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DOGRA HANDWRITTEN TEXT RECOGNITION USING MACHINE AND DEEP LEARNING MODELS

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Abstract

Dogra script which was once used to write Dogri language in the state of Jammu and Kashmir and parts of adjoining states has failed to see any remarkable work towards Dogra handwritten text recognition though reasonable work has been done for text recognition of various other scripts of Indian subcontinent and scripts at the world level. Handwritten Text Recognition is a demanding area of research since many years as the information available in handwritten form is prone to loss, mutilation and also could not be used to its full potential owing to non-understanding by the machine. Absence of standardised Dogra script dataset was one of reason for negligible work in Dogra handwritten text recognition. After creating a Dogra Character Dataset of 39000 characters, various existing classification algorithms/approaches such as Support Vector Machine (SVM), Random Forest, Convolution Neural Network (CNN), K Nearest Neighbours (kNN) and Pre-trained VGG16 CNN were deployed and recognition accuracy analysed. The activation and optimized parameters were affected to further enhance the performance. The testing parameter's result viz accuracy, precision and recall reveals that pre-trained and fine-tuned VGG16 with RMSprop optimizer out performs other algorithms and gave 97% accuracy with reduced time consumption over and above other approaches.

Key words: Dogra Text recognition, VGG16, CNN, Classification, RMSProp, Dataset.

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1. INTRODUCTION

Recognising handwritten characters/text from scanned documents and converting/saving to digital form that is searchable and editable with computer software is called offline handwritten text recognition (HTR) or Handwritten Character recognition (HCR). Text/characters written by different persons usually are never same due to variations in size, shape and style. These variations in writing styles give a challenge to recognition process [1]. The similarities among shapes of different character, the style of writing, the spacing, ligatures [2], and interconnections between neighbouring characters [3] increase complexity of recognition. Presently, HTR, HCR and pattern recognition are demanding research domain [4]. Applications in postal services, cheques processing in financial institutions, data entry, text conversion from one language to other needs offline handwritten text/character recognition system [5]. Availability of standard database/dataset is of utmost importance for evaluating and training HTR/HCR software [6] using machine learning [7], deep learning models [8].

Dogri was officially recognized in Constitution's 8th schedule in the year 2003. Historical reference to Dogri has been seen in Amir Khosrow's Nuh sipihr viz. "The Nine Heavens", [9]. Dogri has ancestral references from Sanskrit, and its written evidences are visible in ending 16th and 19th century. There are 2.3 million speakers of Dogri as per 2001 census[10]. During the rule of Maharaja Ranbir Singh (ie. 1857–85 ce), the script used for writing Dogri was Dogra/Dogra Akkhar, but in the year 1944 Devanagri script replaced Dogra script in the Dogri language. Dogra script is very much similar to Takri script. It was added to the Unicode Standard in June, 2018 with the release of version 11.0.The Unicode block assigned to Dogra is U+11800–U+1184F containing around 60 characters. https://en.wikipedia.org/wiki/Dogri_script. Nonetheless, Dogra has been a mark of attraction for philatelists who collect ephemera from Jammu and Kashmir. Information on Dogra script can be found in website called "Collecting Kashmir, maintained by Carol von der Lin.[11].

Crucial handwritten data available in ancient documents, libraries, museums and offices is difficult to store in raw form because of its deterioration due to various reasons. HTR system for Dogra script would be a boon for those dealing with data. Apart from easy storage it also addresses data security problem, searching and retrieval. Automation is another reason in this digital world due to increasing amount of data which requires ease of storage and accuracy.

