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Handwritten Vedic Sanskrit Text Recognition Using Deep Learning

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Abstract – Vedic Sanskrit Text recognition is an origin to gain the information about classical language - Indo-Aryan language, basically used in Vedas. In current situation very less people are aware about Vedas; hence it is one of the most demanding and challenging research domains in pattern recognition. In order to rapid development in OCR, deep learning method is a vital technology. This article provides novel approach for Vedic Sanskrit Text recognition with its meaning using deep convolution architecture with its meanings. We have proposed three different 4-fold modified CNN architectures and Alexnet model. This system has a handwritten dataset which included 140 different Vedic Sanskrit words. Each word had approximately around 500 images each, the whole dataset had around 70000 images. Dataset is divided for training and testing with ratio 80:20. Dataset is trained using 20 percent samples and the same input is applied to the deep convolution network with several set of neurons in their hidden layers. Proposed method is highly supported for the correct Vedic Sanskrit word classification. The recognition rate obtained for our research was 97.42% in 0.3640 ms average recognition time, superior to which existing approaches with CNN.

Keywords : CNN, Vedic Sanskrit, OCR

I. Introduction

Optical character recognition provides the method to convert printed / handwritten documents into electronic form. Devanagari Script consists of many classical languages like – Sanskrit text recognition is very helpful to history lovers. Devanagari Handwritten character recognition possesses a lot of difficulty due to the complex structure of script, way of writing and writing medium etc. Recognition of handwritten document hardcopy written neat and clean in good handwriting is effortless task [1] Devanagari Script is very popular due to its high usage and documents processing in government offices in Maharashtra the inadequacy in development of efficient solutions for such languages like Sanskrit, etc. created difficulties in document processing. Sanskrit is a cultural language related to history hence possesses its importance even these days people love to read and understand the history documents like Vedas, Bhagwat Geeta and many others. The Sanskrit script recognition is very promising work due to its writing style and complex structure Hence we find the Sanskrit OCR development more interesting and challenging.[2] Machine learning is a super powerful tool for solving many casualties that occurred in pattern recognition. Hence, changing the researcher's mind get involved in solving the problem. Machine learning algorithms are very efficient to reshape the modern time business cycle.[3] Computer vision is a research area in which researchers can take part

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in solving image classification problems. In the current scenario the society desperately needs an accurate and powerful system which will be used by the deaf people for communication. [4] Deep learning algorithms are getting successful in the pattern recognition era at a high extent according to the survey. Convolution neural network giving better performance in several applications like OCR medical imaging video processing, etc. The CNN is layered approach which helps to extract fine features which further passes to classification phase. Softmax classifier is capable of classifying those features to the closest probability class. Vedic Sanskrit script has been gaining importance in several computing fields. due to research conducting on ancient mathematics and scientific calculus. Vedic Sanskrit was classical script of Indo Aryan subgroup of the indo - European family Vedas. OCR is the technique which recognizes text present in the digital image scanned document. It basically converts digital image digital image containing text into electronic text [7]. The OCR is useful only for the exporting text from the input image that needs to recognize. The beauty of it is to create an accessible file or document that can further use or store. The main bottleneck of OCR is in some input conditions it getting fail to recognize text like poor document quality, broken characters in word, overlapped or blur characters in image [9]. Optical Character Recognition takes images containing text- character, symbols, number or paragraph to recognize as an input, further process the same using inbuilt logic and produce output in the form of editable document. In most of business life cycle document processing is essential task like legal documents, invoices. Government Offices required to do lot of paper work also need to process handwritten documents. Due to large volume of data. It creates storage capacity and time management problems; hence it is big need of developing strong OCR for document processing and management.[12]

