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Kannada Handwritten Character Recognition using Machine Learning Approach

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Abstract: The most significant problem present in the digitized world is handwritten character recogni- tion and identification because it is helpful in various applications. The manual work needed for changing the handwritten character document into machine-readable texts is highly re- duced by using the automatic identification approaches. Due to the factors of high variance in the writing styles beyond the globe, handwritten text size and low quality of handwritten text rather than printed text make handwritten character recognition to be very complex. The Kannada language has originated over the past 1000 years, where the consonants and vowels are symmetric in nature and also curvy, therefore, the recognition of Kannada characters online is very difficult. Thus, it is essential to overcome the above-mentioned complications presented in the classical Kannada handwritten character recognition model.There are two steps to be followed in the proposed model that is collection of images and classification of handwritten characters. At first, essential handwritten Kannada characters are collected from the benchmark resources. Next, the acquired handwritten Kannada images are offered to the handwritten Kannada character recognition phase. Here, Kannada character recognition is performed using Serial Dilated Cascade Network (SDCN), which utilized the Visual Geometry Group 16 (VGG16) and Deep Temporal Convolution Network (DTCN) technique for the observation. When compared to the baseline recognition works, the proposed handwritten Kannada character recognition model achieves a significantly higher performance rate.

Keywords: *Kannada handwritten character recognition, Serial dilated cascade network, Kannada scripts, Visual geometry group 16, Deep temporal convolution network*

1. Introduction

This Digitization techniques are applied to most of the historical manuscript documents by the manuscript preservation centers in India. The handwritten documents are degraded due to the factors like arbitrary geometric distortions such as wrapping and folding of manuscripts, and also ink bleed, maintenance and storage condition hence, it is essential to digitize the handwritten documents [1]. The recognition of ancient heritage evolution and its culture for future generations is essential. At first, the specialized scanner and camera are used for acquiring the images for digitization, and then these images are fed to further analysis that includes recognition and interpretation. The scripts are read and written in the Indian state of Karnataka, which is stated as Karnataka script. These scripts evolved in the regime of various dynasties like Devarajaswamy and Manjunath, namely, Shatavahana, Kadamba, Chalukya, Mysore Wodeyars, Rastrakuta, Hoysala, Ashoka, Ganga, and Vijayanagara. Based on the writing style, the evolution of Kannada scripts is categorized into Pre- old, old, middle and modern Kannada. The other name of this categorization is Poorva Halagannada (pre-old), Halagannada (old), Nadugannada (middle), and Aadhunika Kannada (modern Kannada).

Most of the handwritten document character recognition models [2, 3], relied only on the recent- age-type handwritten documents and hence the recognition of characters from old-type-age documents is important. The traditional approaches utilize image processing techniques to improve the quality of images, but there is a chance of missing some relevant information for recognizing characters. The text line identification methods are suggested for recognizing characters, but it needs more time for recognition. The Gabor-zonal and Local Binary Patterns (LBP) features-based approaches are adopted for the recognition of characters from Kannada handwritten documents [4]. But, the accuracy of these approaches is slightly low and hence several deep learning algorithms are recommended for recognizing the characters from the handwritten documents. Most of the deep learning approaches for recognizing characters suffered from insufficient samples. In addition, the recognition time and complexity of these approaches are high. Many deep learning-based handwritten character

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recognition approaches do not consider the consonants, vowels and numerals [5–7], for recognizing the characters. Therefore, a new Kannada handwritten character recognition model using a serial cascaded deep learning network from Kannada scripts is developed to solve the issues aroused during the recognition of characters from the degraded scripts.

The significant objectives of the proposed Kannada handwritten character recognition scheme are elucidated as follows.

To design a new Kannada handwritten character recognition model using deep learning to identify the cursive nature of handwritten texts from scripts with higher accuracy.

To implement a serial cascaded deep learning network for recognizing the handwritten charac- ters very effectively by considering the numerals, vowels and consonants, where the VGG16 and DTCN structures are utilized. To ensure the recognition outcome of the developed Kannada handwritten recognition model in terms of distinct measures with respect to previously developed handwritten character recog- nition models.

2. Literature Survey

In 2018, Rani *et al.*, have developed deformed character recognition approach using Convo- lutional Neural Network (CNN). The input images were collected from the ancient poetry docu- ments under unconstrained environments. The characters from the degraded images were slightly blurry and it resulted in poor classification accuracy. The developed model considered the vowels, consonants, complex compound characters and simple compound characters for characterizing the documents using the CNN model. The final classification accuracy of the proposed CNN-based deformed character recognition approach was high rather than other models.

