

A Customized Hybrid Deep Learning–Machine Learning Framework For EMNIST Handwritten Character Recognition

Balram Yadav¹, Jyoti Bala Gupta², Abhinav Shukla³

Research Scholar, Dr. C. V. Raman University, Kota, Bilaspur, Chhattisgarh, India¹

Faculty, Dr. C. V. Raman University, Kota, Bilaspur, Chhattisgarh, India^{2,3}

yadavbalram869@gmail.com¹, jyotibalagupta.cvru@gmail.com², amitshukla9611@gmail.com³

Abstract: *In the era of modern research, Pattern recognition is vast field for the academician and researchers for their research contribution. There are various kinds of patterns like audio, video, handwritten digit and character images etc. From these patterns, we are concentrated on the field of handwritten characters classification and recognition. In the world, the handwriting of peoples are different to each other and also used different languages, so it is necessary to develop a model which recognize then accurately. There are lots of deep and machine learning methods have been implemented by various authors and achieved good results. In this research, we have proposed a hybrid model, which is combination of deep learning algorithm and machine learning algorithms for handwritten character classification and recognition. The proposed model having two steps , first features extraction and second is classification and prediction. Convolutional neural network has used as feature extractor and Support Vector Machine, K-Nearest Neighbor ,Random Forest Classification and X-tream Gradient Boosting algorithms used for classification and recognition of handwritten characters . We have used very famous handwritten character dataset EMNIST , which is collection of 1456007samples of A-Z characters. In this paper, we enhance the recognition accuracy by our proposed hybrid models like: CNN-SVM, CNN-RFC, CNN-KNN and CNN-XGB model, and the proposed model achieved excellent recognition rate with EMNIST data samples. We have achieved the testing accuracy 87.95% by CNN-RFC, 93.39% by CNN-KNN, 94.99% by CNN-SVM and 96.01% by CNN-XGB with EMNIST dataset. The testing accuracy achieved by our proposed models is tremendous and higher than previous research work.*

Keywords: EMNIST Handwritten Character Dataset ,Convolutional Neural Network(CNN), Support Vector Machine(SVM), K-Nearest Neighbor (KNN) , Random Forest Classification(RFC) , X-tream Gradient Boosting (XGB)

I. INTRODUCTION

In the field of deep learning and machine learning there are various researchers and authors implemeted their task of pattern recognition, face recognition, image processing and many more. The deep learning is a part of machine learning , used for more and more refining the accuracy of any model. In this paper , we have also Hybrid the concept of deep learning with machine learning techniques for handwritten character recognition. For this, we have used convolutional neural network(CNN) for extraction of features and standard machine learning algorithm like: SVM, KNN,RFC and XGB for classification and prediction of image datasets. We have used dataset called EMNIST handwritten character dataset to check the performance and accuracy of our proposed integrated model. EMNIST digit dataset has been downloaded form the <http://www.nist.gov> which is collection of 145600 samples.

The source for building EMNIST database was NIST Special Database 19 (NIST SD 19) [1], containing NIST's (National Institute of Standards and Technology of the US) entire corpus of training materials for hand printed