A detailed study was undertaken about the existing literature with respect to datasets / databases availability and its uses in HTR of various Indian languages. A complete perusal of feature extraction techniques and classifications methods being used at present was undertaken so as to have a transparent view of the research domain. Neural Network (NN) was used by Patil et al [12] which was capable to reading Hindi, English and Kannada scripts and gave satisfactory recognition. Researchers at present are using machine learning tools such as SVM, kNN, Random Forests, Decision Tree etc. Lorigo LM and Govindraju V [13] have given details of various techniques for Arabic text recognition. Khan et al [14] explained saliency detection algorithm using salient/important region in an image. Machine learning and Image processing techniques are together being used by researchers to improve performance of HTR. LeCun Y et al [15] explained how deep learning based techniques using back propagation, CNN and RNN have been a landmark in image, text, audio and video processing. Breual T M et al [16] explained that with the use of cluster computing, GPUs, RNN, CNN, LSTM networks etc. improvement in character recognition of multilingual scripts are being achieved. Feature extraction techniques in HTR on the basis of statistical attribute or transformed field of image performed better. Segmentation of text, line wise and then character-wise for good accuracy was implemented on large Manipuri dataset generated by Inungambi S, et al [17] called Mayek27 and Meitei Mayek(MM). By using Neural Network with convolutional layers, 88.96% and 91.12% accuracy in word and character recognition, respectively was realised. Arnold R and Miklos P[18] explains printed and handwritten character recognition with respect to resolution of projected image by using NN. Xiao X et al [19] proposed Global Supervised Low-rank Expansion method with Adaptive Drop weight technique using CNN for better speed and recognition accuracy for Chinese characters. Li Z et al [20] explains new technique using CNN to

reduce parameters thus increasing speed of recognition of Chinese characters. Unstacked denoising autoencoder was performed on Urdu characters for better recognition [21]. Deep learning approach are preferred by researchers due to better performance [22, 23]. A Roy[24] explained remarkable achievements realised in Bangla handwritten character recognition and pinpointed future task to be accomplished in said script. A Roy and D Ghosh[25] explained techniques in Bangala HCR. A.Roy and N.R.Manna in [26] explained various segmentation and classification algorithm accuracy achievements in Bangla. Arabic word recognition using Hidden Markov Model(HMM) after extracting structural features was proposed by Al-Khateeb JH et al [27] and using Support Vector Machines (SVM) with modified kernel by Athoillah M and Putri RK [28] and writer identification using K-nearest neighbour(KNN) by Hasan Aka et al[29]. During pre-processing slope and skew correction methods were proposed by Kar R et al [30]. Liu B et al [31] explained feature extraction method using siamese-CNN. Ukil S et al [32] with the use of integrated small convolutional neural networks were able to identify 11 different Indic scripts with probabilistic and max voting. Various neural networks/classifiers can be used in a hybrid mode to gain a better accuracy in recognition of handwritten text. Geetha R et al [33] decided on two approaches and selected IAM and RIMES dataset and CNN was used to extract features. Features so extracted as outputs were given to LSTM-RNN sequential learner and gained word and letter recognition accuracy of 95.2% and 97.48% respectively. Similar hybrid approaches has been found in various other cases also. Kumar M et al [34] used three classifiers such as decision tree, random forest, and CNN on 14,000 pre-segmented samples of Gurumukhi characters and achieved an accuracy of 96.2%.Apart from just recognition of text researcher are now moving towards summarization of text automatically by sequence pattern matching[35]. Doan and Nguyen [36] have explained the positive effect of constrained environment and dataset on image recognition.

Availability of Dataset with adequate data for training and testing is very essential for standard research. Inadequate and irrational dataset does not give a good recognition rate and may give unpleasant research output. Availability of Indian scripts dataset is very much required at a approachable and common place for a healthy research performance in the area. Standard format of the dataset could also add feathers in wing. Dedicated Institutions/houses dealing with HTR/HCR should enhance their support and help to grooming researchers in the field of text recognition.

2. MATERIAL AND METHODS

Following are the images of character sets of Dogra script

- Dogra script has 10 vowel signs.