Vedic Sanskrit Script

Sanskrit is gaining importance in several computing fields due to the latest research happening on ancient –mathematics and scientific computing area. Vedic Sanskrit was the -classical language of an Old Indo-Aryan language in which the most ancient documents are the Vedas. 'Vedas' are the most ancient literary constitutions in the world literature Scientists from all over the world, are spending a large amount of time trying to retrieve the important knowledge present in these ancient research manuscripts. However, the lack of accurately digitized versions of Sanskrit manuscripts is a major bottleneck. Additionally, the poor maintenance and text quality of these manuscripts are some problems. Hence, need to digitalize historical documents of chemical manuscripts those are valued to digitalize. Vedic Sanskrit document we develop OCR especially for Vedic text recognition. In the past few years many OCR are available for Devanagari script recognition such as Marathi, Hindi, Pali etc.[16] Sanskrit text consists of a large set of compound characters which are formed by different combinations of half letter and full letter consonants. Due to this complex nature of compound characters forming word and several handwriting styles and shape of writer are very difficult to recognize.[11]

II. Literature Review

Patil et al[1] developed SVM based Sanskrit OCR. Authors used classic SVM. e Freeman chain code (FCC) method was used to extract different features & Support vector machine classifier was used to classify those features to closed class. Hazra et al. [2] Researcher proposed the OCR tool using Logistic Regression and Neural Network they implemented several machine learning algorithms and analyzed outcomes. Anoop et al [3] proposed a large vocabulary continuous speech recognition (LVCSR) system for Sanskrit using CTC- based end-to-end framework and spectrogram augmentation. The system achieved Spec Augment an absolute improvement in word error rate and sentence error rate over the system without special augmentation, when weighted finite-state transducer decoding was employed. Shevgoor et al [4]e surveyed on how to tackle problems on morphological analysis on

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lexical interaction and estimate the extractness of semantics contents, etc. Rohit et al [5] presented an attention-based Long Short-Term Memory (LSTM) model for reading Sanskrit characters in line images. They introduced a dataset of 23848 annotated line images. They used OCR to augment real data and enable high performance; the model achieved a word error rate of 15.97% and character error rate of 3.71% for Indian document collections. Yash et al [6] proposed a system that works on set of 29 constants and one modifier. This system was trained using a dataset of 34604 handwritten images. The consecutive convolution layers used in this model brought advantage in extracting higher level features. The model came with an overall accuracy of 99.65%. Rohit et al [7] proposed a system for OCR corrections in highly fusional Indic languages. The model presents a procedure for training fast Text embedding on sub-word units with desired length of all possible substrings. The model gained high F-scores and word-level accuracy values. The model reduced word level error to 17.85% and coverage to 90% of F-score within 20 epochs of training. Anupama et al [8] proposed model of recognition of printed Hindi characters in Devanagari script. The classification of K-NN technique has been implemented for OCR system design. The model trained using 3000 sample datasets and gave accuracy of 97.4% as compared to 94.5% for existing techniques Meduri et al [9] proposed model of Convolution Neural Network based on Optical Character Recognition System. The model used image segmentation algorithm for calculating pixel intensities to recognize letters in images. They introduced a dataset of 7702 images of Sanskrit letters belonging to 602 classes. The model gave an accuracy of 93.32%. Saluja et al [10] A framework for assisting of error detection and error correction in Indian OCR document. The framework presented an approach of plug-in classification to improve error detection by tuning probability threshold for classification. The framework corrected over 1100 pages of 13 different Sanskrit books, 190 pages in Marathi, 50 pages in Hindi and 1000 pages in English. Raj et al [11] proposed a method that introduced Histogram of Orientation shape context (HOOSC) a novel feature extraction technique that improved recognition results of Grantha characters and an ANN classification which gives high learning speed with minimum error rate and got accuracy 95.6%. Lower error rate, fast learning speed and better recognition accuracy of 96.5%. Bipul et al [12] proposed a recognition system for identification of speaker, the words spoken and language. The system made use of adaptive Neuro-Fuzzy Interface paradigm. The speech database includes 25 speakers including male and female speakers. The minimum performance shown by the system is 73.91% and the best performance is 95.65% and the overall performance is 83.15%.

III. Methodologies

In optical character recognition input image goes under several phases of image life cycle as shown in figure 01.

