RESEARCH ARTICLE

BON VIEW PUBLISHING

Evaluation of Deep Learning CNN Model for Recognition of Devanagari Digit

Kavita Bhosle[1],* and Vijaya Musande[2]

[1]Computer Science and Engineering Department, Maharashtra Institute of Technology, India

[2]Jawaharlal Nehru Engineering College, MGM University, India

Abstract: Devanagari character and digit recognition are a difficult undertaking because writing style depends on a person's traits and differs from person to person. We get more precise results in digit recognition, thanks to deep learning convolutional neural networks (CNNs), which function similarly to the human brain. In this study, the CNN method was put into practice and contrasted with the feed-forward neural network and random forest approaches. In comparison to previous methods, CNN has reportedly provided an accuracy rating of up to 99.2%. CNN is effective with both organized and unstructured data, including pictures, video, and audio.

Keywords: deep learning, convolutional neural network, feed-forward neural network, random forest classifier

1. Introduction

The writing way is a matchless characteristic of a human being because it varies from one person to another. Variety in writing fashion, handwritten character recognition under the purview of pattern recognition, is important. Automation of such task is required for fast recognition.

In the realm of image processing, computer vision and pattern recognition are a key emerging field. One of the key areas in pattern recognition is the handwritten digit recognition system. A handwritten document that has been digitalized or scanned can have its characters recognized by this system. This framework has become a crucial component of many diverse applications, including the automation of office reports, the verification of signatures, the use of manually typed postcodes, and many other uses. This system becomes challenging since characters created by different authors cannot be distinguished from one another from multiple angles, such as literary style, size, and shape.

1.1. Related work

Review paper (Bag & Harit, 2013) studies and considers optical character detection for many Indian scripts, including Devanagari, Bangla, Malayalam, Kannada, Oriya, Tamil, Gurmukhi, Gujarati, etc. Few researchers (Govindan & Shivaprasad, 1990) have discussed character recognition in their works in terms of its reviews, applications, techniques, research work, and practical approach. Some have provided an examination of the many methods investigated for Devanagari word and difficult to read character recognition.

Additionally provided are insights into several Optical Character Recognition (OCR) challenges (Singh & Garg, 2021). The detection of restricted handwritten Devanagari characters has been studied. The categorization process used by the system was multi-stage (Shelke & Apte, 2015). Using multiple stage feature taking away, the detection is conceded out. The initial steps of feature extraction were based on structural traits, and character classification was finished according to their specifications. Radon and Euclidean distance transform are used in the last stage of feature extraction, which is practical for two split feed-forward backpropagation neural network (NN) (Shelke & Apte, 2015). For the purpose of recognizing handwritten Devanagari characters, classifier assemblage has been used (Deore & Pravin, 2022). The similarity between handwritten strokes and stored stroke templates has been determined (Santosh et al., 2012).

For online handwritten character recognition for Bengali and Devanagari script, some researchers have adopted zone-based characteristic extraction. Additionally, each stroke and the slope angles between succeeding spots are taken into account, and properties have been deduced in these confined zones (Ghosh & Roy, 2015). The pattern pixel placement has been treated as a distinct attribute in this paper's new methodology (Ramana et al., 2011). In the discipline of Natural Language Processing (NLP), the identification of Devanagari digits is crucial. The study's findings will be useful for information retrieval, search engines, and other applications.

1.2. Organization of the paper

The objective of this study is to investigate more accurate method for feature extraction, Devanagari digit recognition, implementation of an optimized model for convolutional neural network (CNN), and also evaluation of the CNN model and compare it with conventional

*Corresponding author: Kavita Bhosle, Computer Science and Engineering Department, Maharashtra Institute of Technology, India. Email: kavita.bhosle@mit.asia

classification methods. The organization of the paper is as follows: Section 2 explains data and method used, Section 2.1 discusses dataset used, Section 2.2 discusses method used, Section 3 explains result and discussion, and Section 4 concludes.

2. Data and Method Used

Data required to implement this method are Devanagari digit. We have proposed deep learning CNN.