In 2019, Karthik and Murthy , have proposed a Deep Belief Network (DBN)-based Kannada handwritten recognition approach using a distributed average of points. The printed patterns of the Indian language have been recognized through the proposed deep learning model. The accuracy of the proposed handwritten recognition model has been validated with the traditional algorithms in terms of various measures.

In 2023, Siddanna and Kiran , have proposed a handwritten character recognition model for the Kannada language with the support of CNN and transfer learning. The Kannada handwritten document has been initially subjected to preprocessing techniques like removing noise, cropping each character and image resizing. The enhanced pixel values have been achieved at output that has trained with CNN for classification respective to their classes. The vowels, numerals and consonants were separately considered and then classified with their respective classes. The new style of handwritten documents has been predicted via transfer learning.

In 2020, Rao *et al.*, have employed an exploring deep learning procedure for recognizing Kannada handwritten document. The quality of the image has been enhanced with the help of preprocessing algorithms and the deep learning algorithm was adopted for extraction of features. The experiments have been conducted for validating the performance of the proposed model by con- sidering the Chars74K dataset. The error rate has been considered for measuring the performance and the developed model has proven its effectiveness when compared to other models.

In 2022, Rani *et al.* , have introduced a robust recognition approach for recognizing handwritten language via capsule networks. The layers presented in the capsule networks were the primary capsule layer, input layer, routing capsule layer, and two convolution layers followed by output and tri-level dense convolution layer. Experimental tests have been considered for validating the performance with respect to accuracy and the implementation outcome were revealed the efficiency of the proposed model.

3. Developed Kannada Handwritten Character Recognition

Character recognition from Kannada scripts is challenging because a large number of letters are available in the Kannada language and hence it is an open problem for researchers. Moreover, the recognition of handwritten characters from Kannada scripts is crucial due to the variations in the handwriting styles and also the scanner quality. This recognition process needs network training and it increases the computation overload by processing with large volume of data.In addition, the traditional handwritten character recognition approaches need high memory space to store large volumes of data. The speed of the recognition process is also low in the existing hand- written character recognition models. Therefore, a new Kannada handwritten character recognition model is developed using a serial cascaded deep learning network. The primary illustration of the proposed Kannada handwritten recognition model is depicted in FIGURE 1.

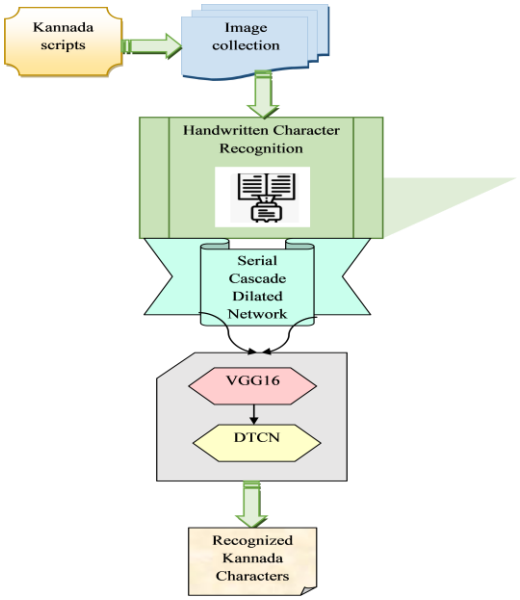

Figure 1: Schematic representation of proposed deep learning-based Kannada handwritten recognition scheme

A new Kannada handwritten character recognition system is designed to recognize the handwritten characters from damaged Kannada scripts with higher recondition efficacy. The data needed for recognizing the written characters are garnered through the online database. The collected images are given to the recognition process, where the proposed Serial Dilated Cascaded Network is used for the recognition of the characters. Here, the VGG16 and DTCN networks are serially connected to provide efficient character recognition outcomes. The results attained from the serial cascaded deep learning network are constricted with the previously used recognition models in terms of several measures to prove its effectiveness.

Dataset Collection

The required data is collected from the database of "Kannada Handwritten Characters", which is taken from [20]. The total images presented in this database are 16,425 images in the Kannada language. Generally, it is a classification dataset and it is utilized mainly for computer vision applications. Totally, 657 classes with 25 images are presented in this dataset. The file size of the dataset is 375.09 kB. The presented version is Version 2 with 171.73 MB. The sample images collected from the Kannada scripts are given in FIGURE 2.