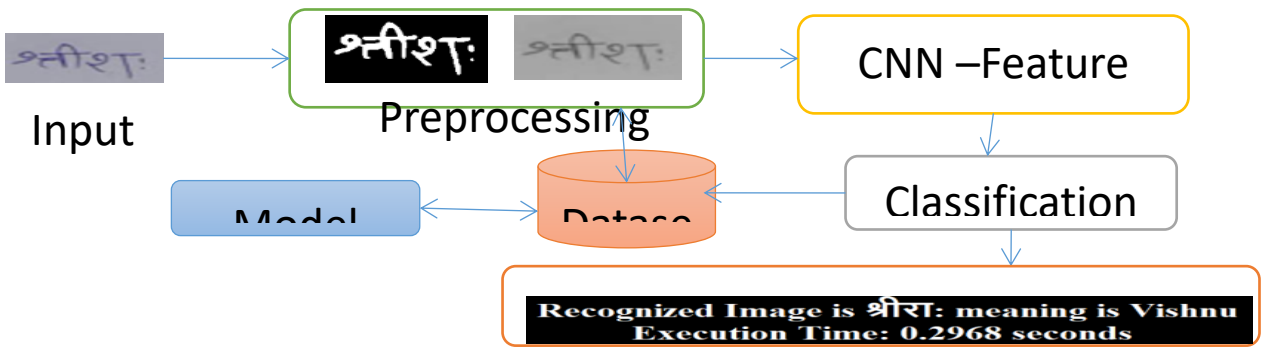

Figure 01 : Proposed System Architecture

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This research work poses the use of deep convolution neural network architecture by because of its effectual nature in feature extraction and classification of image in image recognition problem.[15] CNN is layered approach which extracts fine-tuned features using matrix operation performed on image matrix and kernel matrix, produce feature map and further pass to next layer. We have proposed three different modified Deep CNN 4-Folds Architecture by varying several parameters and analyzed model performance in term of model accuracy, recognition accuracy and recognition time especially for Vedic Sanskrit recognition. Less attempts has been made by researcher on ancient classical language Vedic Sanskrit text recognition, hence it gives more scope to work on this area becomes major motivation behind this research with this there is still have opportunity to improve OCR accuracy for several script like Sanskrit, Marathi, Pali, etc. in near future.[8] In order to simplify document digitalization problems and help history lovers we made attempt to develop method for Vedic text recognition with meaning in English using deep learning approach[11]. Use of accurate dataset is key element for succeed training process.[12] Accurate and concise dataset provides high throughput. The dataset had been created by using combination of different of different types of works that included joint character words, words with punctuation marks like colon, question mark, etc. We also taken publicly available standard dataset DHDC collected form kaggle. N. Shelke et al. [27] and S. Gupta et al. [28] have also contributed in this field.

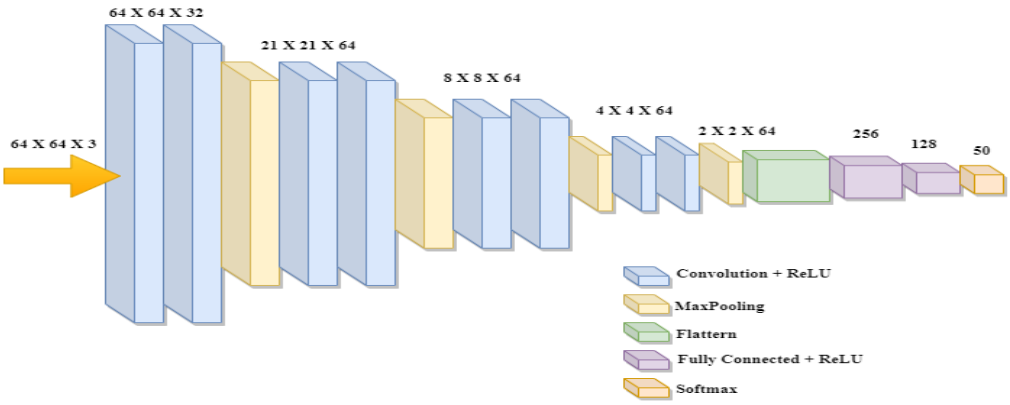

Figure 02: Model Architecture

Created dataset contains 50 classes, 140 Vedic Sanskrit words of total 70000 images with categories like blur, clear and some badly written words.

