Journal of Advanced Zoology

ISSN: 0253-7214
*Volume **44** Issue **S-6 Year 2023** Page **531:536***

Comparison on Logistic Regression, Random Forest, and CNN for Handwritten Digit Recognition

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Article History

Received: 06 June 2023
Revised: 05 Sept 2023
Accepted: 29 Nov 2023

Abstract

The technology of handwritten digit and character recognition is the process of identifying handwritten numbers using computers or other devices, machine train itself to recognize the handwritten digits or characters from various sources like bank cheque, mails, images, etc. This paper is about CNN, Logistic Regression, and Random Forest algorithm in handwritten digit or character recognition system, the system works on MNIST dataset for training and testing the models, to get the best accuracy this work rewrites CNN, Logistic Regression, and Random Forest with python libraries. Finally, these algorithms are analyzed by comparing the accuracy and recognition duration. Where CNN got better accuracy than other algorithms.

Keywords: *Logistic Regression, Random Forest, CNN, MNIST, handwritten digits, recognition.*

1. Introduction

In today's digital age, there are even now documents which are written with hands for safety purpose. A bank cheque is an example of such documents. Similarly, there are different forms being filled by hands. There are a lot of ancient documents that are written by hand and need to be stored in typed form to be easy to read. In such aspects, handwritten digit recognition is very helpful. Online Handwriting recognition is a research field that has the potential to greatly enhance human-computer interaction. [1]. Deep learning is an essential part of machine learning which entirely functions with the help of advanced algorithms inspired by the frame and functionality of the brain (precisely neurons) called artificial neural networks. It illustrates to be precise, how human neurons run data and generate various patterns to form an intelligible decision. Deep learning has strikingly evolved hand-in-hand with the digital era, which has been cooperative with plenty of digital data-related platforms in all forms and from different regions of the globe, for instance, deep-fake. The data, precisely big data is the integration of multiple sources such as, google search engine and plenty more alike, e-commerce platforms and online various other web pages, for instance, online cinemas, which runs on advanced algorithms. This tremendous proportion of data can be easily approachable and can be shared by Fin-tech like cloud computing.

Handwritten digit recognition is split into online recognition and offline recognition where the term "online recognition" refers to allowing a machine to recognize characters written on a handwriting system based on handwriting strokes and stroke orders. [2]. Offline recognition is when a machine recognizes characters written on paper without regard for stroke order.

All experiments are implemented on the standard MNIST data set are collectively 70,000, initially, the training samples dedication is 60,000, whereas, 10,000 experimenting samples, for tests.

Related Work

There are various algorithms and libraries for handwritten digit recognition all have come up to make it faster, and get better accuracy and some of them has been analyzed and discussed below:

- The key contributions of this work are the inclusion of a large online Arabic handwritten digits dataset with 30,000 Arabic digits written by 300 people, as well as the creation of an efficient Arabic

handwritten digits recognition system using the support vector machine algorithm, that has a recognition rate of 98.73 % in this paper [1].

- For segmentation they used horizontal and vertical projections methods, SVM is applied for classification and recognition, and for feature extraction they used convex hull algorithm in this paper [3].

- In this paper [4] to boost the accuracy, a convolutional neural network with non-categorized non-maximum suppression (NMS) and mini-batch fine-tuning (MB-FT) is used to extract features from low-resolution images. Accuracy is 97.30.

- In this paper [5] a CNN(Convolutional neural network) and multilayer perceptron are used together for recognition where recognition result is about 0.68% and accuracy of the F-metrics is 0.99. The MNIST dataset is used for training.

- A dataset contains 22,200 characters with fifteen categories is used where for each category, there are 1200 training and 280 testing characters this dataset includes four arithmetic operations. A CNN algorithm is used and the accuracy is 97.42% in this paper [6].

- Fast R-CNN is applied for adhesive handwritten digit recognition with an accuracy of 94%. There are 17,000 images total, with 3,000 having two handwritten adhesion digits, 4,000 having three handwritten adhesion digits, and 8,000 having four handwritten adhesion digits. Additionally, as negative samples, there are 2,000 images without handwritten strings [7].

- A CNN algorithm is trained with MNIST dataset consist of 5000 images, using System Verilog a handwritten digit was fed in this paper[8].
- The main contribution of this paper is to use the CNN algorithm to construct a model for fingertip writing digit recognition. the recognition rate is 98.4% which is better than an existing work with an accuracy of 95.8% [9].

