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Scalable Handwritten Digit Recognition Application using Neural Network and Convolutional Neural Network On Heterogeneous Architecture

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Abstract*:Recognition of handwritten digit is one of the popular problem associated with computer vision applications. The goal of our research work is to develop scalable Neural Network(NN) and Convolutional Neural Network (CNN) model that would be able to recognize and determine the handwritten digits from its image. Capability of developing the new algorithms and improve the existing algorithms is determined by the accuracy and speed factor for training and testing the models. In this context, performance of the GPUs and CPUs for handwritten digit system and effects of accelerating the training models have been analyzed. The training and testing has been conducted from publicly available MNIST handwritten database. Web based, offline and online handwritten digit recognition system is developed by using Convolutional Neural Network

***Index Terms*: Neural Network(NN), Convolutional Neural Network (CNN), Handwritten Digit, Scalable.**

I. INTRODUCTION

Handwritten digit image recognition is quite useful in various day to day work applications such as recognition of ZIP code in sorting postal mails, processing of various forms, handwritten digits recognition of banking instruments like cheques and drafts, etc.

Many research papers are involved with handwritten digit recognition which using various techniques to classify the data such as Neural Network, Support Vector Machine, Convolutional Neural Network (CNN), Hidden Markov Model and other techniques [1]. Handwritten digit image recognition further required to be improvised in order to make offline recognition simpler with respect to dynamic information. Dynamic data and information always varies in terms of rotation, size, thickness of strokes, deformation etc. Hence offline web based handwritten digit recognition poses new challenges which needs to be thoroughly studied [2].

Neural network is a knowledge enriching unit inspired by the neurological system functioning of the human brain. It comprises of large number of inter-connected refining elements referred as neurons, works in synchronized way to solve distinct problems. Purpose of neural networks is to process the information and solve the problem similar to human brain functioning [3]. Neural network theory is applied in various applications such as classification of the data, recognition of patterns, learning rate identification and recognition rate. Neural networks uses hidden layers, which plays important role in producing the outcome of pattern recognition. Size of the hidden layers plays important role in the classification of digits. Neural network's output layer is very much dependent upon the input layer and the hidden layers [4].

CNN is a popular framework of deep learning. One or more layers of convolution layers with sub sampling, that are further followed by fully connected layers similar to standard neural network are always present in CNN. Common types of layers that are associated with CNN are pooling/sub sampling layers and fully connected layers [5].

In this research we used a CNN to recognize the numbers from the handwritten number entered on the html canvas. The user writes the number to the html canvas and uploads it to the server. Images uploaded on the server are analyzed by image classification processor using Convolutional Neural Network. The image processor determines the number in the image by the stored learning result and returns the recognized number.

II. RELATED WORK

Performance of the various machine learning approaches like K-Nearest-Neighbor(KNN), Neural Network(NN) and Decision Tree(DT) are compared by Hayder Naser Khraibet Al-Behadili [6]. These are used for the HWDR using MNSIT datasets. Usage of MNSIT dataset is found in the relevant research literature.

D. Ciresan et al suggests that the performance, about 0.27% error rate or 27 errors in the full 10,000 test set, is achieved by a committee of convolutional nets [7].

Proficient and accelerated simulated neural network system for manually written digit recognition acknowledgement over the GPU to minimize preparation time with Parallel Training method were exhibited by Viragkumar Et. Al [8].

