Handwritten Bengali Character Recognition Using Convolutional Neural Network

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***Abstract*—Due of the unusual alignment and resemblance in the letters, handwritten character identification in Bangla Script is one of the most challenging and demanding jobs in pattern recognition. The goal of this research is to investigate how a Convolutional Neural Network may be used to detect handwritten Bangla letters. Any pattern recognition task's categorization and feature extraction stages are responsible for properly detecting the patterns. Over the current well-known datasets CMATERdb, BanglaLekha-Isolated, and Ekush, the research offers a unique low-cost CNN architecture for Bengali Character Recognition. The suggested model achieves excellent accuracy and generalises well across diverse datasets using Convolutional Neural Networks. BanglaLekha-Isolated dataset has been used and the overall recognition accuracy of 89 percent has been achieved.**

***Index Terms*—Convolution Neural Network, Handwritten Character Recognition, Language Learning, Devanagari Character Dataset.**

I. Introduction

Bengali is the native language of the Bengal area, which includes the modern-day country of Bangladesh as well as the Indian states of West Bengal, Tripura, and southern Assam. The Bengali alphabet is used to write it. Bengali is the world's fifth most predominant language native language, with roughly 230 million native speakers and about 260 million total speakers. The origins of Bengali script differed from that of Devanagari and Oriyan scripts, however the characters of Bengali and Assamese scripts were typically similar. The Bengali alphabet was virtually complete by the 12th century CE, however spontaneous variations occurred until the 16th century. In the nineteenth century, several deliberate changes were also introduced.

The Bengali writing system is not based only on the alphabet, as is the case with the Latin script. It's written in Bengali abugida, which is a version of the Eastern Nagari script widespread in Bangladesh and eastern India. It's comparable to the Devanagari abugida, which is used in Sanskrit and many current Indic languages like Hindi. It has particularly strong historical affinities with the Assamese and Oriya scripts. The Bengali abugida is a cursive script that consists of eleven graphemes or signs that represent the independent form of nine vowels and two diphthongs, as well as 39 symbols that represent consonants with "inherent" vowels. Our model for identifying Bengali characters written by hand has been included in our language learning system. This concept has been used in the Bengali Language's writing practice module.

Convolutional Neural Networks (CNN) are regular neural networks that have picture inputs. They're used to categorize and analyze photos, cluster images based on similarity, and recognize objects inside a frame. Convolutional neural networks (ConvNets or CNNs), for example, are used to recognize faces, persons, street signs, cancers, and a variety of other visual data. The fundamental goal of a convolutional layer is to identify edges, lines, color dips, and other visual elements in pictures.

The main goal of this study is to develop a low-cost bespoke architecture for recognising handwritten Bengali characters.

II. Literature Review

Handwritten Bangla character recognition has grown in prominence in recent years. Bhowmik et al.[2] proposed a new method for feeding MLP with stroke characteristics that generate a feature vector. It is discussed a multistage strategy based on feature extraction[1]. Using a layer-based and view-based technique with a KNN classifier, Shaik et al.[3] demonstrated a new method for Bengali character recognition. The use of the Euclidean distance measurement technique and the Fourier Transform(FT) measurement technique to distinguish Bengali handwritten characters has been discussed[8]. Later on, writers began to use CNN models. Alom et al.[6] examined the performance of several DCNNs such as CNN, ResNet, FractalNet, and DenseNet on the CMaterDb dataset for bengali character recognition. Rizvi et al.[10] employed two methods: a multiclass SVM classifier for classification and a DCNN model based on ResNet 18 for CNN-based methods. There are 17 convolutional layers and one FC layer in ResNet-18. After analysing their own dataset, CNN-based models outperformed classic classification approaches. Chowdhury et al.[9] used data augmentation and a CNN model to achieve 95% accuracy for Bangla letter recognition using the Bangla Lekha dataset. Using the numtaDB dataset, Chakraborty et al.[14] constructed a deep CNN model and achieved a 93%

accuracy for Bangla digit recognition. Proposed architecture consists of 6 convolution layers of 32, 32, 64, 64, 64, 64 respectively, and 3 dense layers.