- A CNN(convolutional neural network) algorithm is used to create an offline digit recognition system that is trained with the MNIST dataset, LeNet-5 is used to take out the handwritten digit features and Opencv is used for prepossessing images [10].

- The model is trained with MNIST dataset, two network architectures are used which are Convolutional neural network and feedforward network with MLP (multi-layer perceptron) and the accuracy is 98.82 % [11].

- For handwritten digit recognition, a six-layer convolutional neural network is being used, The effect of mini-batch size on learning speed and pattern recognition accuracy is studied, with mini-batch sizes ranging from 32 to 256. [12]. The model is trained with MNIST dataset.

- Unlike traditional handwritten digit recognition approaches, a handwritten digit image recognition method is created based on multi-feature extraction and deep analysis, the model is trained with MNIST dataset and the accuracy is 94.2% [13].

- A SOM(self-organizing map) is used together with the concept of backpropagation, the model is trained with MNIST dataset which was processed via a computer vision pre-processor [14]. The recognition rate of SOM is 97.83% and the recognition rate of backpropagation is 94.65%.

- Multiple Instance Learning (MIL) and its two new methods named HB and HeterML are trained with benchmark datasets to create a handwritten digit representation model [15]..

2. Materials And Methods

This Logistic Regression:

Logistic regression is the very first classification technique a data scientist comes across. Although more powerful methods came up still some banking services use logistic regression. And its originality is machine learning. In fig -1 the blue points are true samples and the red points are false samples.

Classification algorithm [16], which predominantly use for predicting the probability of directing the entire data to organize and put it together as a categorical, depending on its variable where the specific digit if it's 0 (no) or 1 (yes) is stated. Or can say as a function of X the logistic regression prediction which is P(Y=1).

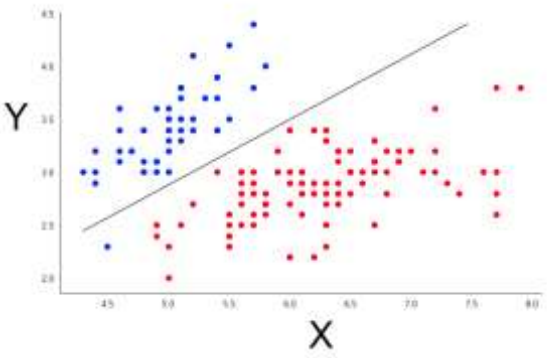

Fig-1: Logistic Regression

The classifier gets trained after the training set data is fed as input to the logistic regression frame. In a trained classifier to get the accuracy, the original label is compared with the guessed label. After the training, to predict the labels and to see the testing accuracy is obtained we give the testing data to the classifier.

A. Random Forest:

Random forest is easy to use supervised machine learning algorithm [17], which often produces a good result even without involving hyper-parameter tuning. It's the most used algorithm because of the simplicity and diversity of the algorithms (it can be then use for both tasks: regression and classification tasks).

The "forest" it builds, is a group of decision trees, normally trained with the "bagging" method. The basic idea affects the overall result by adding the bagging methods when it gets increased with integrated learning models. The predominant limitation of random forest is if there is a tremendous amount of stress it affects the algorithm and makes it comparatively slow and unproductive for its real-time predictability. In common, random forest algorithms are easy and comparatively fast to train, however, a little bit slow in predictions after when it gets trained. More trees are required for a sufficient amount of accuracy, which shows in a slower model. Mostly, the random forest is fast in real-world use however there are certain moments where run-time performances are important and another way would be preferred. With the help of a random forest algorithm in digit recognition, the precision of accuracy is highly predictable, where it can be mentioned as an optimized version of the decision tree algorithm.

