Handwritten Devanagari Character Recognition Using Convolutional Neural Network

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***Abstract*—In this paper, we explore the use of Convolutional Neural Network for handwriting character recognition. The details and working of the numerous tried and tested models is explained in depth. Recent improvements in CNN technology have produced significant advances in Handwritten Character Recognition by learning discriminating qualities from enormous volumes of raw data. The CNN has a substantial benefit over traditional pattern recognition algorithms in terms that it can extract features, decrease data dimensionality, and classify all in one network structure. A 32 x 32 pixel Handwritten character image recorded from canvas can be processed and classified by the neural network. In less than 26 epochs, training converges. The final model for Devanagari consonants (and numerals) and vowels which have been integrated into our intended project achieve an accuracy of 99.54% and 99.64% respectively. These results show that the suggested CNN has superior classification performance, proving that it is a viable real-time solution for Handwritten Character Recognition.**

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

I. Introduction

The Devanagari script evolved from the North Indian script Gupta and, eventually, from the Brahmi script. Devanagari is a left-to-right alphasyllabary. Devanagari Script is composed of 13 vowels and 36 consonants. Consonants and vowel sequences are written as units in this segmental writing system. The Devanagari script is penned from left to right and top to bottom, and it lacks the idea of upper and lower case. Because of the potential changes in the form, number, and position of the constituent strokes, unconstrained Devanagari writing is more subtle than English writing. Like other Brahmic scripts, Devanagari's letter order is founded on phonetic principles that consider both, the place of articulation and the manner of the consonants and vowels they represent [1].

Devanagari Script is the world's fourth most adopted writing system. It has been used to write over a hundred languages. Devanagari Script is essential while learning to write any Indian regional language like Marathi, Hindi or Sanskrit. Handwritten Character recognition of Devanagari text can have multiple applications. Because of its significant contribution to automation and AI-based language learning platforms, handwritten character recognition is garnering more attention. We have integrated our model for handwritten character recognition of Devanagari Characters in our language learning application. This model has found its application in writing practice module of Marathi Language.

Handwritten character recognition (HCR) is the process of detecting and converting characters from photographs, papers, and other sources into a machine-readable format for further processing. Accurate recognition of complex-shaped compound handwritten characters remains a difficult task. By learning discriminatory qualities from enormous amounts of raw data, recent breakthroughs in convolutional neural networks (CNN) have made significant progress in HCR.

The Convolutional Neural Network (CNN) is a deep learning architecture that is inspired by the human brain's natural visual perception mechanism. Due to increase in volumes of available data and the enhanced power of graphic processing units (GPUs), the study of CNN has increased tremendously and it has found its applications in image classification, text detection, object tracking, action detection, speech processing, NLP, etc.

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

II. Literature Review

A paper by S.Gadge, K.Kharde, S.Bhere, R.Jadhav, titled Recognition of Handwritten Devanagari Character using Convolutional Neural Network, has explored the use of Convolution Neural Network on Devanagari characters.[2] In this study, they employed different approaches in CNN architecture and evaluated their accuracy to determine the best match based on the accuracy of each strategy. They covered other methodologies utilised by other individuals employing CNN as well as other methods like as ANN, SVM, and so on. They employed two separate datasets, Devanagari Handwritten Character Dataset and Devanagari (Nepali) Handwritten Character Dataset, which both contained a wide range of data and were large enough to verify validity. These datasets contained consonants, numbers, and vowels. This system's primary focus

was on Marathi language characters. This paper includes a full description of how the convolution neural network was created and how it was used to categorise the photos, as well as a comparison of the four CNN designs and their respective accuracy.

The CNN algorithm is provided in its entirety, including all of the layers and their respective responsibilities. They also looked into other CNN designs with different layer compositions and calculated the accuracy of each. Architectures 1 and 2 go into great depth on the correctness of training and testing data with constants and integers. In addition, designs 3 and 4 discuss performance in terms of training and testing accuracy, as well as the epochs used. They then thoroughly compared the performance consequences of each design[2]. In conclusion, the results demonstrate that architecture 2 has a higher testing accuracy of 98 percent for consonants and 99% for numerals, but architecture 4 has a 99% testing dataset accuracy. The total correctness of recognizing Devanagari consonants is 98%, vowels is 97.56%, and numerals is 99%. [2]

III. Dataset

Three datasets were used in this system. Although the final models were based on only two of them, trial and tests made the decision to choose the correct dataset more precise. The three datasets used are the Devanagari Handwritten Character Dataset (DHCD) [5], Devanagari (Nepali) Handwritten Character Dataset (NHCD)[3], Handwritten Devanagari Characters - Vowels and Numerals dataset[6].

