Handwritten Devanagari Character Recognition using Neural Networks

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ABSTRACT:

Devanagari is an ancient script used for over 120 spoken Indo-Aryan languages, including Hindi, Nepali, Marathi, Maithili, Awadhi, Newari and Bhojpuri. This script is used by millions of people in India to write documents in Marathi and Hindi [2]. Most of the Indian mythology is written in this script. Handwritten Devanagari character recognition has gained popularity over the years due to such importance of the script. Although significant research has been made in full character recognition of Devanagari characters using Convolution neural networks for both feature extraction and classification, the report experiments different classifiers for classifying and predicting the handwritten characters while using CNN and DNN for feature extraction. The scope of report has been widened by making the model to predict partial Devanagari characters while been trained on full characters and vice versa.

KEYWORDS:

Handwritten Devanagari character recognition, Image processing, Feature extraction, Convolutional Neural Networks, Dense Neural Networks, Classifiers

1. INTRODUCTION:

Handwriting recognition is an art of identifying characters from handwritten images. Recognition of hand written images is getting more and more attention due to its wide range of applications. Conversion of handwritten characters is significant for preserving several historical documents related to our history such as manuscripts, into machine editable form. This script (Devanagari) has various characteristics like complex shape, presence of modifiers, similarity between characters which makes recognition of Devanagari characters, a difficult task. Hence, this topic is one of the fascinating topics in the field of image processing and pattern recognition.

Character recognition techniques associate a symbolic identity with the image of a character. These character images are preprocessed and then features are extracted from them. Features extracted from character encode the structural characteristics of character shape[1].

The field of handwriting character recognition is broadly divided into two parts:

1) Online character recognition:
In this the characters are recognized at real time as soon as it is written. Online character recognition gives little better performance than offline recognition as they do not need to locate the character and also have time information.

2) Offline character recognition:
Offline character recognition can be classified further into following:
   1. Printed characters recognition.
   2. Handwritten character recognition.

Classification of handwritten character recognition is more challenging due to shape of characters, great variation of character symbol and image quality. Thus, this topic is chosen as the focus of this report.

1.1 PROBLEM STATEMENT

Character recognition of handwritten Devanagari characters using Convolutional neural networks and Dense neural networks for feature extraction and various multiclass classifiers classifying the characters. Dataset consisting of 36 unique Devanagari characters with 1700 images of each character is being used for training and testing the model. Predicting each character given the full and partial image of the character is the challenging problem solved in the report. Following are the highlights of the report:

1) Training the model on full character image and making it predict the Devanagari character given full image of the character.
2) Training the model on full character image and making it predict the Devanagari character given partial or half image of the character.
3) Training the model on half character image and making it predict the Devanagari character given full image of the character.

1.2 MOTIVATION:

Until now great amount of research has been made in predicting handwritten Devanagari characters and accuracy of 98% has been achieved using Convolution neural networks. However, all the research aims at predicting the character given the full image of the character. The motivation here is to make the model learn and predict the Devanagari character given the partial image of the character.

1.3 REVIEW OF OTHER RESEARCHES:

1. Ashwin S Ramteke, Milind E Rane A "**Survey on Offline Recognition of Handwritten Devanagari Script** "
   This paper uses HMM for feature extraction of Devanagari characters and follows a image segmentation approach where the text is extracted from the image after segmenting the image to read individual characters. K Nearest Neighbors (KNN) SVM, MLP are used for classification of the handwritten images. Thus, the paper tries to achieve automatic recognition of handwritten Devanagari Script by using various algorithms.

2. By Aradhana a Malankara 1, Prof. Mitul M Patel 2" **Handwritten Devanagari Script Recognition: A Survey** "
   This paper gives an insight of the character recognition and surveys the various research work done in this field. The paper discusses the method for character recognition and discusses the various applications of handwritten Devanagari character recognition systems.