2.1. Dataset used

We have used standard popular dataset with 20,000 images of size 32×32 pixels. We are using 17,000 samples for training and 3000 samples for testing 17,000 for training of the machine and 3000 for testing. This dataset is available at Kaggle datasets. We have used Kaggle dataset, which is available on https://www.kaggle.com/datasets/rishianand/devanagari-character-set

2.2. Method used

We investigated the challenges in recognition of Devanagari characters; it has been observed that the writing skill is a matchless characteristic of a human being because it varies from one person to another. Variety in writing fashion, handwritten character recognition under the purview of pattern recognition, is important. Such task is required for fast recognition. We propose deep learning CNN method. CNN method allows us to enter characters in any number or order of strokes and is also tough to certain quantity of overwriting. The CNN architecture provides an increased set of Devanagari character classes.

The character image is divided into 32×32 numbers of pixels. A feature has been calculated from each of these pixels. A feature is based on the black area coverage in that pixel. A feature has been calculated using average pixel density.

To improve test accuracy, many researchers have used deep CNN with a focus on the utilization of dropout and dataset increment approach methods (Acharya et al., 2015). Using DevNet, a specially designed CNN architecture, several CNN models on datasets of handwritten Devanagari characters and numerals are compared (Guha et al., 2020). On the shared ISI, Kolkata ISIDCHAR database, many people have employed deep CNN (Jangid & Srivastava, 2018). This study used a deep learning CNN model to create AlexNet, DenseNet, Vgg, and ConvNet (Aneja & Aneja, 2019). There have been experiments using different CNN and inverse scale annealing technique combinations (Mehrotra et al., 2013).

2.2.1. Deep CNN

We also provide a deep learning architecture for recognizing those characters in addition to the dataset. In several recognition tests, deep CNNs have outperformed conventional shallow networks. A piecewise histogram of pulled-out oriented gradient features was utilized to recognize a handwritten Devanagari character. A characteristic vector made up of the histogram of the oriented gradient characteristics of each division was used to train the NN (Singh, 2018).

One of the writing systems used for several Indian languages, including Sanskrit and Hindi, is the Devanagari script. Shaon proposed an effective handwritten Devanagari numeral digit recognition method using ResNet (Bandyopadhyay, 2020).

CNN model consists of alternate convolutional, max pooling layer followed by fully connected NN layer as shown in Figure 1.

Figure 1
Architecture diagram of CNN
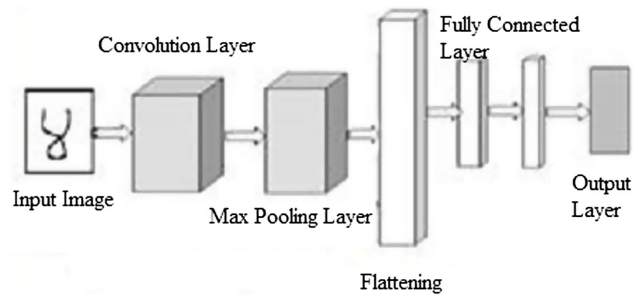
Filter size of 3×3 has been used in this model. Input image is of shape 32×32. We have used ReLU as our activation function. CNN is a sequential model with categorical cross-entropy as number of class label is more than two.

An optimizer is one of the arguments required for compiling a CNN model. As there are number of optimizers available like SGD, Adagrad, Adadelta, Adam, RMSprop, etc. we have used Adam optimizer. We have tested all optimizers; their result was very poor than Adam. We found that Adam has given better accuracy compared to other optimizers.

Using the activation function of the convolution layer, an input image is converted into extract features, a smaller region is used. The data that is input. Data having the highest value in a given area are accepted by the pooling layer. In order to classify the input, these layers function to pick an essential feature. These are given that it has several layers with only one activation function. This makes it impossible to extract the particular characteristic and features.

Researchers have used the CPAR-2012 dataset for a number of investigations. They utilized elements ranging from the most basic to the complex. They have measured the recognition accuracy of several classification algorithms using these features (Kumar & Ravulakollu, 2014).

For the recognition of Devanagari handwritten characters, Kannuru had used deep learning. Because of its significant contribution to automation systems, handwritten character recognition is becoming more important. One of the several language scripts used in India is the Devanagari script. There are 12 vowels and 36 consonants in it (Padmaja, 2022). Deep learning approach has been used by many researchers for recognition of handwritten character or digits (Pandey, 2021).