A. Devanagari Handwritten Character Dataset

The DHCD was created by Shailesh Acharya and Prashnna Kumar Gyawali, and taken from the UCI Machine Learning Repository. An important characteristic of a good dataset is that it much have a variety of data which can provide a better accuracy for models. Large datasets are often preferred for this reason. Based on this notion, the DHCD dataset was made by extraction and manual notation of various handwritten documents. This image dataset of Handwritten Devanagari characters consisted of 46 classes of characters, 36 consonants and 10 numerals, with 2000 examples each. The dataset was split into training set (85%) and testing set (15%). There were a total of 92000 images (78200 in the training set and 13800 in the testing set). The images are of 32 x 32 pixels with the actual image centered within 28 x 28 pixels, with a padding of 2 pixels on all sides. Figure 1 and 2 show what the numerals and consonants in the dataset look like. [5]

B. Devanagari (Nepali) Handwritten Character Dataset

The DHCD dataset described above did not contain vowels, hence, two datasets were used for Devanagari vowels. The first dataset was the NHCD (Devanagari (Nepali) Handwritten Character Dataset). This dataset consisted of 12 classes, with 221 samples per class for vowels, and the rest of the 46 classes (10 for numerals and 36 for consonants) was not utilized. The

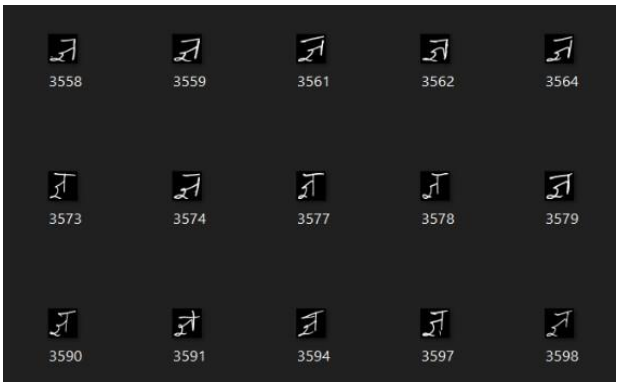

Fig. 1. Devanagari Consonant Dataset (DHCD)

Fig. 2. Devanagari Numeral Dataset (DHCD)

samples were collected from 40 individuals who were from different fields. Each picture in this collection is 28 by 28 pixels in size, with a white backdrop and a black character, and it has been cropped to show character boundaries. Figure 3 shows what the dataset looks like.[3]

Fig. 3. Devanagari Vowels Dataset (NHCD)

C. Handwritten Devanagari Characters - Vowels and Numerals

Handwritten examples of Devanagari vowels and numerals are included in the data. As a result, the collection contains a total of 23 distinct Devanagari characters (10 numerals and 13 vowels). The vowels were obtained from 1400 participants

of various ages, respectively. Data was also separated, pre-processed, and saved in a publicly accessible place. Since the DHCD already contained consonants and numerals, only the vowels from this dataset were used to train and test the model. After eliminating the occluded pictures and scribbles, and the numerals, the final data collection comprises 16,250 digitised images of vowels (1250 each). This data was manually divided into folders and was also made available in CSV format, with labels attached. Each image in this dataset has a black background with white character. [6]

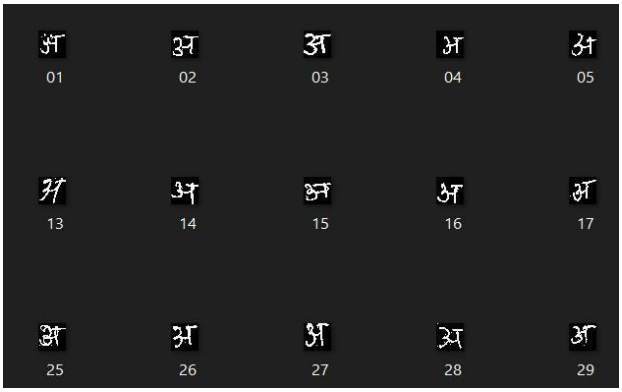

Fig. 4. Devanagari Vowels Mendeley Dataset

IV. Methodology

In this section, we discuss the workflow of the models used for handwriting character recognition of Devanagari consonants, numerals, and vowels. The workflow for both the models is the same, the only difference is the datasets used. The pictorial representation of the layers is shown in Fig 5. Before splitting of the dataset, the images were scaled down by a factor of 255. The shear range, the axis along which the image was distorted was 0.2. After this, the dataset is split into training and testing set. The dataset was categorized into 45 classes for Devanagari consonants and numerals, and in 13 classes for Devanagari vowels. After splitting the dataset, it is passed through the CNN model and the model is trained for 25 epochs. Our proposed models for Devanagari consonants and vowels use a total of 11 layers each. The input shape of the image is 32x32 and the kernel size for the model layers is (3, 3). The CNN Model is composed of mainly three things, convolutional layer, max pooling layer, and fully connected layer. Different combinations of multiple layers can be applied to enhance the feature extraction and increase accuracy achieved. Non- activation function reLu is used in the initial layers. In the final layers, the softmax activation function has been used. The key advantage of employing Softmax is the range of the output probabilities, which will be between 0 and 1. The optimizer used in the model for computing the adaptive learning rates at each epoch is Adam optimizer. The feature extraction involves repetition of sequential steps as is visible in Fig 5.