document and character recognition, including over 800,000 manually checked and labelled characters. Author [2] studied about the research on MNIST and EMNIST dataset with different different techniques and model , which have been proposed by the various authors and results of that research is also displayed. Author [3] used deep neural network technique with encoder for validation of testing samples, they got 98.5% recognition rate with testing image samples. Deep- CNN techniques has been implemented by the author [4] and they also comapre the accuracy with number of iterations. Some of the author used committees of neuroevolved CNNs using topology transfer learning, obtaining good accuracy with EMNIST Letters and EMNIST Digits[5]. Evolutionary –DNN techniques proposed by the author [6] for handwritten digit recognition and achieved 99.3% accuracy with digits dataset and they also calculated the performance of their model with various datasets. Author [7] proposed LeNet model for recognition of handwritten digit and got 99.50% balanced recognition accuracy with digits data. Author [8] proposed method that is combination of discrete wavelet transform (DWT) and discrete cosine transform (DCT) were hybridized to extract features from the handwritten samples, later using K-NN and SVM for classification. Authors report that SVM outperform K-NN in all scenarios, attaining an accuracy of up to 89.51% in EMNIST Letters and 97.74% in EMNIST Digits. Author Cavalin and Oliveira [9] presented a method to generate a hierarchical classifier by automatically studying the confusion matrix of a “flat” (regular) classifier. They test logistic regression, multi-layer perceptrons and CNNs, and report the best results for the CNN, although with this technique the hierarchical classification do not beat the flat setting. They report an accuracy of 99.46% for EMNIST Digits and 93.63% for EMNIST Letters. Author Dufourq and Bassett [10] presented EDEN model, where they applied neuroevolution obtaining an accuracy of 88.3% in EMNIST Balanced and 99.3% in EMNIST Digits. Here we have used Convolutional neural network has used as feature extractor and Support Vector Machine, K-Nearest Neighbor ,Random Forest Classification and X-tream Gradient Boosting algorithms used for classification and recognition of handwritten characters .Also compare the proposed model results with the previous implemented models and results.

In this paper, we enhance the recognition accuracy of tetsing dataset by our proposed hybrid models, which is combination of convolutional neural network and machine learning algorithms like CNN-SVM, CNN-RFC, CNN-KNN and CNN-XGB. Here convolutional neural network has been used for the feature extraction of training and testing samples and SVM, KNN, RFC and XGB technique has used for the prediction of testing data samples. Our proposed hybrid models CNN-SVM, CNN-RFC, CNN-XGB and CNN-KNN achieved good recognition rate with EMNIST dataset , that proves the performance of our proposed model are excellent and provide better result.

II. PROPOSED ARCHITECTURE

In this section, we have explored the proposed architecture and their description of research work. The proposed Hybrid Technique for handwritten characters recognition consist two steps ,where first step is feature extraction using convolutional neural network and second step is classification with prediction using Machine learning techniques like: SVM, KNN, RFC and XGB. We have implemented the proposed hybrid CNN-SVM, CNN –KNN, CNN-RFC and CNN-XGB models with EMNIST handwritten character dataset. Here we have represents the model architecture and description.

Proposed Architecture - The model architecture has been represented in figure-1.