2.2.2. Feed-forward NN

A multilayered feed-forward perceptron is a form of NN that is frequently used and is composed of multiple layers of neurons coupled to one another. Many fields have successfully used artificial neural networks for remote sensing. Deep NN is the name given to multilayer perceptron with deep hidden layer. The complexity of a deep NN rises as there are more hidden layers added. Four dense layers make up the deep NN in this study. A ReLU activation function and 30 nodes are present in each layer. A parallel computing system with a very large number of interconnected basic processors can be used to explain the deep NN classifier.

2.2.3. Random forest classifier

Random forests, also known as random choice forests, are one of the ensemble learning techniques. Regression, classification, and

other tasks have used it. It builds several decision trees throughout training period and predicts the class labels.

3. Result and Discussion

We have examined pre-trained models that use deep learning CNNs to recognize handwritten Devanagari digits (CNN). Results indicate that CNN performs better, with a 99.2% accuracy rate. The 98.5% accuracy of the feed-forward NN demonstrates its effectiveness. The accuracy of the random forest approach was 96.29% as shown in Figure 2.

We used a dataset that contained 20,000 photos. Seventeen thousand of the entire dataset were used to train the model, and 3000 were used to test the model. The model has been trained with adequate amounts of data. By doing this, we have prevented overfitting. To prevent overfitting, L2 regularization has been applied.

Table 1 represents the comparison of accuracy between CNN and other method. It has been observed that CNN model is best for Devanagari digits.

And CNN model has given 99.2% accuracy which is better than other methods. Accuracy has been calculated using confusion matrix, precision, and recall. The model that has been proposed and compared is evaluated using confusion matrix. The overall accuracy is the ratio of summation of all true positive number for all classes and total test record. Zero to nine Devanagari digits of 10 classes have been considered for evaluation of this model.

Table 2 shows confusion matrix. The following evaluation parameters have been used to calculate accuracy.

Figure 2
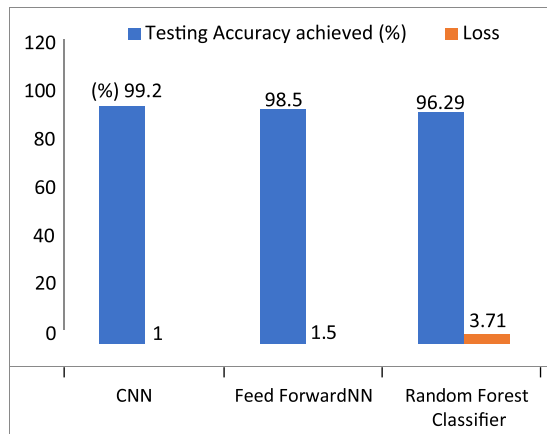**Graph showing comparison between CNN and other methods**

Table 1
Accuracy achieved using CNN

Methods	Testing accuracy achieved (%)	Loss (%)
CNN	99.2	1
Feed-forward NN	98.5	1.5
Random forest classifier	96.29	3.71

Table 2
Confusion matrix

		Predicted values									
		0	1	2	3	4	5	6	7	8	9
Actual values	0	TP 0	E 01	E 02	E 03	E 04	E 05	E 06	E 07	E 08	E 09
	1	E 10	TP 1	E 12	E 13	E 14	E 15	E 16	E 17	E 18	E 19
	2	E 20	E 21	TP 2	E 23	E 24	E 25	E 26	E 27	E 28	E 29
	3	E 30	E 31	E 32	TP 3	E 34	E 35	E 36	E 37	E 38	E 39
	4	E 40	E 41	E 42	E 43	TP 4	E 45	E 46	E 47	E 48	E 49
	5	E 50	E 51	E 52	E 53	E 54	TP 5	E 56	E 57	E 58	E 59
	6	E 60	E 61	E 62	E 63	E 64	E 65	TP 6	E 67	E 68	E 69
	7	E 70	E 71	E 72	E 73	E 74	E 75	E 76	TP 7	E 78	E 79
	8	E 80	E 81	E 82	E 83	E 84	E 85	E 86	E 87	TP 8	E 89
	9	E 90	E 91	E 92	E 93	E 94	E 95	E 96	E 97	E 98	TP 9

$$\text{Precision } 0 = (TP0)/(TP0 + E10 + E20 + E30 + E40 + E50 + E60 + E70 + E80 + E90) \tag{1}$$

$$\text{Recall } 0 = (TP0)/(TP0 + E01 + E02 + E03 + E04 + E05 + E06 + E07 + E08 + E09) \tag{2}$$

$$\text{F1 Score} = (2 \times \text{Precision} \times \text{Recall})/(\text{Precision} + \text{Recall}) \tag{3}$$

$$\text{Overall accuracy} = \text{Number of correctly classified samples}/\text{Number of test samples} \tag{4}$$

$$\text{Overall accuracy} = (TP\,C + TP\,M + TP\,S + TP\,R)/(\text{Total test record}) \tag{5}$$