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A. Sharma et al has the main step which is image processing and next to use Neural Network for pattern recognition. For image processing, captured images are converted into 16 x 16 pixels and transformed into a gray scale image.
Datasets of images contain 1,000 handwritten digits with 100 images of each digit that are used to train and test in Neural Network.
Their work used a logistic regression algorithm to get the best probability of scanned images and got approximately 90% accuracy in the results [9]
Gradient Descent Back Propagation algorithm was used to develop Neural Network Training by Y.Perwej and A. Chaturvedi. This system gave the best recognition accuracy of 94% and the worst recognition accuracy of 64%. The average accuracy of this system is 82.5%. Therefore, this system needs a lot of training epochs to get higher accuracy[10]
H. A. Alwzwazy et. al used Convolutional Neural Network in the classification step. They began with collecting dataset of digits from students in the different study levels of school. There are 46,612 samples which 36,612 samples are used for training and 10,000 samples for testing. Next, an input image is resized into 64 x 64 pixels of RGB and provided to Convolutional Neural Network with randomly initialized by using Gaussian distribution. In Convolutional Neural Network, this paper separated into three main parts which the first part is feature maps and cropping image. Two fully-connected layers are used next to the first part and softmax layer gave the classification results in the final. Their work gave the highest recognition accuracy of 95.7% in a result [11].
The accuracy point was mainly focused in related works. Our research work objective in this context is to analyze handwritten digit recognition system on the execution time factor and accuracy factor.

III. MNSIT DATASET

MNIST dataset is used to train and test hand-written digit recognition application. The MNSIT dataset comprises of 60,000 labeled training set and 10,000 labeled test set. Keras deep learning library is used to import the MNSIT data set [12].

IV. NEURAL NETWORK ARCHITECTURE

- Three layered neural network architecture comprises of an input layer of 784 neurons, hidden layer of 32 neurons and output layer of 10 neurons.
- Multi-class classification is achieved through Softmax activation function.
- Model is trained with a batch size of 128 with the help RMSprop learning algorithm.

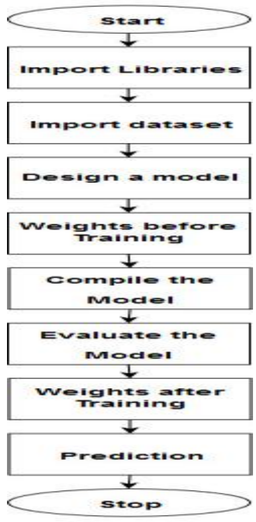

Figure 1: Flow diagram of Neural Network Architecture

V. CONVOLUTIONAL NEURAL NETWORK ARCHITECTURE

CNN model built using Keras Sequential API with the help of architecture listed below.

- Using ReLU activation functions and Three Conv2D layers with 32 and 64 filters each for Kernel_size=(3,3) and padding='same'.
- Every Conv2D layer is then followed subsequently by a MaxPooling2D layer with a pool_size=(2,2).
- Multi-class classification is achieved through Softmax activation function and 10 output classes are mapped with Dense layer.
- The built model is compiled with categorical_crossentropy loss and adam optimizer.

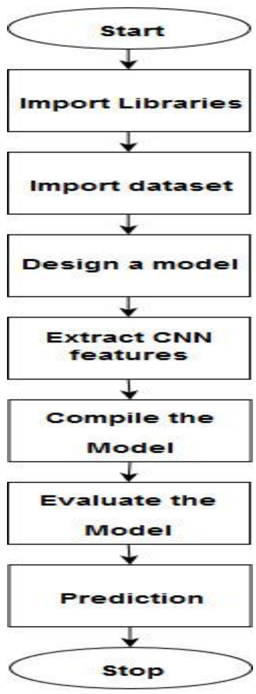

Figure 2: Flow diagram of Convolutional Neural Network Architecture

VI. EXPERIMENTAL RESULT & DISCUSSION

For the experiment below devices are used

CPU Processor: 8th Gen Intel Core i5-8300H processor @ 2.3 GHz
CPU memory (RAM): 8 GB
GPU Device: NVIDIA GeForce GTX 1080

The model proposed has been evaluated considering the factors listed below.

i) Accuracy
ii) Execution Time

Results of NN based handwritten digit recognition on CPU and GPU is shown in Table 1. It is observed that three layered neural network yields 92.53% accuracy. This is the highest possible accuracy with three layered neural network yet cannot be accepted as optimal accuracy, because better results than this can be achieved using other methods. Results of CNN based handwritten digit recognition on CPU and GPU is shown in Table 2. To achieve better results CNN based system is implemented using Keras Framework, that yields 98.42% accuracy. Convolution layer utilizes filter matrix in place of array of image pixels, performs the operation of convolution and delivers convolved feature map. The learning speed is slow as CNN involves complex matrix calculation