A	AA	I	II	U	UU	E	AI	O	AU
□	□	□	□	□	□	□	□	□	□

- Dogra Script has 10 dependent vowel signs

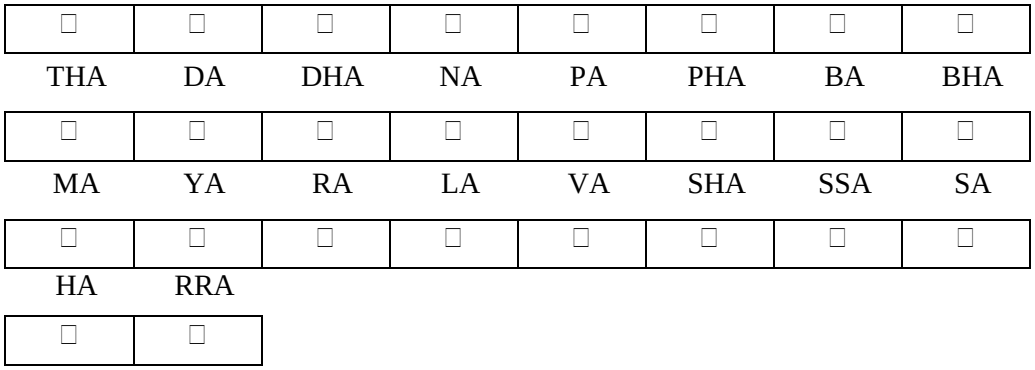
AA	I	II	U	UU	R	E	AI	O	AU
○□	□○	○□	○□	○□	○□	○□	○□	○□	○□

- Digits used in Dogra script are similar to Devanagari

१	२	३	४	५	६	७	८	९	०

- Dogra Script has 34 consonant letters

KA	KHA	GA	GHA	NGA	CA	CHA	JA
□	□	□	□	□	□	□	□
JHA	NYA	TTA	TTHA	DDA	DDHA	NNA	TA



Above images are excerpts from [37] and available on https://www.unicode.org/charts/PDF/U11800.pdf

Kumar and Roy [38] created DograNet dataset of above 72 images totalling about 38000 characters and the same dataset is used for evaluation of HTR algorithms and techniques. General process that is adopted in handwritten text recognition is shown in Figure 1.

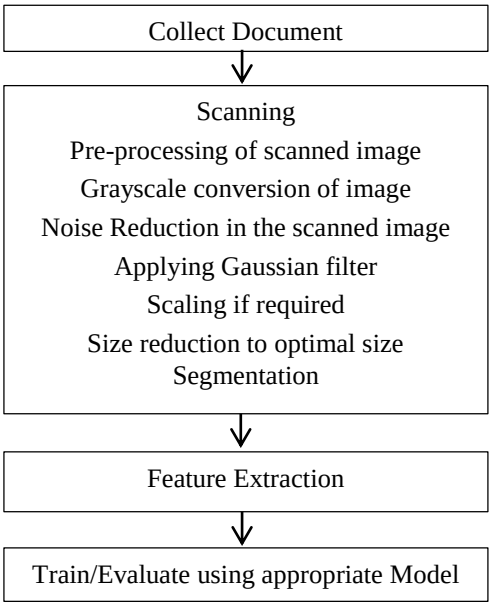


Figure 1. General steps followed in handwritten text recognition

Machine Learning is usually classified as supervised, unsupervised and reinforcement learning. In supervised learning, it is bottled up in a controlled way to supervise result accordingly and machine learns as per user choice. Whereas in unsupervised learning, the machine simply explores the unlabelled and non categorized data given to it without any supervision and control and does clustering and predictions based on similarity. Reinforcement learning is feedback based learning usually by imposing a pattern of behaviour. Various machine learning algorithms and Deep learning is a type of machine learning which uses neural networks and algorithms on large datasets for complex problems. techniques are available which are being used for handwritten text/characters recognition and classification. The most common techniques used are Support Vector Machine (SVM), Convolutional Neural Network (CNN), Random Forest (RF), Recurrent Neural Network (RNN), K-Nearest Neighbour (KNN). Features were manually extracted in traditional machine learning methods with feature engineering. Classification algorithms were then applied for classification of characters by using extracted features. RNN and CNN have capacity of extracting features automatically. In Machine learning, data is fed into the machine to train and a possible outcome is predicted using

various algorithms. Following algorithms and classification techniques were used in our study.