3. J. Pradeep1, E. Srinivasan2 and S. Himavathi3 "**Diagonal Based Feature Extraction for Handwritten Alphabets Recognition System using Neural Network**" -
   In this multilayer feed forward, neural network is used for handwritten character recognition. the paper introduces a new method, called, diagonal based feature extraction for extracting the features of the character images. Fifty data sets, each containing 26 alphabets written by various people, are used for training the neural network and 570 different handwritten alphabetical characters are used for testing [3].

1.4 OPEN QUESTIONS IN THE DOMAIN:

After a brief overview of the domain and performing a literature survey following open questions were thought of:

- Analyzing the effect of using classifiers that take features from Neural Networks as input and then predict the target label.
- Assess the effect of predicting a printed image by a model that is trained and validated on handwritten image classification.

1.5 SUMMARY OF PROPOSED APPROACH:

Recognizing handwritten Devanagari images give the full and partial image is the proposal in the report. From all the proposed work seen in the papers cited in the reference section, character recognition has been done with respect to the context of full character image. Given the various applications of character recognition of Devanagari script been used in ancient writings, we can have scripts or documents where partial characters are present. This means we can have half the image of the character.
This report proposes to predict such partial images of the characters. The application of the new proposal can be made to various documents which have incomplete characters of the Devanagari script.

1.6 FEEDBACK RESPONSE:

Based on the **feedback** received from the Professor, following attempts are made for the implementation to differentiate from the work proposed by various authors so far:

1. Training the model on full character images and making it predict the Devanagari character given partial or half image of the character.
2. Training the model on half character images and making it predict the Devanagari character given full image of the character.
3. Extract the features of the images from the Neural Networks and then pass these features to the classifiers which predict the target label.
4. Analyze the impact of predicting a printed Devanagari character image by a model trained and validated using handwritten Devanagari character images.

2. BACKGROUNDS

Background study of the proposed work by various authors has been done to study and understand the work done so far on handwritten Devanagari characters. The methods and models used for predicting the images have been understood and then future scope and experiments of the project is decided based on the outcomes of these papers.

Following were the research papers used for study:
1. Ashwin S Ramteke, Milind E Rane "**A Survey on Offline Recognition of Handwritten Devanagari Script**":

The paper tries to achieve automatic recognition of handwritten Devanagari Script by using various algorithms Various algorithms used in this paper are studied and used in our experiments. MLP and K Nearest Neighbors (KNN) used in this paper are tried on our model.

2. Aradhana a Malankara 1, Prof. Mitul M Patel 2 “**Handwritten Devanagari Script Recognition: A Survey**”:

This paper talks about character recognition and surveys the various research work done in this field and discusses the various applications of handwritten Devanagari character recognition systems. All these applications have been studied and thought of when increasing the scope of the Report.

3. J. Pradeep1, E. Srinivasan2 and S. Himavathi3 “**Diagonal Based Feature Extraction for Handwritten Alphabets Recognition System using Neural Network**”:

In this multilayer feed forward, neural network is used for handwritten character recognition. Diagonal based feature extraction introduced in this paper is a new and interesting methods for extracting the features of the character images. This method was studied and tried however not implemented in this report.

3. METHODS

The model uses CNN and DNN for feature extraction and various classifiers mentioned in above sections for Classifying the images.
The following approach has been made for the proposal

1. Build and configure a CNN network to extract features
2. Feature extraction using Convolutional and Deep Neural Networks.
3. Classification of the 36 unique characters using following classifiers:
a. Random Forest
b. Multi-layer perceptron
c. KNN
4. Training model on 36 unique characters with 1700 images of each character. Predicting the character given the full or partial image of the character.
5. Training model on few unique characters. Predicting the character given the partial and full image of the character.
6. Visualizing the accuracy of each classification model
7. Visualizing the actual and predicted character.