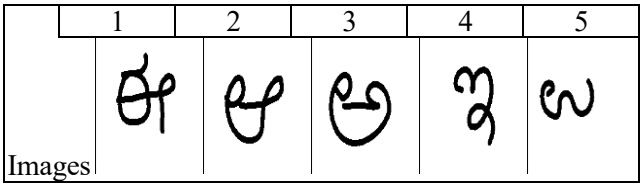

Figure 2: Sample images collected from Kannada scripts

The collected Kannada language images are considered as H^{Kan}, where y indicates the total count of the sample images.

Recognition Of Handwritten Charecters Using SCDN

Basic VGG16

It is adopted in the developed Kannada handwritten character recognition framework to learn the more robust features from the input data.VGG16 : The VGG architecture is categorized on the basis of the number of layers present in the network architecture. It is simple in structure and it takes the baseline features from the input images that are useful for training the network. The VGG16 architecture includes 5, maximum pooling layers, 13 convolutional layers and 3 dense layers.Pooling layer is used for decreasing the computations and training features.

The classification is done in the fully connected layer. The conv1 has 3 × 3 with 64 filters, and conv2 has 3 × 3 with 128 filters, conv3 has 3 × 3 with 256 filters, conv4 and conv5 has 3 × 3 with 512 filters. The maximum pooling has the kernel size of 2 × 2. Between each convolutional layer and two dense layers, the ReLu activation function is inserted. For prediction, the softmax activation function is utilized at the final dense output layer. The learning rate and weights of the network plays the significant role during training the network. The usage of high learning rate reduces the error rate in the network. The VGG16 architecture is shown in FIGURE 3**.**

Basic DTCN

The DTCN model is used in the proposed approach to recognize the handwritten characters from the Kannada scripts. The description of the DTCN model is given as below.

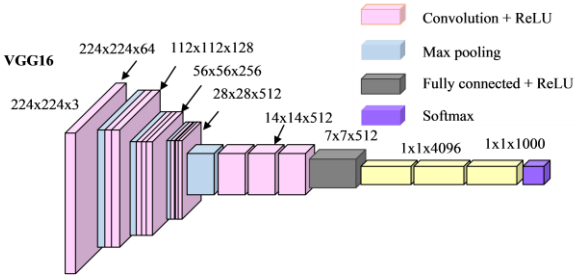

Figure 3: Architecture of VGG16

DTCN : The TCN structure decreases the number of parameters used for recognizing the hand- written characters. The output size mainly depends on the size of the input and hence this network is constructed in regard to some parameter settings like padding, kernel size and stride. The size of the interval among two consecutive convolution centers is defined as stride. In padding, the boundary of the input is added and the dimensionality is represented with respect to a number of kernels. The long-term correlations are displayed by the sequential data by using the 1Dconvolutional network. It performs sliding dot product operation among the kernel as well as the input vector. From the input series data $d_1, d_2, ..., d_P$, the predicted outputs $\hat{d}_1, \hat{d}_2, ..., \hat{d}_P$ are created.

The output d is convoluted with the input from the previous layer. The future patterns are used for predicting the past patterns and hence it is not appropriate. Therefore, casual convolutions are adopted to solve this issue. Here, the output is convoluted with the input only, which is attained from the previous layer. Zero padding is applied to the beginning of the input series with a length of (kernel size - 1). Due to this factor, the shifting of output toward a number of the time step is happened.

The shortcut connections are directly connected to the later layer. This process is called identity mapping.zThe input applied to the residual block is indicated by p and the activation function is represented by The previous layer activation function is reused until the weight is learned by the adjacent layer and hence the vanishing gradients problems are eliminated. The DTCN model is illustrated in FIGURE 4**.**

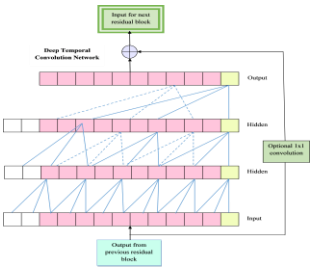

Figure 4: Basic structure of DTCN

Proposed SCDN-based Character Recognition

The SCDN model is developed to recognize the Handwritten Kannada characters from scripts with higher recognition accuracy. The collected Kannada language images H^{Kan} are given to SCDN to get the recognized characters. In the implemented SCDN, the VGG16 and DTCN models are integrated and the dilated convolution is added to improve the recognition performance. The vowels, consonants from the Kannada language are taken into consideration during the recognition of handwritten characters.