A highly developed research field in pattern recognition is the recognition of handwritten digits. Pre-segmented handwritten digits are categorized using it. Sanskrit and Hindi are two of the many Indian languages that use the Devanagari script as their writing system. This study proposes a CNN-based method for efficient handwritten Devanagari numeral digit recognition. Modern research in this area is focusing on deep learning. CNN is a deep learning architecture that is expensive to compute yet offers great accuracy in classification issues.

We have incorporated Adam optimizer into our model. It is a technique that employs an adaptable learning rate. Using training data as a guide, it is utilized to update network weight. Adam modifies the learning rate for each weight of the neural system using the first and second moments of the gradient for estimate.

The creation of a handwritten and printed Devanagari character recognition system has been the subject of numerous research attempts by numerous research groups. There is also a description of how different methods are compared in terms of feature extraction methods, classifiers, datasets, and accuracy metrics (Sharma et al., 2019).

For usage in library and office automation, postal services and banking, publishing companies, and communication technologies, digital document processing is becoming more and more popular. More than 500 million people who speak Devanagari as their mother tongue should be given special consideration in order to efficiently retrieve documents and analyze the wealth of ancient and current Indian literature (Dongre & Mankar, 2010).

Proposed method can be helpful for number plate recognition, character recognition, and many more. The implications of this research can be benefited to society as Devanagari script is widely used in India. Chatbots are a type of virtual assistant where we communicate with a computer program rather than a real person. However, it appears as though we are conversing with a genuine person. Proposed research can be used for making chatbot using Devanagari script. The hot issue in machine learning right now is chatbots. It responds appropriately to the user's requests after processing them (Mane et al., 2022).

The proposed work can be applied after the use of segmentation technique for words and characters of Devanagari handwritten scripts (Dhaka & Sharma, 2015).

4. Conclusions

It has been observed that if we use proper learning rate and optimizers with CNN we will get maximum result output.

This paper fulfills every need of the researcher who is working on Devanagari digits. CNN mode is simple to understand as well as efficient in working. CNN works well on unstructured data like audio, video, and images. CNN has given 99.2% accuracy; feed-forward NN has given 98.5% accuracy, whereas random forest method has given 96.29% accuracy. CNN also worked well on noisy data. CNN as per the observation memory requirement for CNN is less compared to feed-forward NN.

Deep learning CNN works efficiently and given better accuracy than traditional methods. Primary motive is to develop a network which is better to every performance measure and provide results for all kinds of datasets which can be trained and trained.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

References

Acharya, S., Pant, A. K., & Gyawali, P. K. (2015). Deep learning based large scale handwritten Devanagari character recognition. In *2015 9th International Conference on Software, Knowledge, Information Management and Applications*, 1–6. https://doi.org/10.1109/SKIMA.2015.7400041.

Aneja, N., & Aneja, S. (2019). Transfer learning using CNN for handwritten Devanagari character recognition. In *2019 1st International Conference on Advances in Information Technology*, 293–296. https://doi.org/10.1109/ICAIT47043.2019.8987286.

Bag, S., & Harit, G. (2013). A survey on optical character recognition for Bangla and Devanagari scripts. *Sadhana*, *38*, 133–168. https://doi.org/10.1007/s12046-013-0121-9.

Bandyopadhyay, S. (2020). A study on handwritten Devanagari digits recognition using residual neural network. *Advances in Mathematics Scientific Journal*, *9*(9), 6999–7007. https://doi.org/10.37418/amsj.9.9.49

Deore, S. P., & Pravin, A. (2017). Ensembling: Model of histogram of oriented gradient based handwritten devanagari character recognition system. Traitement du signal, 34(1-2), 7–20.

Dhaka, V. P., & Sharma, M. K. (2015). An efficient segmentation technique for Devanagari offline handwritten scripts using the Feedforward Neural Network. *Neural Computing and Applications*, *26*, 1881–1893.