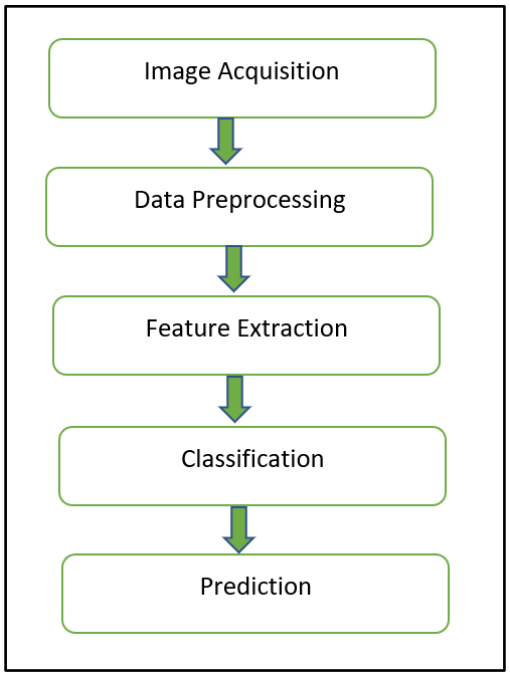


Figure 1: Handwriting recognition system approach

3.1 Data preprocessing:

The dataset picked up from UCI contains training and test data. Each having 36 Devanagari characters. For each character a folder is created containing the name of the character in English. Each folder contains 1700 images of the respective character. The target labels (the character name in English) is not given separately.
Thus, data is preprocessed by extracting the character name from the folder and storing into and label array which is further used for training the model.

Each image is a 32 * 32 grayscale image which is to be converted into array and then flattened a stored in an image matrix to train the model.

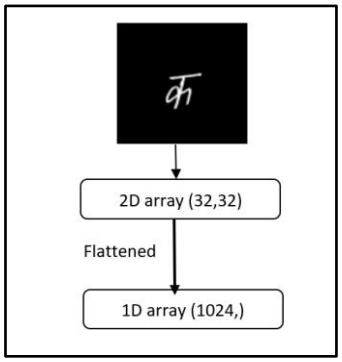
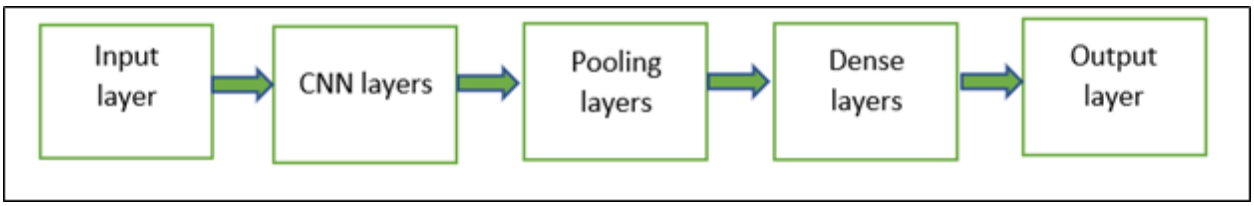
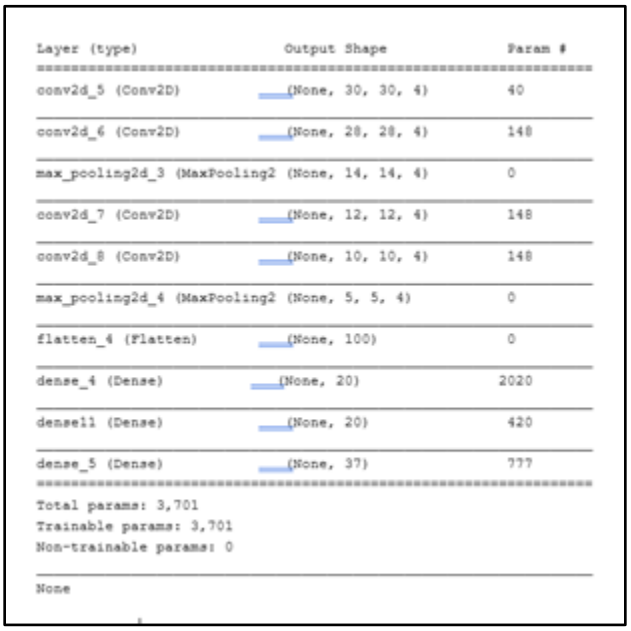


