0261

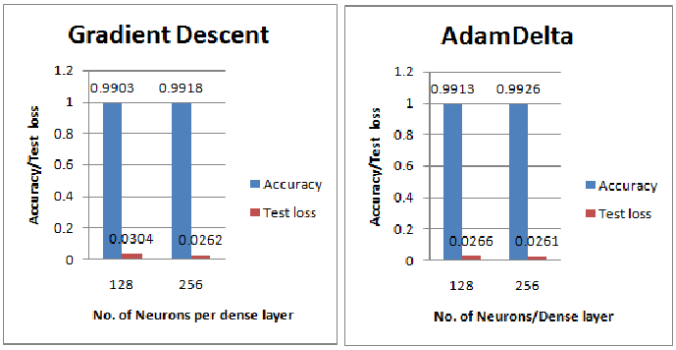

Figure 7. No. of Neurons/Dense layer v/s Accuracy/Test loss

III. CONCLUSION

In this paper, tested how different parameters affect the handwritten digit accuracy in deep learning. To select the appropriate parameters according to dataset the paper is using is also a challenging task. Here this paper clearly show that how changing in these important factors can affect the result. It can effectively use in the further research in the Pattern recognition area. CNN is the well-known area for pattern/image/handwritten digit recognition technique. Our result shows how different parameters affect the desired output. This paper concludes the following:

1. By keeping all the parameters constant, Adam optimizer shows better result on MNIST dataset to recognize the digit.
2. By changing the Number of hidden layers and CNN layers, the result varies. It concludes that not always result improves by increasing the hidden layers or CNN layers.
3. Increasing number of Neurons per layer shows effective good results with both the optimizers' i.e AdamDelta and Gradient Descent.

We know that there are other parameters also which can affect the desired output. But this paper provides the baseline in this field.

IV. FUTURE WORK

This paper can be further use in improving the Accuracy in digit recognition field. We have used only 3 optimizers but there are many more and a new one can be developed which shows better result than the existing one. Improvement in recognition is still a challenge. We need a machine which can recognize like the human being. This paper also shows a numbers of parameters which should be keep in mind while recognizing pattern using CNN or any other Artificial Neural Network.

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Authors Profile

Ms. VIDUSHI pursed MTech from Guru Gobind Singh Indraprastha University, Delhi, India in 2012. She is currently pursuing Ph.D. from Banasthali Vidyapith. She has 6.5 years of teaching experience. She qualified National Elligibility Test (NET). She also qualified Graduate Aptitude Test Engineering (GATE) two times. She is also a member of ACM (Association for Computing Machinery). She has written papers in the field of Artificial Neural Network, Fuzzy Logic, and others.

Dr. Manisha Agarwal is an Associate Professor in Banasthali Vidyapith. She pursed her Ph.D from Banasthali Vidyapith. Her specialized areas are High Performance Computing, Operating System, RTS, Cloud Computing, Web Technologies, Data Base and Data Mining.