In addition, the authors of certain works have concentrated on constructing low-cost Bengali character recognition structures. The BornoNet model, proposed by Rabby et al.[5], is a 13-layer convolutional neural network with two sub-layers. It makes use of the ADAM optimizer. Cmaterdb, Bangla lekha, and ISI datasets are used to test it.Inception Convonet, a CNN architecture, was presented, with 95.3 percent accuracy on a handwritten Bangla character database[7]. Using the Mobilenet CNN architecture, Ghosh et al.[12] achieved 96.46 percent accuracy. Sayeed et al.[13] suggested BengaliNet, a low-cost CNN model for Bengali character recognition.

For the cmaterdb, bangla lekha, and ekush datasets, this architecture was designed to use fewer parameters while maintaining good performance. It obtained 96-99%. Rabby et al.[15] created a Borno multiclass CNN model and tested it on a dataset of 1069132 pictures, reporting a model accuracy of 91.88%. Borno employed four convolutional layers with values of 32, 64, 128, and 256, followed by a batch normalisation layer, which is connected to a max-pooling layer, which is then followed by a dropout layer. Despite the fact that these approaches have a bright future, more work has to be done to produce a system that is totally capable of identifying Bengali script for practical use[11].

III. Dataset

Recognizing handwritten Bangla letters is a significant difficulty to tackle, given the increased usage of technology in several industries in many countries. While machine learning technologies have had considerable success in the English language, the same degree of efficacy has not been demonstrated in Bangla. The lack of a single comprehensive dataset encompassing the most often used Bangla characters is one of the several reasons for this. Existing data sets cover either only the Bangla numbers, only the Bangla characters, or only the Bangla compound characters. This happens to be the largest dataset for Bengali characters as of yet. BanglaLekha-Isolated is the dataset used for training our model, this dataset contains isolated Bangla handwritten character examples. It includes 50 Bangla basic characters, 10 Bangla numerals, and 24 chosen compound characters as examples. For each of the 84 characters, 2000 handwriting samples were gathered, scanned, and pre-processed. After removing errors and scribbles, the final dataset had 1,66,105 handwritten character pictures. The age and gender of the subjects from whom the handwriting samples were collected are also included in the dataset. This data is associated with each unique photograph. A secondary spreadsheet compiles three independent assessors' opinions on the aesthetic quality of the handwriting samples. This evaluation is based on 84-character groupings rather than individual characters.

Fig. 1. Bengali Vowel Dataset

Fig. 2. Bengali Consonants Dataset

Fig. 3. Bengali Numeric Dataset

IV. Methodology

In this section, we discuss the workflow of the models used for handwriting character recognition of Bengali characters. The workflow for the two models has been shown in the figures below, the only similarity between the models is the dataset used for training them. In CNN, an input image is given over which numerous layers of convolutions are used to generate feature maps. A pooling procedure is used in the inner layers to degrade the resolution of the succeeding feature maps while increasing their amount. The final layer of feature maps is processed by a linear classifier, which outputs a one-dimensional array called the output layer, which includes the tags that the image may be associated with. When a pixel in this one-dimensional array is active, it indicates that the picture has been classed as its associated label. Rectified linear activation function (reLu) is a piecewise linear function. If the input is positive, it will be given as an output unchanged, else the output given is zero. It has been used in the initial layers and softmax activation layer has been used in the last layers. The workflow of our model and it's layers have been shown in Fig 5.