2.1 Support Vector Machine (SVM)

SVM is used for classification and regression problems. Chandra and Bedi [39] have given detail about SVM, its alteration and supporting techniques. Mainly it is used for solving classification problems. SVM works on the concept of creating a boundary between data to classify them separately. Creating these separation lines is called making decision lines. The best separation line is declared as a hyperplane for the given classification problem, which segregates data into classes. The best decision boundary or hyperplane is which has maximum margin or distance from the nearest points of all the classes. To find an appropriate line (hyperplane) is many times difficult where SVM overcome this confusion by finding the best boundary line also called a decision line which is also called as hyperplane. Mathematically it is possible to calculate the hyperplane. SVM has proved its worth in recognition of digits. Other algorithms such as Logistic Regression and Perceptron like SVM were also specific for Binary classification. Though SVM is mainly for binary classification but it can also be applied to multiclass using One-vs-One and one-vs-Rest strategy. Using python programming SVM algorithm was employed with general parameters and various kernels on Dogra Dataset and results realized is shown in Table 1.

Table 1. Multi-class classification using SVM

Algorithm/Classifier	Accuracy	Precession	Recall
SVM-SVC (Kernel-Linear)	48	48	48
SVM-SVC (Kernel-RBF)	47	46.4	45
SVM-SVC (Kernel-Polynomial)	50	48	47
SVM-SVC (Sigmoid)	43	42	41
LinearSVC	41	41.3	40
Average	45.8	45.14	44.2

It was also inferred that with the increase in data size, it becomes very slow and time consuming.

2.2 Random Forest (RF)

It is a technique under machine learning algorithm used for classification and also for regression [40]. It is a bagging technique. Random forest is a bunch of decision trees (DT) selected randomly from a subset of training set. It analyse the output from different decision trees and accordingly determine endmost prediction. Output of all decision trees is taken and final output is calculated by evaluating the majority value that is the voting system. So, the base learner for the random forest algorithm is the decision tree. The concept is shown in Figure 2 below:

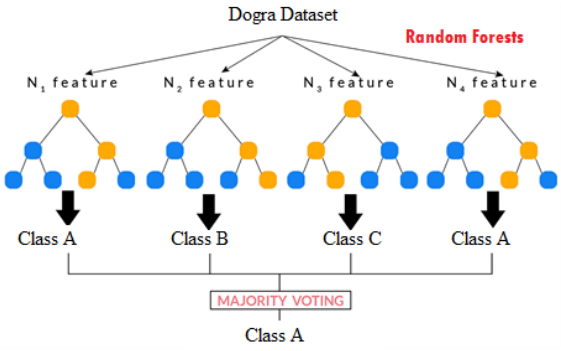


Figure 2. Random Forest working

In the above Figure 2, we have a dataset X in which N features are available. Decision trees are created by performing row sampling and column sampling with replacement. That is to say, a subset of X is taken out with few rows and columns. This process of creating a subset of the dataset is called bootstrapping. Then after this step output of each decision tree is taken and voting is considered as the final result. This process of considering the majority is called

aggregation in a random forest. The combination of both is called bagging.