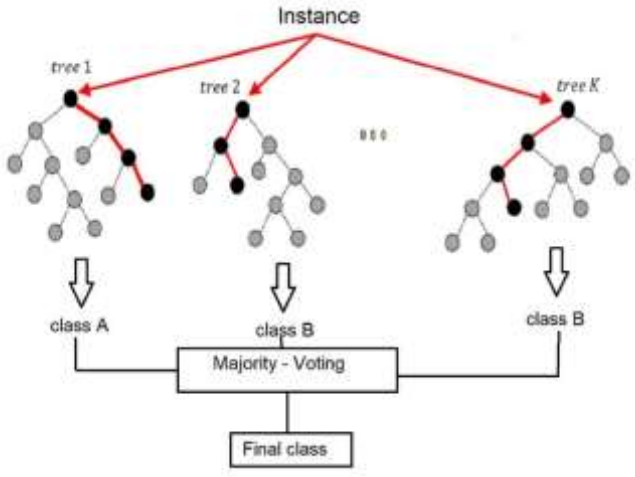

Fig- 2: Random Forest

In a random forest at each vertex, the decision tree consists of a series of questions, and it's every descending edge of the answer to the related question, the possible results are the children (leaves) of tress. The decision trees are constructed automatically from a training tree. In the forest, each tree is created from its original training set, and by only studying its subset of the features. The control of numbers in trees is considered by cross-validation.

B. Convolutional Neural Network:

Over the past few years, deep learning has steadily inclined as the most utilized research and beneficial to almost all other sectors of computer especially CNN (Convolutional Neural Network) algorithm has been remarkably recognized starting from image classification to recognition detection and hitting the path of segmentation and prospect towards application in UAV, bionic life even for humans and robots [18]. A CNN is also known by ConvNet, is a neural network that is being known for detecting and analysing images for computer vision tasks.

A CNN algorithm can be made of hundreds of layers where each learns to dig out different features of an image.

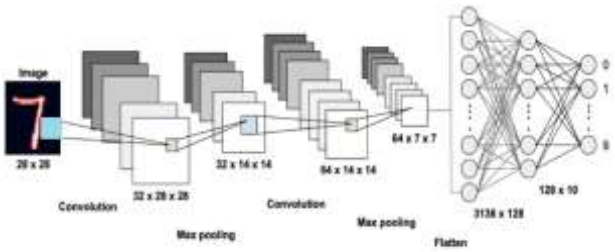

Fig -3: Convolutional neural network

On every training image filters are applied at different resolutions, therefore the output of every image that is convoluted is used as the input to the following layer. The filters can be very basic features, including brightness and edges, or growth of the difficulty to features that individually define the object.

An image can be mathematically defined as a tensor consist of the following dimensions:

$\dim(image) = n_H, n_W, n_C)$

n_H: Size of the height

n_W: Size of the width

n_C: Number of channels

Convolutional Layers: Like the other layers, a convolutional layer receives input, transforms it in some way, and then outputs the transformed input to the next layer. Inputs to convolutional layers are called input channels, and also the outputs are called channels. . The transformation that occurs with a convolutional layer is known as a convolution operation. The convolution operations carried out by convolutional layers are mathematically termed cross-correlations. With every convolutional layer, we should specify how many filters the layer can have. These filters are responsible for detecting patterns. Pattern identification is how CNNs are so useful for image analysis. Edges, shapes, textures, curves, objects, and textures are all patterns that a filter can detect in an image.

Max-pooling: it is a pooling procedure that picks up the maximum features from the sector of the feature map that is sheltered by the filter. Therefore, after max-pooling, the output is going to be a feature map with the most important features from the early feature map.

Flattening: it converts the data into a 1-dimensional array for processing it to the upcoming layer because later on, we need to insert the data into a neural network.

After a series of layers of Convolution and the max-pooling, the result is in series base expanded by rows and interconnected to vector input to the entire connected network. The Soft-max Logistic regression is commonly used for feature patterns classification, and the classification method is illustrated below:

$$y_1 = f(w_1\ x_{1-1} + b_1), x_{1-1}$$

Where, w_1 the weight multiplier is equivalent to the entire connected layer.

b_1 the counteract (offset) of the layer-1.

2D Convolutional Layer: It's the uttermost general used convolution layer. As an acronym, it can be written conv2D. The input image of conv2D is generally not so much as the layer features of a kernel/filter's height and width. A specific section where the filter falls on the image is called the receptive field. Conv2D increased filters happen only with RGB (Red, Green, and Blue). The filter

entirely gets different from every other channel too. When the convolutions are performed stepwise for every channel then they are toted up to form a final image. Succeeding a convolution operation, the outcome of a filter is called a feature map. In conv2D every filter is consist of a matrix of numbers. The matrix correlate to a feature or pattern that the filter is looking for.