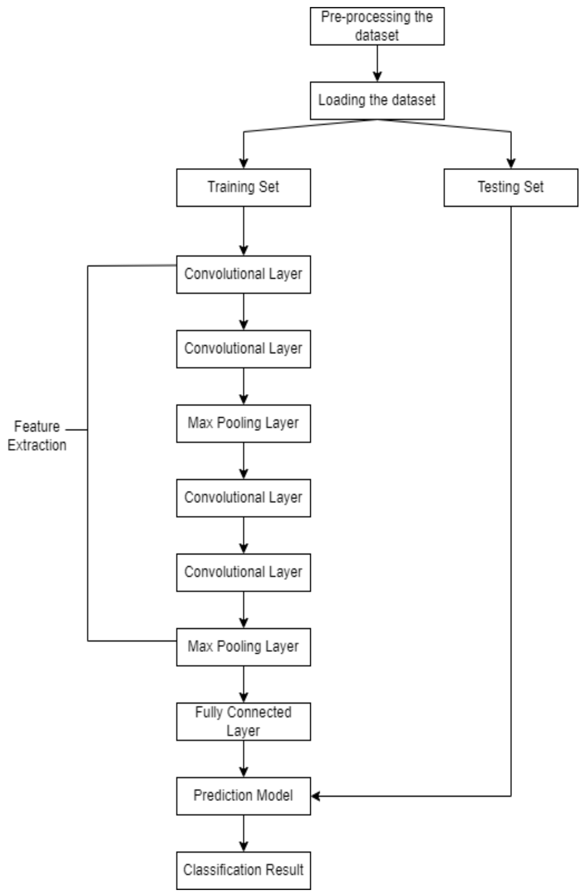

Fig. 4. Flowchart of CNN Model 1 for Bengali characters

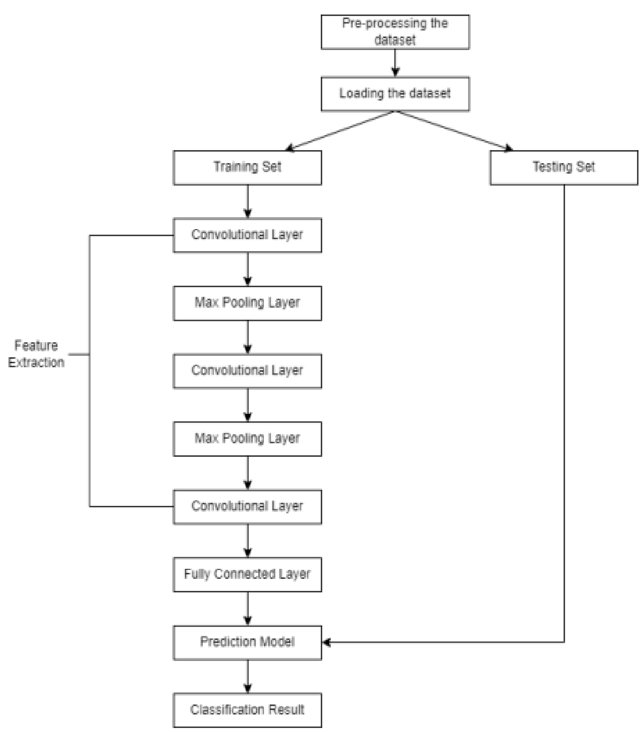

Fig. 5. Flowchart of CNN Model 5 for Bengali characters

Results and Conclusion

The first model implemented had 11 layers as shown inthe figure 5 above. The dataset was split in a 70:10:20 ratiofor training, validation and testing respectively. The dataset used was categorized into 83 classes after training. The model was run for 25 epochs. The training accuracy achieved by the model was 86.92% and the testing accuracy was 93.26%. However, this disparity in the accuracies gave rise to poor prediction. The term used for such a case is ’overfitting’.Our training dataset, which is used to train the model, has a higher accuracy than our testing dataset, as is observed after the training. When the model has a low error in the training set but a higher error in the testing set, this is referred to as overfitting. We can visually notice this by visualising our loss and accuracy measurements and observing where the performance indicators converge for the datasets. Overfitting can be resolved by tuning the hyperparameter. So, when we started figuring out changes, we changed the combination of the models’ layers and the new model was as shown in Figure 6. Dropout layer was added after the first max pooling layer and then after the second max pooling layer. This solved the problem of overfitting. The second model gave a testing accuracy of 89.45% and training accuracy of 85.02%. The accuracy achieved is better than that of the model under study. The prediction results were manually checked and the models predictions were not that accurate for some of the characters. The explanation for this is the fact that Bengali characters are way too complex to draw that prediction is a little tough. The model’s accuracy can further be improved by trying out more combination of layers and changing the hyperparameters.

Model Name	Number of Layers	Number of Epochs	Training accuracy	Testing accuracy
Bengali Model under study	11	10	73%	70.36%
First Bengali Model*	11	25	86.92%	93.26%
Final Bengali Model	11	25	85.02%	89.45%

** - first model is rejected because of overfitting (the difference between training and testing accuracies is large)*

Table 1. Results of model

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