$$\boldsymbol{bagging = bootstrap + aggregation}$$

The reason for creating multiple trees instead of one decision tree is because of over fitting. Every decision tree has two properties. Low bias and high variance. When tree is created to its depth the model is trained so well that the error in training data is very less, which is called a low bias. But when new data is tested on the decision tree it is highly prone to errors called high variance. Now, when multiple trees are taken the new dataset for testing is divided into many trees because of random selection feature of this algorithm. This impacts in reduction of errors and resolves the over fitting problem giving accurate predictions. If Random Forest is used as a regression technique, then every tree will generate continuous output. Then the final output is calculated either using the mean of all values or by performing median on the output of all decision trees. Random Forests is preferred in case of fused datasets [41]. Disadvantage of Random Forest is it takes more time due to complexity. Random Forests classification technique was tried with DograNet Dataset and an accuracy of 89 % with Precession 88% was realised. Fine tuning with some selected hyper parameters affects the results like increasing size of training data of a particular class.

2.3 Artificial Neural Network (ANN)

ANN is a depiction of nervous system function. It has the ability to learn from given data patterns. Predefined constraints/ assumptions/rules about the model are not required. For instance, constraints between dependent and independent variables. The sigmoid function is used to compute the weight of the relationship between input and output.

$$y = f(x) = \frac{1}{1 + e^{-x}}$$

Where *x* is input and *y* is output.

Besides, ANN can detect and analyze the complex non-linear relationship in data itself. ANN is a network of connections between input and output. The network of ANN has one layer of input, then one or more than one in between layers, and finally one output layer. The same structure is shown in Figure 3.

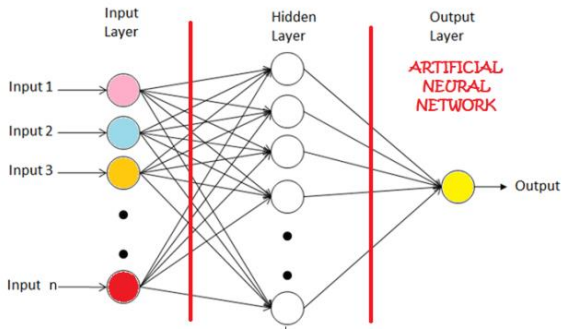


Figure 3. Structure of ANN

ANN is classified into feed-forward network and recurrent network. In feed-forward ANN no cycle is formed between connections and on the flip side, a cycle is created in recurrent ANN. Neural Network learn by adjusting the weights of nodes. The performance of neural network is improved by iteratively improving the weights of nodes and output of the model gives minimum error because of iterative modification in structure and connection weights. ANN is usually used in Tabular data analyses, image recognition, text recognition and nonlinear function learning. Challenges of ANN is that while solving an image classification problem , a 2-dimensional image is to be converted to 1-dimensional vector prior to training a model because of which trainable parameters' number shoots up drastically with increasing image size as a result spatial features of image is lost. Padhy N et al [42] explains that ANN has shown a better performance than other algorithms in terms of reusability of code, feature selection, accuracy and costing. Because of high number of trainable parameters and also spatial loss, ANN did not work well for our dataset.

2.4 K-Nearest Neighbours (KNN)

KNN is simple supervised Machine Learning algorithm which works on the concept of distance metrics. For classification by KNN, proper features extractions of the images are required though fine tuning only few hyper parameters give reasonable results. KNN scores less when the size of the database is big.

KNN algorithm was applied to Dogra Dataset wherein the dataset was split into training and test set in the ratio 70:30 as a general practice and used default parameters while fitting the classifier wherein an accuracy of 89.6 % was achieved. After fine-tuning the hyper parameters with Grid search method, recognition accuracy increased to 92%.

