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Effect of Manuscript Distortions on the Accuracy of Automatic Identification using Deep Learning

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Abstract— India is a land of culture and traditions. The richness of Indian literature lies in its age-old manuscripts. These manuscripts have significant scientific, historical, cultural, religious, and aesthetic values. The script used to write these manuscripts is primarily Devnagri and the language as Sanskrit. Most of the manuscripts found in India date back to second millenium BCE. The total number of Indian manuscripts is challenging to estimate due to the vastness of the country's literary heritage and the ongoing discovery of texts. However, it is generally accepted that there are millions of manuscripts which are preserved across various formats, languages, and regions. These manuscripts were originally written over palm leaves, cloth, metal, birch bark or handmade paper which is prone to damage from humidity, pests, pollution, light exposure, inadequate storage, etc. As these manuscripts are centuries old, many age-related distortions are increasing day by day. Oil extracts of some natural products, sandalwood powder, black pepper, clove oil, etc., are some natural remedies to protect manuscripts. Chemical treatments like fumigation chambers and thymol, chloromate solutions are also used to protect the manuscripts. Digitization not only promises documentation and preservation of original texts but also helps in protection from physical deterioration. It also guarantees accessibility and promotion in research. In this research paper, a study is conducted to investigate the effect of distortions on the automatic recognition of the text. The reference dataset used for research is taken from Kaggle database. An algorithm based on a deep learning is employed for training and testing. The synthetic distortion is introduced within the characters and its effect on the recognition rate is investigated. The analysis of the results demonstrates the robustness of the algorithm with respect to different types of distortions present in the input text.

Keywords—Deep Learning; Devnagri; Digitization; Distortion; Manuscript; Sanskrit.

I. INTRODUCTION

India is an ancient land well known for the vast diversity of its traditions, cultures, philosophy, spirituality, literature and religious diversity. Indian culture evolved over thousands of years with a long and complex history. Indian culture is established as dynamic and diversified entity that holds its ever evolving historical foundations firmly. The diversity of India is found in its literature, geography, festivals, art, and music which makes it unique and vibrant among various cultures spread worldwide.

India has recognized itself as a nation with the greatest diversity of cultures in the world due to its incredible accommodation of religious and cultural variations within itself. The major religions found in India include Hinduism, Islam, Christianity, Sikhism, Jainism, and Buddhism. This leads to its multilingual diversity where thousands of languages are spoken across the country. India is among countries with the greatest linguistic variety in the world with approximately 1,600 languages spoken there. Every language has its unique dialect, literature and social customs. The ethnical abundance of a nation may be estimated through its language diversity. Literature and traditions have deep relation with language. Every language contributes to nation's cultural heritage through the means of folktales, poetry, and storytelling with its own characteristics. Culture and language are dependent on each other for their growth and prosperity. Every major language is composed of a huge number of dialects that represent the cultures and traditions of a particular region. Language forms a unique component of regional identity. India's rich cultural heritage can only be perceived and conveyed through language and literature.

The foundation of Indian literary heritage is derived from sacred literary works like the Vedas, Upanishads, and epics like the Mahabharata and Ramayana. Philosophical and moral issues are discussed in these written works. Language specific literary work has been composed across multiple regions: Literature frequently acts as a mirror reflecting society's values and principles, challenges, and objectives. Language and literature interact in a vibrant and creative manner that enriches a nation's cultural identity. The domain of Indian culture continues to grow and expand due to its language and literature. The knowledge is transmitted from one generation to another through the literary work composed in many languages in the form of songs, proverbs, and stories from the past. Indian

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literature has a broad and varied past which reflects the immense cultural and linguistic diversity of the nation.

The Vedangas, Upanishads, Samhitas, Aranyakas, and Brahmanas are considered the oldest manuscripts which are written in Sanskrit [1]. They are storehouse of knowledge about philosophy, chants, and rituals. The fundamental masterpieces like Mahabharata and Ramayana that emphasize on human relationships, ethics, and dharma are written between 400 BCE and 400 CE. The Vedic period has profound importance in ancient Indian history with a time period from 1500–500 BCE. The Vedas, the primary identified sacred texts in Hinduism, came into existence during this time period. Many significant ideas that influenced ancient India's spiritual, philosophical, and social environment were originally introduced during the Vedic era. The primary texts of the vedic period include Rigveda, Samaveda, Yajurveda and Atharvaveda[1]. Rigveda is considered as the oldest and most significant Veda. It is composed up of hymns dedicated to various gods. Samaveda is a collection of chants and songs which are used in religious ceremonies.