Dilated convolution: The long-term autoregressive dependencies are solved via the dilated convo- lutions. The casual convolutions have a larger receptive field, which problem to be solved via the usage of dilated convolution. Therefore, the number of large filters used is decreased. It does not follow the simple sequential manner for convoluting the output with the input in the dilated convolutional layer. But, it skips the constant number of inputs in between them. Based on the layer depth, the dilation rate multiplicatively increased. Then, the receptive field is increased exponentially and hence the 2^{m-1} affect of the m^{th} hidden layer. The detailed description of the developed SCDN-based handwritten character recognition model for Kannada scripts is depicted in FIGURE 5.

Results and Discussion

The proposed SCDN-based Kannada handwritten character recognition framework from Kannada scripts has been designed using Python software. The empirical experimental results have been compared to the previously suggested deep learning-based handwritten character recognition mod- els to verify the recognition performance in accordance with several observation measures. The previously used handwritten character recognition models like LSTM , ResNet , VGG16 , and DTCN , are considered to validate the effectiveness of the proposed SCDN-based handwritten character recognition framew

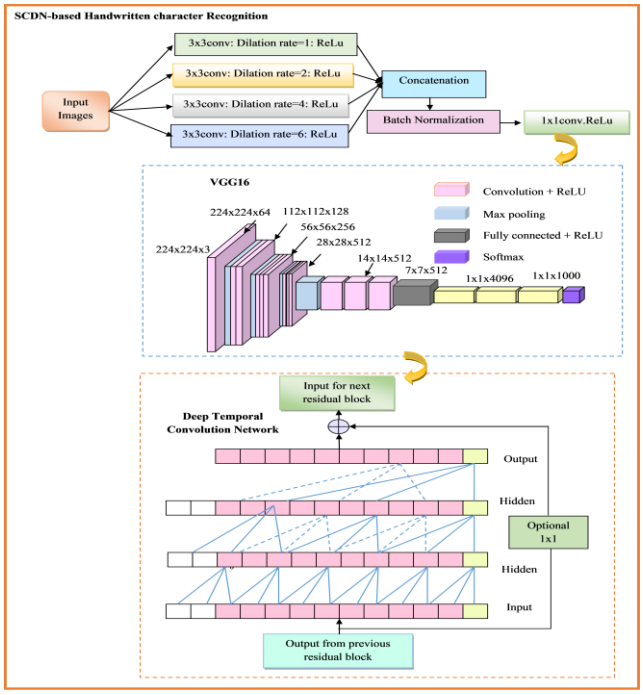

Figure 5: Recognition of Kannada Handwritten Characters using SCDN

Analysis of the ROC Curve

The ROC curve validation of the developed SCDN-based Kannada handwritten character recog- nition model among various baseline schemes is represented in below FIGURE 6. We have set the threshold value as None, hence all data points will be classified as positive. This will result in a ROC curve that is a straight line from the origin to the upper left corner. The true positive observation metric, as well as the false positive observation metric is varied here for validating the effectiveness of the developed handwritten character recognition framework. The ROC analysis outcomes show that the Roc curve of the presented SCDN-based Kannada handwritten character recognition framework is improved by 5.06% rather than LSTM, 3.75% rather than ResNet, 2.46% rather than VGG16, and 1.21% rather than DTCN while taking the false positive rate of 0.4. In between the false positives of 0.2 and 0.6, the developed Kannada handwritten character recognition scheme obtained with better performance in accordance with ROC when analyzed over the previous recognition models.

Analysis with Various Performance Measures

The performance of the proposed SCDN-based Kannada handwritten character recognition model among divergent baseline frameworks is considered for validating the effectiveness of the proposed. The analysis outcome among the classifiers is demonstrated in FIGURE 7. The epoch value is varied for conducting experiments over the tra- ditional methods. The proposed model F1-score is improved by 35.48%, accuracy is progressed with 2.12%, FNR is enhanced with 15.21%, FDR is enhanced by 1.04%, MCC is improved by 15.96%, FPR is progressed with 20.87%, precision is progressed with 46.10%, NPV is enhanced with 2.12%, specificity is improved with

4.34%, and sensitivity is progressed with 3.26% than DTCN for the epoch value of 30. Furthermore, the F1-score, precision and MCC values are achieved more extensive performance than the traditional algorithms

Efficiency validation of the Proposed Model With Previous Models

The developed Kannada handwritten character recognition model is validated through conducting experiments over the traditional approaches in terms of several metrics like NPV, FNR, precision, FPR, F1-score, accuracy, FDR, MCC and FPR, which is given in Table 2. The F1-score value of the proposed SCDN-based Kannada handwritten character recognition model is gained with 57.63%, 50.28%, 66.68%, and 33.02% than the LSTM, ResNet, VGG16, and DTCN classifiers