2.5 Convolution Neural Network (CNN)

CNN is a kind of ANN architecture for deep learning algorithm mostly used for image recognition/classification. CNN which started its use in 1980s was capable of determining visual patterns straight from pixel images with minimum pre-processing. Other major success of CNN is use of shared weights in the convolutional layers. This infers that same filter is used for each input in the layer. The shared weights reduce the parameter numbers and improve the overall performance. Another advantage of CNN is that it learns the filters by its own without specifically mentioning it. Correct and relevant features can be extracted from input data with the help of these filters. This is the reason why CNN is considered more efficient for HCR. Sharma R et al [43] have realised accuracy of 88.95% in Dogra character recognition using CNN

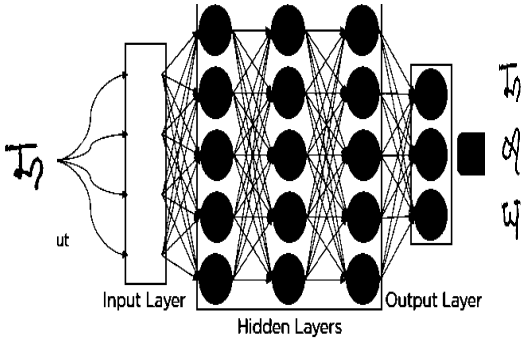


Figure 4. CNN Structure

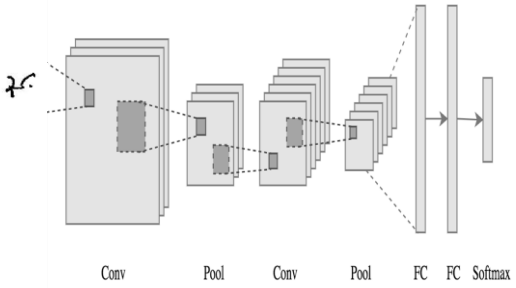


Figure 5. CNN Layers and Architecture

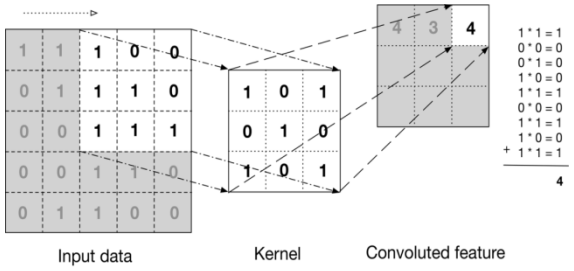


Figure 6**.** Actual working of CNN

2.6 VGG16

This convolution neural network architecture considered to be best among visual model architecture. It was used in a competition in 2014 and won ILSVRC (Imagenet). Important regarding VGG16 is that they focused on having convolution layers of 3x3 filter with a stride 1 instead of large number of hyper-parameter and mostly use maxpool layer of 2x2 filter with a stride 2 and use similar padding. It follows the said arrangement of max pool and convolutional layers consistently in whole architecture. There exist two fully connected layers, after that a softmax layer for output. VGG16 has 16 layers having weights at the end. This is a large network having 138 million parameters approx. VGG16 also use the concept of pre-trained model and transfer learning and hence training process speed is enhanced on new data having small size and proves to be effective and accurate model. Deore and Pravin [44] proposed that VGG16 architecture of Deep Convolution Neural Network (DCNN) helped in detecting key attributes/features automatically and thus effective in categorizing them. They achieved a good classification accuracy of 96.55% on Devnagari characters using fine-tuned VGG16 architecture. The VGG16 architecture comprises of thirteen convolutional layers, five max-pooling layers and three dense layers. Conv1, Conv2, Conv3, Conv4, Conv5 has 64, 128, 256, 512 and 512 filters of 393 kernel respectively as depicted in Figure 7. All max-pooling layers on other hand have 292 kernel. The ReLu activation function is added to each convolution layer and 02 dense layers to filter out negative values to the subsequent layers. Softmax activation function is used in the end by last dense output layer for prediction.