Dongre, V. J., & Mankar, V. H. (2011). A review of research on Devnagari character recognition. *arXiv preprint 1101.2491*.

Ghosh, R., & Roy, P. P. (2015). Study of two zone-based features for online Bengali and Devanagari character recognition. In *2015 13th International Conference on Document Analysis and Recognition*, 401–405. https://doi.org/10.1109/ICDAR.2015.7333792.

Govindan, V. K., & Shivaprasad, A. P. (1990). Character recognition — A review. *Pattern Recognition*, *23*(7), 671–683. https://doi.org/10.1016/0031-3203(90)90091-X.

Guha, R., Das, N., Kundu, M., Nasipuri, M., & Santosh, K. C. (2020). DevNet: An efficient CNN architecture for handwritten Devanagari character recognition. *International Journal of Pattern Recognition and Artificial Intelligence, 34*(12), 2052009. https://doi.org/10.1142/S0218001420520096.

Jangid, M., & Srivastava, S. (2018). Handwritten Devanagari character recognition using layer-wise training of deep convolutional neural networks and adaptive gradient methods. *Journal of Imaging*, *4*(2), 41. https://doi.org/10.3390/jimaging4020041.

Kumar, R., & Ravulakollu, K. K. (2014). Handwritten Devanagari digit recognition: Benchmarking on new dataset. *Journal of Theoretical and Applied Information Technology, 60*(3), 543–555.

Mane, D., Patil, M., Chaudhari, V., Nayakavadi, R., & Pandhe, S. (2022). A survey on Chatbot in Devanagari language. *In Proceedings of the 6th International Conference on Advance Computing and Intelligent Engineering: ICACIE 2021*, 341–354.

Mehrotra, K., Jetley, S., Deshmukh, A., & Belhe, S. (2013). Unconstrained handwritten Devanagari character recognition using convolutional neural networks. In *Proceedings of the 4th International Workshop on Multilingual OCR* 1–5. https://dl.acm.org/doi/abs/10.1145/2505377.2505386.

Padmaja, K. (2022). Devanagari handwritten character recognition using deep learning. *International Journal for Research in Applied Science & Engineering Technology*, *10*(1), 102–105. https://doi.org/10.22214/ijraset.2022.39744

Pandey, S. P. (2021). Handwritten Devanagari digits recognition using deep learning. *International Journal of Education, Modern Management, Applied Science & Social Science*, *3*(2), 48–51.

Ramana Murthy, O. V., & Hanmandlu, M. (2011). Zoning based Devanagari character recognition. *International Journal of Computer Applications*, *27*(4), 21–25. https://doi.org/10.5120/3289-4481.

Santosh, K. C., Nattee, C., & Lamiroy, B. (2012). Relative positioning of stroke-based clustering: A new approach to online handwritten Devanagari character recognition. *International Journal of Image and Graphics*, *12*(2). https://www.worldscientific.com/doi/abs/10.1142/S0219467812500167.

Sharma, A. K., Adhyaru, D. M., & Zaveri, T. H. (2019). A survey on Devanagari character recognition. In *Springer Conference Smart Systems and IoT: Innovations in Computing, Proceeding of SSIC 2019*, 429–437.

Shelke, S., & Apte, S. (2015). A fuzzy based classification scheme for unconstrained handwritten Devanagari character recognition. In *2015 International Conference on Communication, Information Computing Technology*, 1–6. https://doi.org/10.1109/ICCICT.2015.7045738.

Shelke, S., & Apte, S. (2010). A novel multi-feature multi-classifier scheme for unconstrained handwritten Devanagari character recognition. In *2010 12th International Conference on*

Frontiers in Handwriting Recognition, 215–219. https://doi.org/10.1109/ICFHR.2010.41.

Singh, N. (2018). An efficient approach for handwritten Devanagari character recognition based on artificial neural network. In *2018 5th International Conference on Signal Processing and Emerging Science and Technology Department, MIT, Integrated Networks (SPIN)*, 894–897. https://doi.org/10.1109/SPIN.2018.8474282.

Singh, S., & Garg, N. K. (2021). Review of optical Devanagari character recognition techniques. In *Intelligent System Design, Advances in Intelligent Systems and Computing, 1171,* 97–106. https://doi.org/10.1007/978-981-15-5400-1_11.