Table 1: Comparison of NN based handwritten digit recognition on CPU and GPU

Neural Networks(NN)				
Epoch No	Accuracy (CPU)	Spent time (CPU) (seconds)	Accuracy (GPU)	Spent Time (GPU) (seconds)
1	90.71	13	90.61	2
2	91.50	12	91.48	1
3	91.78	12	91.75	1
4	92.10	12	92.10	1
5	92.28	13	92.24	1
6	92.35	12	92.32	1
7	92.40	12	92.38	1
8	92.46	12	92.42	1
9	92.50	12	92.48	1
10	92.53	12	92.50	1

Table 2: Comparison of CNN based handwritten digit recognition on CPU and GPU

Convolutional Neural Networks(CNN)				
Epoch No	Accuracy (CPU)	Spent time (seconds) (CPU)	Accuracy (GPU)	Spent time(GPU) (seconds)
1	96.40	71	95.56	5
2	97.10	74	96.67	4
3	97.36	75	97.21	4
4	97.59	77	97.30	4
5	97.68	77	97.68	4
6	97.95	77	97.80	4
7	98.06	77	97.78	4
8	98.15	77	97.89	4
9	98.09	77	97.90	4
10	98.42	76	98.10	4

The training time can reduced by using GPUs as Keras support built-in data parallelism. Keras based CNN achieves 19 times faster per epoch when GPU is used.

VII. PROPOSED APPLICATION MODULE

CNN based handwritten digit recognition learned model is used identify the digits. Canvas of html is used for the test drawing and xampp is installed for local server system. The pictures made by canvas as shown in figure 3 are loaded on the server and the server program identifies the pictures and outputs the results to the requester.

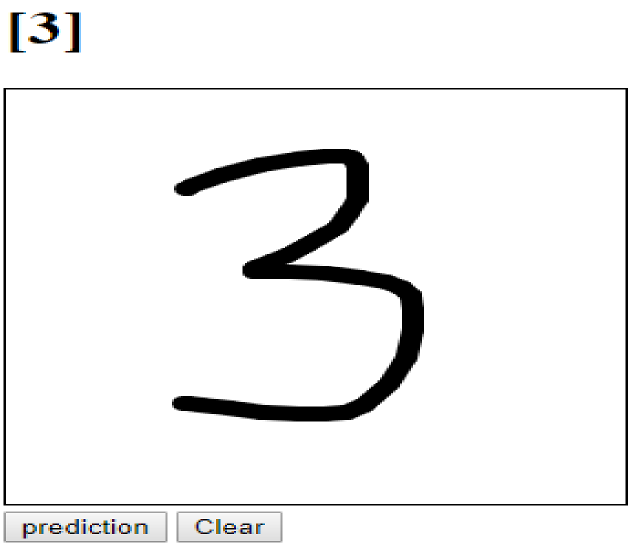

Figure 3 : Canvas based handwritten digit recognition system

(Part of upload_data.php)
$pyscript = 'D:\xampp\htdocs\handwriting\prediction.py';
$python = 'C:\Users\admin11\AppData\Local\Programs\Python\Python36\python.exe';
$filePath = 'D:\xampp\htdocs\handwriting\test.png';
$cmd = "$python $pyscript $filePath";
print exec($cmd);

User input also can be given to identify the handwritten digit recognition system. Converting the image into gray scale and resizing is achieved through cv2 library. JSON and HDFS is used to save and load the model.

VIII. CONCLUSION

Hand written digit recognition system is developed with the help of NN and CNN architectures and analyzed by MNSIT data set. Optimal accuracy is not possible with system based on NN. In terms of execution time, NN based system yields optimal accuracy. Optimal accuracy of 98.42% on MNSIT data set is achieved by implementing Keras based CNN handwritten digit recognition. When CNN is used, the network training time takes longer time due to increase in convolution layers. In order to decrease the testing time and the training time, it becomes necessary to use GPU.

Data parallelism and scalability is achieved through Keras framework. Future work requires further studies associated with deep learning frameworks and optimization techniques.

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