Figure 2: Image preprocessing

3.2 Feature Extraction:

The features should be selected in such a way that it reduces the intra-class variability and increases the inter-class discriminability in the feature space. [1]
Convolution Neural networks (CNN) has been the best feature extraction Neural network used so far by various authors. Here, the scope has been tested and experimented by using Dense Neural networks in combination to CNN. “RELU” activation function is used for input and hidden layers and “sigmoid” activation function is used in the output layer. Given below is the Neural network architecture:





Layer (type)	Output Shape	Param #
conv2d_5 (Conv2D)	(None, 30, 30, 4)	40
conv2d_6 (Conv2D)	(None, 28, 28, 4)	148
max_pooling2d_3 (MaxPooling2	(None, 14, 14, 4)	0
conv2d_7 (Conv2D)	(None, 12, 12, 4)	148
conv2d_8 (Conv2D)	(None, 10, 10, 4)	148
max_pooling2d_4 (MaxPooling2	(None, 5, 5, 4)	0
flatten_4 (Flatten)	(None, 100)	0
dense_4 (Dense)	(None, 20)	2020
dense11 (Dense)	(None, 20)	420
dense_5 (Dense)	(None, 37)	777

Total params: 3,701
Trainable params: 3,701
Non-trainable params: 0

None

Figure 3: Neural Network architecture

The features extracted from the dense layers are then passed to the classification model.

3.3 Classification:

- The features extracted from the Neural Network layer are passed to different classifiers for purpose of classification.
- The classifiers are then used to predict the target labels based on the extracted features.
- Since the target class contain 36 different labels the problem is a multiclass classification problem.

- Following classifiers which are popular for multiclass classification are used to classify the target labels from the extracted features:

1. **Random Forest Classifier:**

- A random forest fits a number of decision tree classifiers on various sub-samples of the dataset and uses averaging to improve the predictive accuracy.
- For model trained on all 36 characters the accuracy of Random Forest Classifier was found to be in a range of 68% to 78%
- For a model trained and validated on limited number of characters the accuracy was around 85% to 90%
- A model where the cropped images were used for training and validation the CNN-Random Forest accuracy dropped to 22% to 30%

2. **Multi-Layer Perceptron Classifier:**

- One of the popular classifiers for multiclass classification which uses stochastic gradient descent to optimize log-loss function.
- For fully trained and validated network across 36-character images the accuracy of MLP was around 74% to 80 %
- For model validated on limited number of character images the accuracy of this classifier was between 87% to 92%
- In experiment to train and verify the model on cropped images, MLP gave an accuracy of around 55%

3. **K-Nearest Neighbor Classifier:**

- K Nearest Neighbor classifier implements the k-nearest neighbors vote.
- For all 36 characters trained and validated model, KNN had a classification accuracy of around 78% to 82%
- KNN had an accuracy ranging between 88% to 92% for model trained and validated on small number of target classes.
- The accuracy of KNN dropped down to 25% when the model was trained and validated on the cropped images

3.4 Prediction:

Prediction of Devanagari characters have following variations:

1. Predict the given full image of the handwritten Devanagari character.
The model has been trained on full character images of the Devanagari character set. It then predicts the character (given full image of the character) with high accuracy.

2. Predict the given partial image of the handwritten Devanagari character.
The model has been trained on full character images of the Devanagari character set. It then predicts the character given only partial image of the character. However, as the

alphabets in Devanagari are similar their partial images also look similar. Hence much accuracy cannot be obtained in this prediction.

Given below are two characters “Kaa” and “Waa”. If “Ka” is cut horizontally it will look like “Waa” and hence the model gets confused.

Figure 3: Devanagari character "Ka"

Figure 3: Character "Ka" cut horizontally

Figure 4: Devanagari character "Waa"

3. Predict the given full image of the printed Devanagari character:
The model has been trained with handwritten images and using Tesseract OCR the model predicts printed Devanagari character. Thus, the handwritten recognition model can be used for predicting printed images as well.