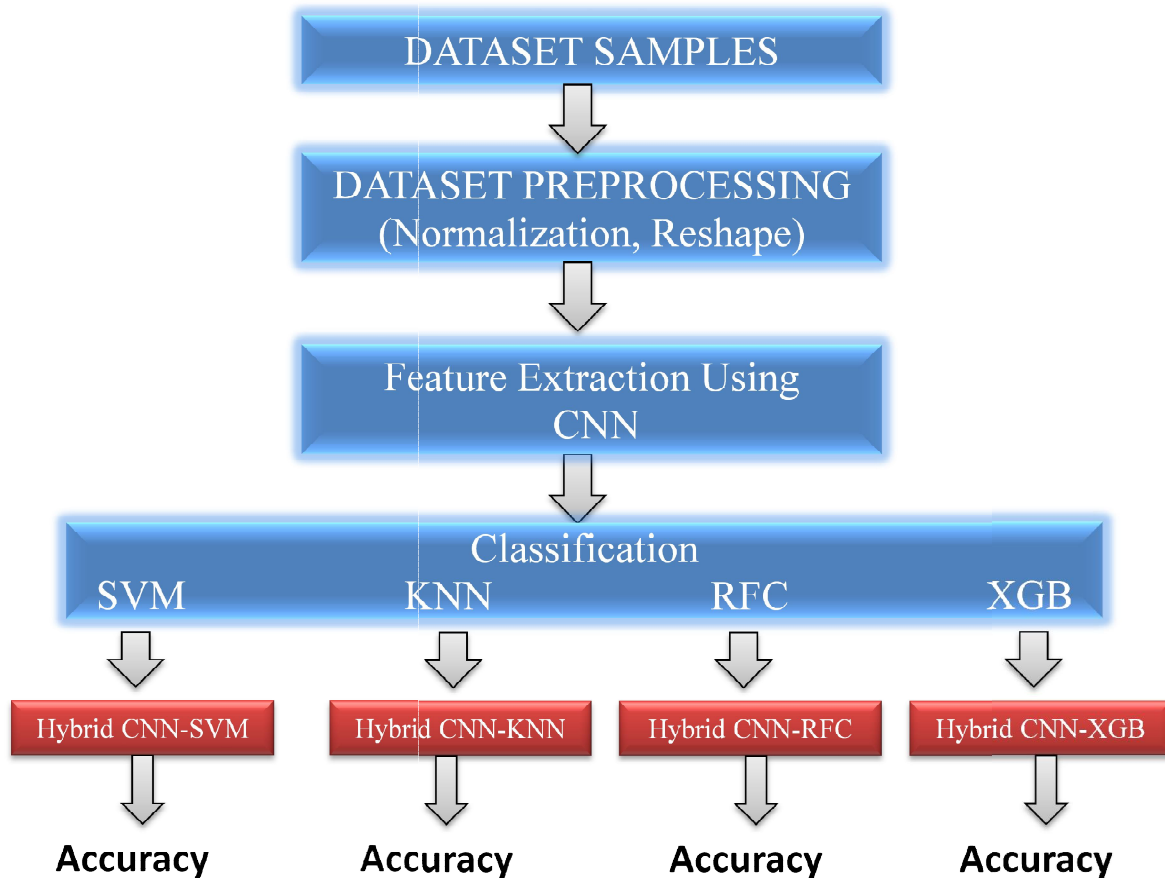


FIGURE I. FLOW DIAGRAM OF PROPOSED HYBRID MODEL

Proposed Architecture description – This model contains three step for implementation :-

- Data Collection & Preprocessing
- Feature Extraction by CNN
- Classification & Recognition

The proposed architecture of integrated CNN with SVM, KNN, RFC and XGB model has used several steps to calculate training and testing accuracy of handwritten character dataset. The proposed have many of the convolutional layers with 'relu' activation function. The architecture of model is already represented by Figure 1.

III. DATA COLLECTION & PREPROCESSING

For handwritten character recognition, we have downloaded the dataset Extended Modified National Institute of Standards and Technology database (EMNIST) form https://www.itl.nist.gov/iaui/vip/cs_links/EMNIST/gzip.zip. The dataset EMNIST is a collection of 145600 samples, which is divided into four files, 1st for 124800 image sample used as training images, 2nd for 124800 labels of training samples, 3rd for 20800 image sample used as testing images and 4th for 20800 labels of testing samples. For implementation on model, dataset needs preprocessing, for that first normalize the data images and then reshape it as 28*28 dimensions. The sample of the images of data represented by figure -2 and total number of training and testing samples of each digit represents in figure-3.



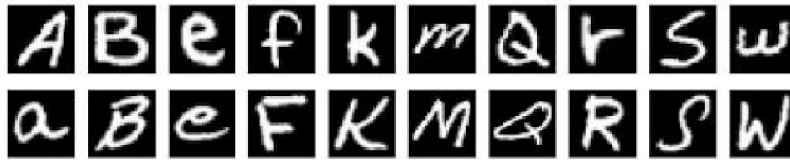


FIGURE II. Sample of EMNIST Training dataset image

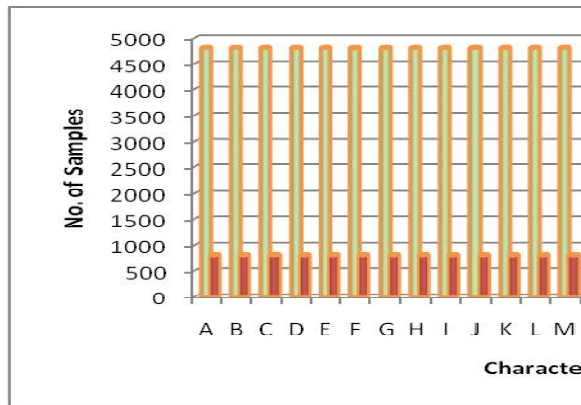


FIGURE III. Training and Testing samples of each characters (A – Z)