Sample image	Vedic character	Class label assigned	Meaning
	जननी	91	Mother
	भ्राता	89	Brother

Figure 03 : Dataset samples

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A single page contains about 70-80 words. We have taken five pages for every Vedic Sanskrit word, hence approximately 500 images per class considered for model training. In total 70000 samples were taken from several right handed and left handed writers with classes 140 (70+70) . The split ratio of testing to training is 80:20. The sources used for collecting data samples are YouTube, Kaggle and the book used for the collection of sample characters is 'Laghu Siddhanta Kaumudi' book and the author is 'Kaushal Kishor Pandey'.[23] Table 02 shows some samples of the dataset. Preprocessing: Data preprocessing is essential to improve data quality for better information readability [8]. Input image is preprocessed for better recognition. Under preprocessing phase, the input image was converted into grayscale then it converted into binary form and image size was set 64*64. This stage produced a clean and resized image at output. This work is carried out using a layered deep learning approach. We have created three different 4-Fold CNN architecture containing several layers as shown in table3.
Feature Extraction & Classification: Convolution neural network is layered approach used to extract fine-tuned features and classify them into closed class.[19] Preprocessed image produced by the previous stage is taken as input for feature extraction. CNN consists of several layers. Initial layer - input layer takes input image and saves it in pixel format.

$$Dim(I) = D_h D_w D_c \quad \text{.....(1)}$$
$$Dim(K) = K_h K_w K_c \quad \text{.....(2)}$$

Equation (1) & (2) defines the size of the input image, where Dh, Kh is height, Dw Kw and Dc, Kc channel of input image and kernel respectively. Here (62,62,32) is set input image size for M1, M2 and M3 with 896 parameters and (23,23,96) for Alex net with 34944 parameters. Next layer is the deep convolution layer, which is the most important layer in CNN architecture. It performs matrix product of input image and filter and generate feature map at output. The activation shape produced at Conv layer by M1 was Conv1L -(19,19,32) with 9248, Conv2L -(8,8,64) with 256, Conv3L -(3,3,64) with 16448 parameters, M2 was Conv1L & Conv2L -(62,62,32) with 896 &1056, Conv3L & Conv4L -(19,19,32) with 9248 & 1058, Conv5L & Conv6L -(8,8,64) with 18496 &4160, Conv7L & Conv8L -(3,3,64) with 16448 & 416 parameters. M3 was Conv1L, Conv2L &Conv3L - (62, 62, 32) with 896 &1056 ,1056. Conv4L, Conv5L & Conv6L -(19,19,32) with 9248 & 1056,1056, Conv7L, Conv8L & Conv9L -(8,8,64) with 18496 & 4160, 4160,Conv10L ,Conv11L & Conv12L -(3,3,64) with 16448 & 416,4160 parameters respectively.

$$Conv(D,K) = Dim(D).Dim(K) \quad \text{.....(3)}$$

Equation (3) calculates convolution of image I and kernel K. Convolved image is forwarded to batch normalization for fast and accurate processing.[4] In our models we used 32,64,256,128 batch normalization for all three models. It is further forwarded to ReLu activation to avoid the model from over fitting and also to categorize the neurons to carry out training process.

$$Dim(Conv(D,K) = ([[(D_h + 2m - k)/S] + 1][[(K_w + 2m - k)/S] + 1]) \quad \text{.....(4)}$$

To find dimension of image D in convolution layer equation (3) is used. Where S is stride, m is convolution factor and k is number of filters. Feature map generated in this layer is further passes to pooling layer as input. Pool layer is down sampling layer, having beauty of dimension reduction capability tends to reduce number of parameters and computation cost in the network.[14]

$$Dim\big(Pool(D)\big) = ([Dh + 2m - k/s + 1], [Dw + 2m - k/s + 1], P_c) \quad \text{.....(5)}$$

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In our case we set value of k=2 and S=2 and is valid padding. Max pooling is performed to pick maximum value from the output received from convolution layer.[15] This helps for making model more robust by reducing number of parameters to learn in the network. Here in our study pool layer reduced dimension to generate light weight pool map for M1, M2 and M3 are (21,21,32) ,(10,10,32), (4,4,64), (2,2,64) at pool 1,2 3 and 4 respectively. The output of pool further passes to fully connected layer to produce high level reasoning in the network by connecting previous layer all neurons and connected it to every neuron it is having, onwards produced single vector. Adam optimizer is used in combination with ReLu to improve training rate for faster processing and prevent model from over fitting. Equation (5) shows ReLu function which take only zero or value itself and converts negative values into zero.[17]

$$f(t) = \begin{cases} t, & t > 0 \\ 0, & t < 0 \end{cases} \quad \text{.....(6)}$$