Experimental Comparison

The proposed methods are analyzed practically with the help of python (3.8.5) in (Jupyter notebook) and Python libraries for machine learning and deep learning named scikit-learn[19], Tensorflow[20], and OpenCV[21], the simulation is run on Dell G6 with a processor: (Intel® Core™ i7-6500U CPU @ 2.50GHZ), Memory: 8GB RAM, and the operating system Microsoft Window 10 (64-bits). All three algorithms are trained with MNIST dataset which is consists of 6000 training and 1000 testing images, the dataset is 28/28 pixels grayscale images of numbers between 0 to 9 [22-27].

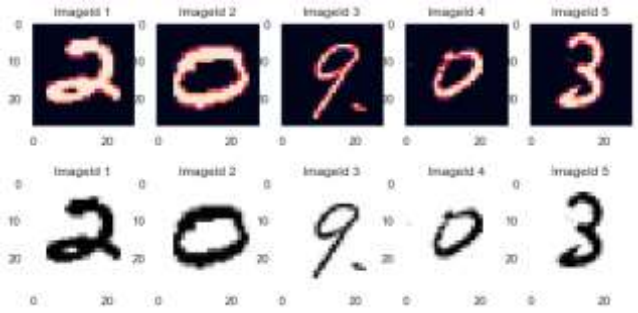

Fig -3: MNIST data set grayscale and binary digits

According to Fig-3 the five images on the top are the original grayscale images of the MNIST dataset and the other five images are the binary conversion of it, images have to be converted to binary before the training.

The accuracy of the algorithms is shown in Table1 below.

Algorithm	Logistic Regression	Random forest	CNN
Accuracy	0.9145	0.964	0.9961

Table1: The performance of logistic regression, Radom Forest, and CNN.

4. Conclusion

The key contribution of this paper is a comparison of CNN, Random forest, and Logistic Regression algorithms for handwritten digit recognition, after a brief summary of handwritten digit application, this work defines the three algorithms that are trained and tested with MNIST. In the training process, we implemented CNN using TensorFlow library, implemented Random forest, and Logistic Regression with Scikit-learn library. Through the process, we obtained the recognition rate of the Logistic Regression, Random forest, and CNN algorithm in handwritten digit recognition. After comparing the results, CNN (Convolutional neural network) algorithm has accomplished the best recognition rate.

Acknowledgement

I wish to express my sincere gratitude to **Dr.Sunilkumar S.Manvi,** Director of the School of Computing and Information Technology, Reva University for providing this opportunity.

I sincerely thank **Dr.Laxmi Rananavare** for her guidance and encouragement in carrying out this work, I came up learning a lot of new things. And all also thanks to the coordinator of M.tech CSE/DS, **Prof.Ashok Patil**, and my friends who rendered their help during the period of my project work.

References:

1. S.A.Azeem, M.El.Meseery, H.Ahmed(2012). “Online Arabic Handwritten Digits Recognition” 2012 International Conference on Frontiers in Handwriting Recognition.
2. Jinze Li, Gongbo Sun, Leiye Yi. “Handwritten Digit Recognition System Based on Convolutional Neural Network” 2020 IEEE International Conference on Advances in Electrical Engineering and Computer Applications (AEECA).
3. Rohan Sethi, Ila Kaushik. “Hand Written Digit Recognition using Machine Learning,” 9th IEEE International Conference on Communication Systems and Network Technologies.
4. Y.Xu, J.Guo(2020). “Low Resolution Handwritten Digit String Recognition based on Object Detection Network” 2020 International Joint Conference on Neural Networks (IJCNN).