IV. EXPERIMENTAL APPROACH

For implementation of proposed model, we have used python software available on anaconda navigator (anaconda3) with Tensorflow and Keras environment. In this research work, we have proposed integrated CNN-SVM, CNN-RFC, CNN-KNN and CNN-XGB models for recognition of EMNIST handwritten character datasets. The proposed hybrid network is divided into two major parts: first is feature extraction which is performed by convolutional neural network and in second phase one of machine learning classification algorithm SVM, KNN or RFC and Boosting algorithm XGB has been implemented.

Before implementation of proposed model, first we require to preprocess the image sample of datasets, for that we have normalize the dataset by dividing each image sample value by 255 and convert the pixel value between 0 to 1. After that reshaping image samples in 28*28 (784 dimension).

Now we perform process of feature extraction. For this, we have used convolutional neural network, which have following number of layers that is already represented by figure 4. After completing the process of feature extraction process the dimension of each image is 3136 of both training and testing samples.

Layer Name	Layer Type	Output Shape	Parameters
input_layer_3	Input Layer	(28, 28, 1)	0
conv2d_24	Conv2D (32 filters)	(28, 28, 32)	832
conv2d_25	Conv2D (32 filters)	(28, 28, 32)	25,632
max_pooling2d_6	MaxPooling2D	(14, 14, 32)	0
batch_normalization_15	Batch Normalization	(14, 14, 32)	128
conv2d_26	Conv2D (32 filters)	(14, 14, 32)	25,632
batch_normalization_16	Batch Normalization	(14, 14, 32)	128
conv2d_27	Conv2D (32 filters)	(14, 14, 32)	25,632
batch_normalization_17	Batch Normalization	(14, 14, 32)	128
conv2d_28	Conv2D (64 filters)	(14, 14, 64)	18,496
conv2d_29	Conv2D (64 filters)	(14, 14, 64)	36,928



conv2d_30	Conv2D (64 filters)	(14, 14, 64)	36,928
max_pooling2d_7	MaxPooling2D	(7, 7, 64)	0
batch_normalization_18	Batch Normalization	(7, 7, 64)	256
conv2d_31	Conv2D (64 filters)	(7, 7, 64)	36,928
batch_normalization_19	Batch Normalization	(7, 7, 64)	256
flatten_3	Flatten	(3136)	0
dense	Dense (128 units)	(128)	401,536
dense_1	Output Dense (26)	(26)	3,354

FIGURE IV. PROPOSED ARCHITECTURE OF CONVOLUTIONAL NEURAL NETWORK

Experimental outcome

Outcome with EMNIST character dataset

Table 1. Accuracy of training & testing samples by proposed models.

Model	Sample	Accuracy
Hybrid CNN-RFC	Training samples	100%
	Testing samples	87.95
Hybrid CNN-KNN	Training samples	100%
	Testing samples	93.39
Hybrid CNN-SVM	Training samples	100%
	Testing samples	94.99
Hybrid CNN-XGB	Training samples	100%
	Testing samples	96.01%

Here Table-I represented the accuracy of model with EMNIST dataset, the training accuracy of the model is 100% and validation accuracy of model is nearly 90 to 96%. The result shows that the accuracy achieved by the proposed model is good and efficient.