Dropout function used to dropout unwanted units from both visible and hidden units in network [16] to shape network lighter. It is responsible to decide ability of model performance. In our models we used cross entropy loss function & set probability p =0.2 to calculate model loss. The Softmax classifier gives good response in CNN-classification which converts logistics into probabilities to find closed match.[18] In the output we get total number of parameters in dense layer were M1=3250, M2=6450 & M3=6450 respectively. The models were trained up to 50 epochs at their pick by keeping batch size 32 to boost model performance along with correct prediction. Validation is carried out by passing input image to the system to predict correct Vedic word/ Marathi character in outcome based on created models. Thereafter results are produced as labels of the word/character at the output stage for applied input. While experimentation we have analyzed impact of use of SGD- Stochastic gradient descent and Adam optimizers and outcome is reflected in table 04. With the help of this analysis, it is stated that Adam optimizer giving superior results than others. We also analyzed various learning rate Lr with minor change in values as shown in table 05. After experimentation we come to know that Lr=0.015 is best suited for our models with good model accuracy against default Ir = 0.01.

Table 02: Model Accuracy

Models	4F-CNN-M1		4F-CNN-M2		4F-CNN-M3	
	SGD	Adam	SGD	Adam	SGD	Adam
Training Accuracy	62.70	94.40	74.01	97.42	90.38	91.32
Validation Accuracy	55.77	90.78	78.88	95.88	95.07	87.58

Table 03 : Learning Rate Analysis

Learning Rate	Ir = 0.01	Ir = 0.015	Ir = 0.025
Training Accuracy	48.47	93.14	62.64
Validation Accuracy	39.50	93.06	62.34

After Investigation various factors of optimizers SGA and Adam by verifying parameter like Lr in model building process it is analyzed that Optimizer Adam was best appropriate for our system, hence we chosen model 2 with acceptable validation accuracy of for validation of 98.88 for testing our system in real time.

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IV. Experimental Results:

Experimentation was carried out on system – all three 4Fold-CNN models and Alexnet for Vedic Sanskrit text recognition to analyze the outcomes in terms of recognition accuracy and recognition time. For comparison purpose no existing solution available on Vedic Sanskrit text recognition hence we analyzed our models only Marathi text. We also tested our model M2 for evaluating results on Marathi – DHDC data set to compare the proposed system performance against existing approaches containing the same dataset.

Table 04: Model wise Recognition Accuracy & Time

Model	**4F-CNN-M1**	**4F-CNN-M2**	**4F-CNN-M3**
Recognition Accuracy	98%	98.8%	92.6%
Recognition Time	0.3621	0.3640	0.6342
Optimizer used	Adam	Adam	Adam

Figure 4 : Sample Output

From table o4 we can say that 4F-CNN-M2 is better than other models. Table 05 shows comparative analysis of proposed method and existing approaches. As any solution could not find for Vedic Sanskrit recognition to compare our model, hence we have implemented the same for Marathi character recognition and test on that. Recognition accuracy obtained for Vedic text recognition is 97.42 % in average time 0.3640 ms and Marathi txt recognition is 98.94 % in average time 0.3357 ms.

Table 05: Comparative Study on Devnagari Text Recognition.

Reference Work	Proposed Algorithm	Data Set	Recognition Accuracy (%)
[13] Bhardwaj et al - 2022	Deep Learning Model	DHDC	98.13
[14] Manocha et al - 2021	Deep Learning Convolution neural network	DHDC	92
[15] Bhist et al- 2020	Deep control neural network	DHDC	98.93
[16] Deore et al - 2020	Fine-tuned deep convolution neural network	DHDC	96.55
[17] Acharya et al - 2015	Deep convolution neural network	DHDC	98.26
2022	**Our Model 4-Fold Deep CNN Model**	**DHCD**	**98.94**
		Own Dataset	**97.42**

Confusing characters/words in Devanagari Script are major factor in recognition performance degradation. Due to its confusing nature, it gets difficult to recognize by OCR. We have also tested our model for few pairs of confusing characters quite similar in structure [10]. We also tested our

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model for blur and badly written text images. Performances of the proposed system for such categories are shown in table 06.