4. EXPERIMENTS

Various experiments were performed to analyze the effect of extracting features from Neural Networks and then using Classifiers to predict the target using those features. Each of the experiment performed has been explained in detailed below:

1) **Extract features using Neural Networks and predict target using Classifier**s

- All the currently available work on character recognition of Devanagari script has been done by implementing CNN and DNN only.
- An attempt was made to modify this approach by integrating the Neural Networks and multi class classifiers.
- In this experiment, Neural Network was configured to extract the features from the images.
- Read images were then fed to this network consisting of multiple convolution, pooling and dense layers.
- The output of the second last layer (dense layer) from the Neural Networks consisting of the features was extracted after passing the inputs to the model.
- This output was then divided as train and test data to evaluate classifier performance.
- The classifiers were trained using these extracted features and their corresponding labels from the train data.
- Test data created above was used to assess the performance of the classifiers.

- In order to better understand the variations, different classifiers like Random Forest, Multi-Layer Perceptron and K-Nearest Neighbors were evaluated.
- Performance of each classifier showed variations depending on the type of data used to train and evaluate the model.

KEY FINDINGS:

- Small variations were observed in the accuracies of different classifiers which took the features extracted from CNN as input and predicted the target labels on test data.
- The accuracy of the CNN model, if used for classification, was found out to be in a range of 70% to 80% for 10 epochs.
- If the classifiers were fed with features from this neural network, then their classification accuracy was in range of 72% to 81%.
- Thus, it could be seen that using the classifiers led to a small increase in the accuracy.

2) **Train the model on cropped character images and predict full character images**

- In real life scenario it may be possible that the available images may contain cropped/partial characters due to poor data quality.
- An experiment was performed to evaluate the effect of training the model using the cropped images and then using it to predict full character images.
- Due to unavailability of data existing data with cropped images and time constraints, only a small amount of data was used for training and validating the model.
- This however displayed interesting results and can be made a part of future scope.
- In this experiment, a few images of each character were cropped manually and given to the model for training and validation.
- Full character images were then passed to the model and model was then used to predict those images.
- The results showed that model could identify the pattern from cropped images and could be used predict the full images.
- This was an important finding as it proved that the features extracted from neural networks could be used by the classifiers to correctly predict images.

KEY FINDINGS:

- This experiment yielded some interesting results and hypothesis.
- It was observed that when the images containing cropped characters were used to train the model, the model was able to learn the features of images.
- Here the CNN model was passed with cropped images and the features extracted were used by classifiers to predict labels.
- Since only cropped images were used for training and validation the accuracy of the model was less (around 25% to 55%) as expected only a few cropped parts could be predicted by the model.

- However, it was observed that when full character images were passed to such a trained model for prediction, at least 2 of the 3 classifiers correctly predicted the labels.
- It was because the classifiers had an intimation of the features from the cropped images which they could locate in the full images and correctly identify them leading to better accuracy.

3) **Training the model on full character images and predict the cropped image**s

- Following the reverse methodology implemented above, an experiment was performed to train the model on full character images and then predict an image with cropped character in it.
- The primary motivation of this experiment was to analyze how the model performed on receiving a partial character for prediction.
- In order to perform this experiment, the model was first trained and evaluated on all 36 target character labels.
- Certain cropped images were then passed to the model for prediction to analyze if it correctly predicted the images.
- Similar to above experiment, the model showcased some interesting findings and we could hypothesize some of the reasons for such behavior.
- Based on this experiment it could be said that the unlike the experiment above, the model would not be efficient to predict cropped images after training it on full character images.

KEY FINDINGS:

- Unlike the above experiment, this experiment provided with some unusual results.
- Here the model was trained on full character images and then used to predict the cropped images.
- Such an arrangement led to the mediocre performance of the model due to the ambiguity introduced by cropping of the images.
- The model yielded good prediction accuracy when trained and validated on the full character image data.
- But when cropped images were provided, the model led to misclassification possibly since cropping of the image may lead for the model to interpret it as a different character.
- Since Devanagari contains many such similar looking characters, a small modification can lead to a complete change of character.
- For e.g. if character ‘ka’ is cut into 2 exact vertical halves then the left image is identical to another character ‘waw’.
- This lead to mediocre performance by the model in such an arrangement.