V. RESULT ANALYSIS

Comparison of Proposed Integrated model with previous research work: -

In the field of handwritten character recognition, various authors contributed their research experience by using convolutional neural network technique and Hybrid techniques of machine learning and deep learning. In this paper, we have also Proposed Hybrid model based on deep learning and machine learning, we achieved excellent result with this proposed model. The comparative analysis of various framework of CNN and Hybrid model represented in Table-II

TABLE II. COMPARISON OF ACCURACY OF VARIOUS MACHINE LEARNING AND DEEP LEARNING FRAMEWORKS WITH EMNIST DATASET

Reference	Name of the Model	Validation Accuracy
[8]	DWT-DCT + SVM	89.51%
[9]	CNN (flat; 2 conv + 1 dense)	93.63%
[10]	EDEN	88.30%
Proposed	Hybrid CNN-RFC	87.95%



Model	Hybrid CNN-KNN	93.39%
	Hybrid CNN-SVM	94.99%
	Hybrid CNN-XGB	96.01%

VI. CONCLUSION

In the area of pattern recognition, the domain of handwritten character recognition has been adopted by various authors. In this paper we have also proposed integrated hybrid model for recognition of EMNIST handwritten character dataset. The hybrid model is combination of deep learning and machine learning approach. CNN is the part of the deep learning used for feature extraction and machine learning based SVM, KNN, RFC & XGB technique has been used for classification and prediction of samples. From the implementation of proposed Hybrid model, we achieved 96.01% validation accuracy with EMNIST character dataset which represents the excellent performance of model.

REFERENCES

- [1] NIST. NIST Special Database 19. 2017. Available online: <https://www.nist.gov/srd/nist-special-database-19> (accessed on 28 April 2018).
- [2] A. Baldominos, Y. Saez, P. Isasi, "A Survey of Handwritten Character Recognition with MNIST and EMNIST," MDPI Applied Science 2019, vol. 9, pp. 1-16, 2019.
- [3] Teddy Surya Gunawan,, Ahmad Fakhur Razi Mohd Noor,, Mira Kartiwi "Development of English Handwritten Recognition Using Deep Neural Network", Indonesian Journal of Electrical Engineering and Computer Science Vol. 10, No. 2, May 2018, pp. 562-568.
- [4] Srishti Singh, Amrit Paul, Dr. Arun M,," Parallelization Of Digit Recognition System Using Deep Convolutional Neural Network On CUDA ",2017 IEEE 3rd International Conference on Sensing, Signal Processing and Security (ICSSS), 978-1-5090-4929-5©2017 IEEE,379-383.
- [5] Baldominos, A.; Saez, Y.; Isasi, P. Hybridizing Evolutionary Computation and Deep Neural Networks: An Approach to Handwriting Recognition Using Committees and Transfer Learning. Complexity 2019, 2019, 2952304. [CrossRef]
- [6] Emmanuel Dufourq, Bruce A. Bassett,," EDEN: Evolutionary Deep Networks for Efficient Machine Learning", arXiv:1709.09161v1 [stat.ML] 26 Sep 2017
- [7] Weiwei Jiang,," MNIST-MIX: a multi-language handwritten digit recognition dataset", IOP SciNotes 1 (2020) 025002.
- [8] Ghadekar, P.; Ingole, S.; Sonone, D. Handwritten Digit and Letter Recognition Using Hybrid DWT-DCT with KNN and SVM Classifier. In Proceedings of the 4th International Conference on Computing Communication Control and Automation, Pune, India, 16–18 August 2018.
- [9] Cavalin, P.; Oliveira, L. Confusion Matrix-Based Building of Hierarchical Classification. In Progress in Pattern Recognition, Image Analysis, Computer Vision, and Applications; Lecture Notes in Computer Science; Springer: Berlin, Germany, 2019; Volume 11401, pp. 271–278.
- [10] Dufourq, E.; Bassett, B.A. EDEN: Evolutionary Deep Networks for Efficient Machine Learning. arXiv 2017, arXiv:1709.09161.