Table 06: Comparative Analysis- Text Categories

Category	Recognition Accuracy (%)	Average Recognition Time (ms)
Confusing Text	82	0.2654
Blur Images	65	0.4062
Badly Written Images	78	0.3280

Table 07: Comparative Analysis – 4F-CNN-M2 & Alexnet

Vedic Text Recognition	4F-CNN-M2	Alex Net
Recognition Accuracy	98.8	53.75
Average Recognition Time	0.364	0.406

We have tested both proposed CNN and Alexnet models on Vedic Sanskrit dataset and results are plotted in table 07. From all the above epoch wise accuracy and loss graph of Model 1, Model 2 and Model 3 we can clearly observe that model 2 has given the best performance among all other models.

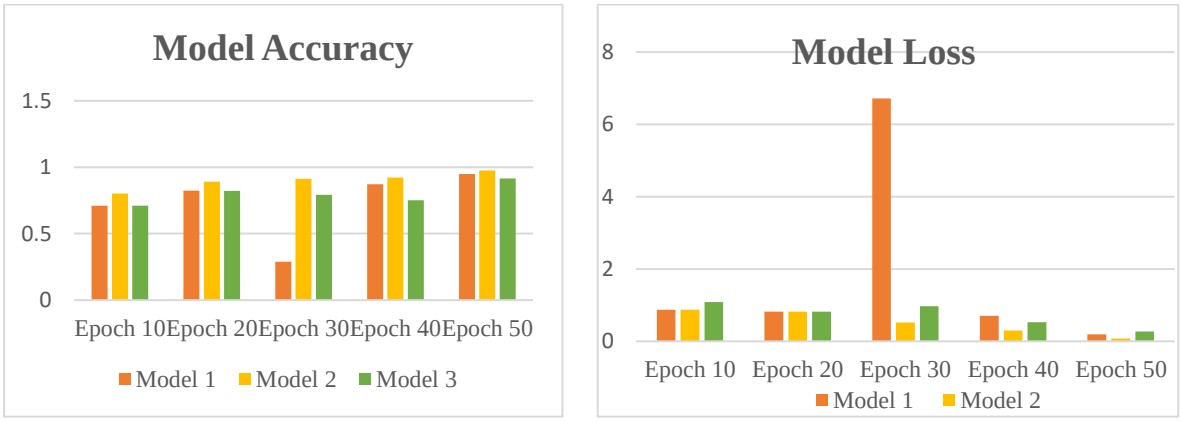

Figure 05: Epoch wise Model Accuracy & Loss.

Conclusion

Several OCR systems were studied and various methods, techniques were analyzed. An off-line handwritten character recognition system with modified 4Fold deep CNN and Alexnet for recognizing handwritten Vedic Sanskrit Text and Marathi characters have been described in this paper. In this work a modified approach based on Optical Character Recognition (OCR) system was built which experimentation is carried out on several samples from own and standard dataset to analyze the response of proposed models. Among four proposed model modified 4Fold – Model2 is superior in terms of accuracy and recognition time with recognition accuracy for Vedic text with its meaning was 97.42% and Marathi characters was 98.94% in average recognition time 0.364 and 0.328 respectively. We did not find any existing solution for comparing our model for Vedic Sanskrit text recognition. So, to compare our model with existing methods we have trained our Model using the Devanagari Handwritten Character Dataset (DHCD) and shown the comparison table 5 mentioned above. As per the comparative analysis we can state that proposed work giving superior outcomes than existing approaches. It also provides a good solution for history lovers and tries to resolve text recognition problems for ascent script like Vedic Sanskrit etc. Our system gives less accuracy for blur and

overlapped text images. The work can be extended to recognize several scripts and various ancient manuscripts such as Mahabharata manuscripts and Ramayana manuscripts.

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