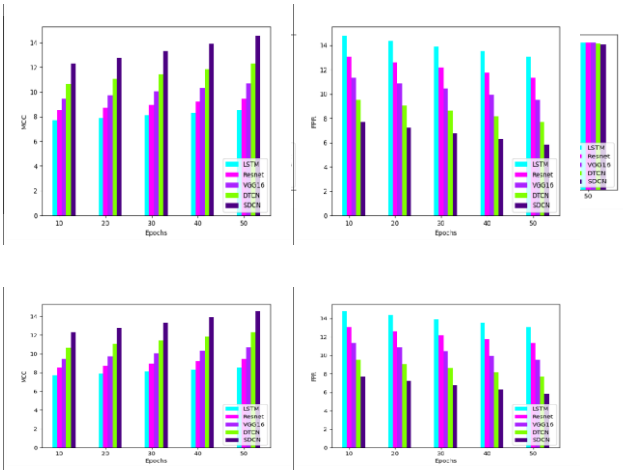

Figure 7: Performance computation of the developed SCDN-based Kannada handwritten character recognition framework among various baseline recognition models in terms of "(a) F1-score, (b) Accuracy, (c) FNR, (d) FDR, (e) MCC, (f) FPR, (g) Precision, (h) NPV, (i) Specificity and (j) Sensitivity"

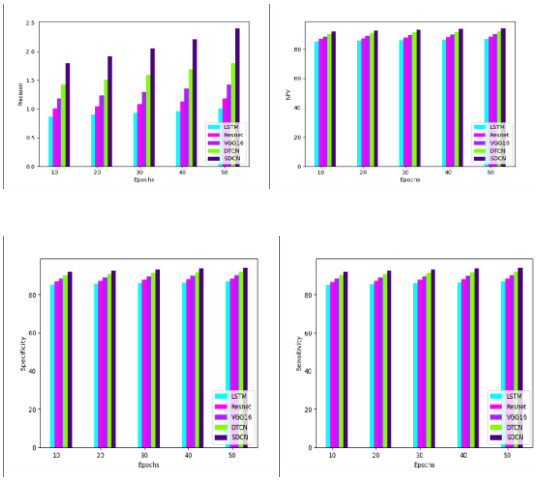

Figure 7: Continued.

from Table 2 analysis. The developed scheme has given extensive efficiency during the recognition of handwritten characters from Kannada scripts.

Conclusion

A new handwritten character recognition framework has been implemented to recognize the char- acters from the ancient Kannada scripts. The characters were effectively recognized from the degraded Kannada scripts with higher efficiency. Initially, the required images were taken from traditional online databases and then processed in the recognition process. The obtained images were given to the SCDN for recognizing the documents, where the VGG16 and DTCN have been utilized for recognition purposes. The requirement of a large receptive field has been eliminated with the help of integrating dilated convolution in the proposed scheme. The serially cascaded VGG16, and DTCN has provided higher recognition outcome from the Kannada scripts. The implementation results have been contrasted with the previously implemented deep learning-based Kannada handwritten recognition models while concerning with various evaluation metrics. Table 2: Performance computation of the developed SCDN-based Kannada handwritten character recognition framework among various baseline recognition schemes

Metrics	LSTM [24]	Resnet [25]	VGG16 [21]	DTCN [22]	SDCN
NPV	86.736	88.697	90.48302	92.3146	94.173
FPR	13.264	11.393	9.516984	7.6854	5.871
Specificity	86.736	88.007	90.48302	92.3146	94.113
Accuracy	86.747	88.013	90.48309	92.3142	94.116
FDR	98.484	98.827	98.57061	98.2024	97.552
FNR	12.239	11.549	9.467275	7.70773	5.8031
MCC	8.3047	9.5931	10.70098	12.2893	14.554
Sensitivity	87.761	88.451	90.53272	92.2924	94.787
F1-Score	1.736	2.2389	2.81434	3.5236	4.6964
Precision	1.516	1.1727	1.429387	1.7964	2.4848

analysis outcome revealed that the accuracy of the proposed gained with 8.32%, 6.18%, 4.07%, and 2.07% than the LSTM, ResNet, VGG16, and DTCN classifiers from Table 2 analysis. Finally, the proposed SCDN-based Kannada handwritten character recognition model outperformed well than the traditional handwritten character recognition approaches. The accuracy of the proposed model was also greater while analyzing the experimental outcome.

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