4) **Predict a printed Devanagari character by a model trained to classify handwritten characters**

- To bring some novelty into the existing work, a printed Devanagari character was passed to the model for prediction which was trained on the handwritten characters.
- To pass the printed characters, first images of words with Devanagari characters were read and individual characters from those words were extracted.
- To extract individual characters from a word in the image, Google's Tesseract OCR was used.
- After extracting the character, each character was stored in a string as Unicode character.
- Each of these Unicode characters were then rendered and stored as image files which could be later passed to the model.
- The images created above were read and converted into appropriate format like gray-scale image, 32X32 size, etc.
- The images were then passed to the model trained on handwritten character images and predicted using the classifiers which took features from the model.
- After analyzing the performance, the model was re-trained using limited number of character targets and then printed image passed for prediction.

KEY FINDINGS:

- As a preliminary experiment, its results largely depended on the characters passed for prediction and the classifiers used to predict the target label.
- The results were also impacted by the data used for training at that instant and also the uniqueness of the character to be predicted.
- Characters like 'ka' and 'ma' which are mostly unique in the script could be predicted correctly by the classifiers.
- Whereas the characters like 'ha' or 'yaw' which have similar looking identities may lead to misclassification.

5. CONCLUSION:

In countries like India huge volumes of historical documents and books (handwritten or printed in Devanagari script) remain to be digitized for better access, sharing, indexing, etc. [1]. This will be helpful for other research communities in India in the areas of social sciences, economics, and linguistics. [2]

Handwritten character recognition is still a research area of burning pattern recognition. Each step that directly contributes to the accuracy of the system, as pre - processing, segmentation, feature extraction, training methods, etc. all. So, all these areas are open for independent research. [3]

Character recognition of handwritten Devanagari script is a difficult task considering the similarities between its characters. With the use of Neural Networks for extracting the important features of the character in the images has been very useful in mining the characteristics of the image and hence making classification of the characters simple using various multiclass classifiers.

Moreover, experimenting with full and partial images of the characters using different neural network architecture has helped understand how the quality of the extracted features change, thus affecting the classification models and its accuracy.

To conclude, Handwritten character recognition, Image processing, Feature extraction, neural networks are the various popular fields of research and the insights of these topics can be obtained from the report.

6. RESPONSE TO FEEDBACK:

Feedback about the progress plays a vital role when experimenting over a given field of study and working on a project. With respect to the feedback obtained from the professor, the following has been done:

1. Instead using CNN for both feature extraction and classification (as done in most of the research papers), CNN and DNN is used for feature extraction and different classifiers are used.
2. Novelty is introduced by widening the Scope of the project by using partial images to train and predict the model. Following experiments were done:
    a. Partial character image was passed to the model for prediction while been trained on full character image
    b. Full character image was passed to the model for prediction while been trained on partial character image.
    c. A printed Devanagari character was passed to the model for prediction which was trained on the handwritten characters.

7. REFERENCES

[1] Ashwin S Ramteke, Milind E Rane “A Survey on Offline Recognition of Handwritten Devanagari Script “. Available at https://pdfs.semanticscholar.org/0bdd/aeae131a4bcfa7832d10efb049420cc875ab.pdf

[2] Aradhana A Malanker 1 , Prof. Mitul M Patel 2 “Handwritten Devanagari Script Recognition: A Survey”. Available at http://www.iosrjournals.org/iosr-jeee/Papers/Vol9-issue2/Version-2/L09228087.pdf

[3] J.Pradeep1 , E.Srinivasan2 and S.Himavathi3 “DIAGONAL BASED FEATURE EXTRACTION FOR HANDWRITTEN ALPHABETS RECOGNITION SYSTEM USING NEURAL NETWORK”. Available at https://arxiv.org/ftp/arxiv/papers/1103/1103.0365.pdf

[4] R. Jayadevan “Offline Recognition of Devanagari Script: A Survey”. Available at https://ieeexplore.ieee.org/document/5699408

[5] R. Jayadevan “Database Development and Recognition of Handwritten Devanagari Legal Amount Words”. Available at https://ieeexplore.ieee.org/document/6065324/