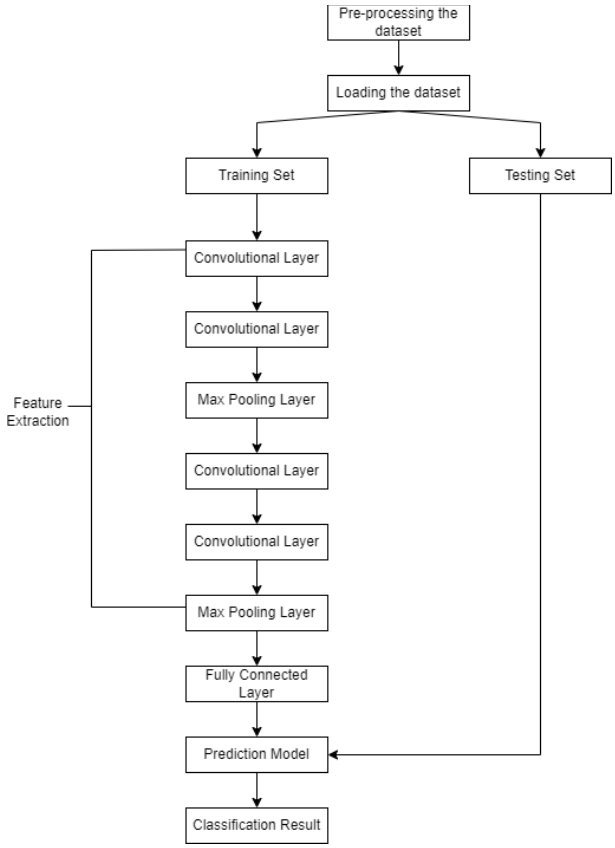

Fig. 5. Flowchart of CNN Model 1 for Devanagari Consonants and Numerals

V. Results and Conclusion

In the beginning stages of the development, some different layer combinations were tried and tested in the CNN, and these models were studied extensively to give us a perspective. Upon further study and trials, two models were proposed by us for Devanagari consonants and numerals, and vowels handwritten character recognition. The model under study was trained for 30 epochs initially. But the accuracy achieved could be further improved and hence, the next run of the models were done for 25 epochs, along with changes in the optimization process. The training accuracy achieved by the model is 99.54%, the testing accuracy achieved is 99.16%. The accuracy achieved is better than that of the model under study. The prediction results were manually checked and the models predictions were thus verified to be correct. The dataset used for vowels was categorized into 13 classes. The training and testing accuracy of the Devanagari vowels model were 99.64% and 99.73% respectively, which were again better than the model accuracy being studied prior to the implementation. The comparison of the accuracies of all the models studied and proposed have been tabulated below in Table 1. As can be seen from the table, the performance of our model has been significantly better than the existing ones.

Model Name	Number of Layers	Number of Epochs	Training accuracy	Testing accuracy
Devanagari Model under study	6	30	98.85%	96.86%
First Devanagari Model (Consonants and Numerals)	11	30	91.88%	95.52%
Final Devanagari Model (Consonants and Numerals)	11	25	99.54%	99.16%
Final Devanagari Model (Vowels)	11	25	99.64%	98.73%

Table 1. Results of models

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…are written as units in this segmental writing system. **The Devanagari script is penned from left to right and top to bottom**, and it lacks the idea of upper and lower…

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The Devanagari script is penned from left to right and top to bottom. Devanagari script lacks the idea of upper and lower case [6] .

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…the idea of upper and lower case. Because of **the potential** changes **in the form, number, and position of the constituent strokes**, unconstrained Devanagari writing is more subtle than English writing.

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6) Unconstrained Devanagari writing is more nuanced than English language due to **the potential** differences **in the form, number, and position of the constituent strokes**.

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letter order is founded **on phonetic principles** that **consider both, the place of articulation** and the manner **of the consonants and vowels they represent** [1].

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The **letter order** of Devanagari, like nearly all Brahmi scripts, **is** based **on phonetic principles** which **consider both the** manner and **place of articulation of the consonants and vowels they represent**.

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The **Convolutional Neural Network (CNN) is a deep** learn- ing **architecture** that is **inspired by the** human brain's **natural visual perception mechanism**. Due to increase in volumes of available data and…

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Introduction **Convolutional Neural Network (CNN) is a** well-known **deep** learning **architecture inspired by the natural visual perception mechanism** of the living creatures.

Recent Advances in Convolutional Neural Networks - arXiv https://arxiv.org/pdf/1512.07108

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…36 consonants and 10 numerals, with 2000 examples each. **The dataset** was **split into training set (85%) and testing set (15**%). There were a total of 92000 images (78200 in…

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There are 46 classes of characters with 2000 examples each. **The dataset** is **split into training set(85%) and testing set(15**%).

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…which the image was distorted was 0.2. After this, **the dataset is split into training and testing set**. The dataset was categorized into 45 classes for Devanagari…

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There are 46 classes of characters with 2000 examples each. **The dataset is split into training** set(85%) **and testing set**(15%).

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