5. Zufar Kayumov, Dmitrii Tumakov, Sergey Mosin. "Combined Convolutional and Perceptron Neural networks for Handwritten Digits recognition", "2020 22th International Conference on Digital Signal Processing and its Applications (DSPA)."
6. Kecheng Wang, Junwen Deng, Linfeng Xu, Cong Tang, Zian Pei, Hongtao Wang. "The Four Arithmetic Operations for Handwritten Digit Recognition Based on convolutional Neural Network", "Proceedings of the 39th Chinese Control Conference July 27-29, 2020, Shenyang, china."
7. J.Tang, P.Han, D.Liu(2020). "Adhesive Handwritten Digit Recognition Algorithm Based on Improved convolutional Neural Network", "2020 IEEE International Conference on Artificial Intelligence and Information system (ICAIIS)."
8. MD.Shahbaz Khan, Niharika, Priya Yadav, Rishabh Verma, Dr. Indu Sreedevi(2020). "FPGA Simulation of Fingertip Digit Recognition Using CNN" 2020 7th International Conference on Signal Processing and Integrated Networks (SPIN).
9. M.Kristan, R.Pflugfelder, A.Leonardis, J.Matas, F.Porikli, L.Cehovi, G.Femandez, T.Vojir. "The visual object tracking the visual object tracking" 2019 IEEE/CVF International Conference on Computer Vision Workshop (ICCVW)
10. Jinze Li, Qian Cao, Gongbo Sun, Fusen Liang, Leiye Yi, Yu Sun. " Handwritten Digit Recognition System Based on Convolutional Neural Network" 2020 IEEE International Conference on Advances in Electrical Engineering and Computer Applications(AEECA).
11. A Harikrishnan, Sourabh Sethi, Rashi Pandey. "Handwritten Digit Recognition with Feed-Forward Multi-layer Perceptron and Convolutional Network Network Architectures", 2nd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA)(2020).
12. Z.Kayumov, D.Tumakov(2020). "Convolutional Neural Network learning Features for Handwritten Digit Recognition" 2020 IEEE East-West Design & Test Symposium (EWDTS).
13. Caiyun.M, H.Zhang(2015). "Effective Handwritten Digit Recognition Based on Multi-feature Extraction and Deep Analysis" 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD).
14. S.Srivastava, K.Agrawalla, S.Yadav, T.Malhotra(2018). "Recognition of Handwritten Digits Using Computer Vision Preprocessor Based Combined Architecture of Self-Organizing Map and Backpropagation on MNIST Dataset", "International Conference on Recent Innovations in Electrical, Electronics & Communication Engineering - (ICRIEECE)."
15. Yuan hanning, Wang Peng. "Handwritten Digits Recognition Using Multiple Instance Learning", "2013 IEEE International Conference on Granular Computing (GrC)."
16. Vidushi Garg. "Handwritten Digit Classification using Machine Learning Models", "International Research Journal of Engineering and Technology (IRJET)."
17. S.Bernard, L.Heutte, S´ebastienAdam(2007). "Using Random Forests for Handwritten Digit Recognition", "Ninth International Conference on Document Analysis and Recognition (2007)."
18. Rui Xiao, Junsheng Shi, Chao Zhang(2020). "FPGA Implementation of CNN for Handwritten Digit Recognition", IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference (ITNEC 2020)
19. [19] https://scikit-learn.org
20. https://www.tensorlow.org
21. https://www.opencv.org
22. Sudhan Murugan Bhagavathi, Anitha Thavasimuthu, Aruna Murugesan, Charlyn Pushpa Latha George Rajendran, A Vijay, Raja Laxmi, Rajendran Thavasimuthu, Weather forecasting and prediction using hybrid C5.0 machine learning algorithm International Journal of Communication Systems, Vol. 34, Issue. 10, Pp. e4805, 2021.
23. PM Surendra, S Manimurugan, A New Modified Recurrent Extreme Learning with PSO Machine Based on Feature Fusion with CNN Deep Features for Breast Cancer Detection, Journal of Computational Science and Intelligent Technologies, Vol. 1, Issue. 3, Pp. 15-21, 2020.
24. PK Sadineni, Comparative Study on Query Processing and Indexing Techniques in Big Data, 2020 3rd International Conference on Intelligent Sustainable Systems (ICISS), pp. 933-939, 2020.
25. AH Omar Baabood, Prajoona Valsalan, Tariq Ahmed Barham Baomar, IoT Based Health Monitoring System, Journal of Critical Reviews , Vol. 7, Issue. 4, pp. 739-743, 2020.
26. Sajay KR, Suvanam Sasidhar Babu, Vijayalakshmi Yellepeddi, Enhancing The Security Of Cloud Data Using Hybrid Encryption Algorithm, Journal of Ambient Intelligence and Humanized Computing, 2019. https://doi.org/10.1007/s12652-019-01403-1
27. Bindhia K Francis, Suvanam Sasidhar Babu, Predicting academic performance of students using a hybrid data mining approach, Journal of Medical Systems, 43:162, 2019. https://doi.org/10.1007/s10916-019-1295-4