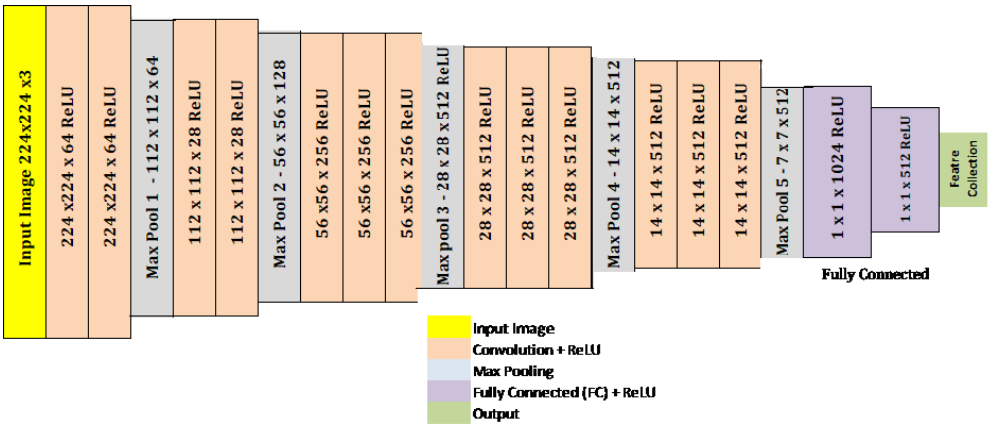


Figure 7. Illustration of VGG16 Pre-trained CNN Model

3. RESULTS AND DISCUSSION

The results obtained from above models were compared and conclusion was drawn based on parameters like accuracy, precision and recall which were taken as performance indicators.

The Dogra dataset in most of the cases was divided in the ratio of 70:30, in which 70% of data is kept for experimentation and 30% for testing and validation. Keras. Image Data Generator class was mostly used for data augmentation during training of model on image batches. In the various classification/ predictions models as elaborated above, fine tuning of various common parameters were done to get best accuracy possible. The recognition accuracy achieved by Random Forest, CNN, VGG16, KNN, SVM in terms of accuracy, precision and recall is shown in Table 2 and pictorially depicted in Figure 8.

Table 2. Recognition efficiency of various Algorithms/Classification Techniques

Model	Accuracy	Precession	Recall
Random Forests	89.10	88.00	89.13
CNN	96.36	94.00	95.51
VGG16	97.00	94.17	95.88
kNN	92.00	90.31	91.12
SVM	45.80	45.14	44.21

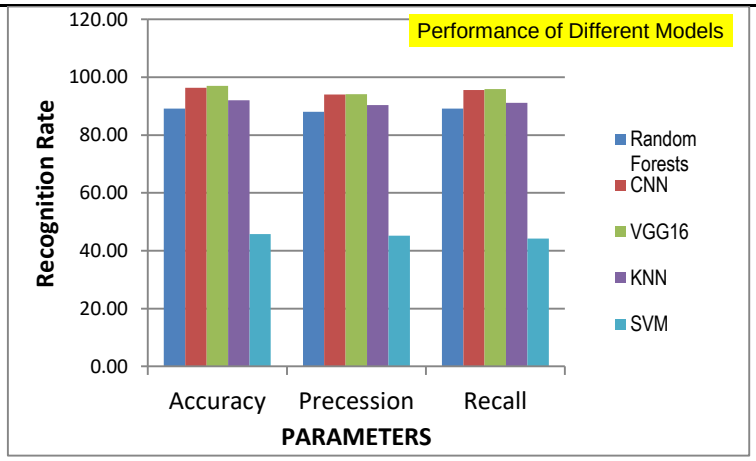


Figure 8. Bar graph showing performance of various classification Techniques

It was concluded that fine-tuned VGG16 CNN based model gave better as compared to others. Parameters such as number of epochs, optimizers viz RMSProp and Adam, batch size in data were also tested for their effect on accuracy, precession and recall in VGG16 model. The results showed that number of epochs has positive effect on accuracy but upto a certain value as shown in Figure 9. Similarly RMSProp optimizer yielded better results as compared to Adam as depicted in the Figure 10.

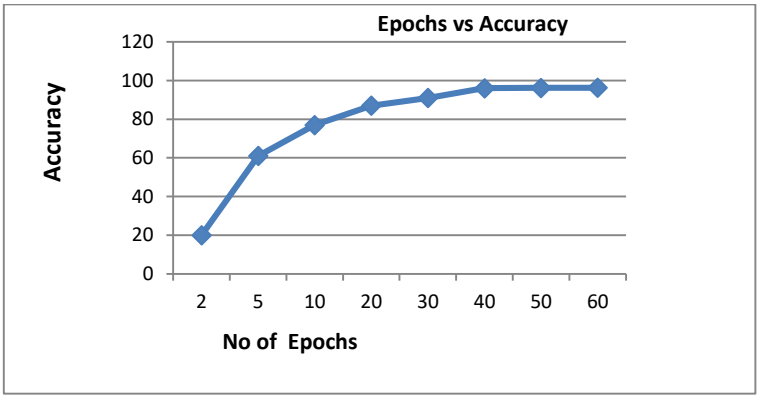


Figure 9. No. of Epochs and Accuracy obtained

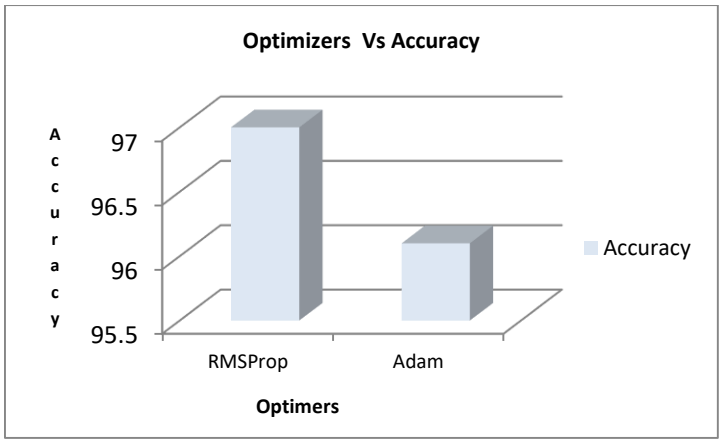


Figure 10. Bar graph showing accuracy in terms of optimizers used in VGG16

4. Conclusion

This study has explored handwritten text recognition for Dogra Script using various machine learning algorithms and classification techniques with DograNet dataset as automation in the process of Handwritten Text Recognition is need of the hour. The fine tuning with weights, optimizers etc play important role. The accuracy, precession and recall outcome reveals that pre-trained and fine tuned VGG16 has shown better results for handwritten character recognition of Dogra Script when compared with SVM, Random Forests, CNN and KNN. The findings further revealed that every algorithm/model gave variable results which are influenced by various parameters. Number of epochs were directly proportional to accuracy i.e increasing the epochs increased the accuracy but after a reasonable number of epochs i.e around 40, accuracy does not show much increase. Deploying RMSProp and Adam optimizer reveals that RMSProp has a positive effect on recognition accuracy. The data size of dataset also has a proportional positive effect in terms of recognition accuracy and precision. Though SVM is suitable for binary class classification but was tried for multiclass with small size dataset and polynomial kernel showed better results that other kernels, however with bigger data size it became time consuming though testing parameters gave slightly improved results but did not outperformed result of VGG16. Current trends call for further research opportunities which lie in simple algorithms in coding and also in implementation with deep

learning and building sophisticated text data models. Evaluation detail of various classification models shall be a guiding force for new research in the field.

5. Future scope

DograNet Dataset can be broadened further by including more sample characters. A website shall be made available from where any user can download the form, fill it and upload scaned copy for automatic extraction of characters which shall be added to the dataset after due verification and check. Compound characters can also be added to DograNet in future. New algorithms can be explored for better Handwritten Text recognition of characters and compound characters of Dogra Script in future. Concept of Knowledge distillation can also be applied by future researchers.

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