The classical mantras written in the form of prose for sacrifices and rituals constitute Yajurveda. Atharvaveda contains information about everyday prayers, spells, and chants. Vedic society works according to customs, with complex ceremonies called yajnas. Yajnas form the procedure and sequence of events performed by humans to please gods and ensure their blessings. The multidimensional tradition of the Vedas worshipped a wide range of deities associated with the elements of nature, including Varuna (cosmic order), Agni (fire), and Indra (thunder). Around 500 BCE, the focus of spiritual discovery moved from religious ceremonies to more comprehensive philosophical enquiries, which ended up in the emergence of the Upanishads. The Upanishads explore concepts such as Brahman (universal soul) and Atman (individual soul), reflecting a shift away from ritualistic procedures and towards inner intellectual investigation.

A huge number of manuscripts were written during vedic era that had a significant impact on Indian philosophy, spirituality, and culture. Their application and transmission across the years ensured their continued relevance in discussions regarding ethics as well as spirituality even today. Indian manuscripts include a wide range of texts that preserve the diverse cultural, historical, and literary traditions of the country. Manuscripts were usually written on materials such as parchment paper, handmade paper, birch bark, and palm leaves in ancient times. As palm leaves are not much effected in humid areas, they were commonly used in ancient times for manuscript writings. Manuscripts can be organized in the form of tablets, rolls or books. They record developments in fields of astronomy, astrology, mathematics, ayurveda, medicine, literature, and much more. There are many categories of manuscripts which are as follows:

Vedic Texts – These form the basis of hindu ceremonies and philosophy. It consists of the Brahmanas, Aranyakas, Upanishads, and the four Vedas.

Epics – It consists of manuscripts of the Ramayana and Mahabharata that contain commentary, criticism and opinions along with the stories.

Puranas – Holy Scriptures such as the Vishnu and Shiva Puran covers cosmological theory, and divine lineage.

Dharmashastras – Manusmriti is one of the ethical and legal scriptures that explains moral responsibilities and standards of society.

Scientific texts – It includes works on astrology, mathematics, and medicine such as the Sushruta Samhita and Aryabhata's works.

Poetry and Drama - Playscripts that represent the literary traditions, culture, social setup of their time period and the masterpieces of classical poets like Kalidasa.

These manuscripts need to be preserved properly in order to preserve the rich cultural and intellectual legacy [2]. Manuscripts are subject to deterioration from use and exposure to the elements, especially those made from natural substances like paper and palm leaves. Many manuscripts are still kept in private possessions or in difficult to reach locations with little maintenance or care. Many institutions lack the necessary facilities and skilled staff needed to handle and conserve manuscript collections in an effective way. Inadequate funding for conservation programs may hinder essential infrastructure as well as successful preservation operations. These invaluable manuscripts need to be stored in proper storage locations with optimal conditions for temperature and humidity to avoid further deterioration. The fading and deterioration of manuscripts can be minimized by limiting exposure to artificial light and direct sunlight. Manuscripts may be stored in archival-quality containers and folders which ensure to keep them in ideal physical position like in flat position or properly rolled to prevent creasing. Repairing damaged manuscripts with specialized binding techniques, acid-free paper, and chemicals that are appropriate for conservation can also be used.

Digital copies of manuscripts can be created by scanning or any other method for digital reproductions that can be used for study, and research while safeguarding the original manuscripts from handling damage. Digital repositories may be created to store digital manuscripts, which provides increased accessibility and research opportunities. Educating conservation techniques and manuscript handling procedures to archivists, librarians, and academicians including scholars, scientists, researchers, etc. may also help. The stakeholders and the general public may be made aware about the importance of manuscript preservation. India's National Archives is primarily constituted with an aim to safeguard the valuable historical manuscripts, and cultural artifacts. Digital Library of India is an effort by Government of India to digitize and make available a large number of texts and manuscripts from different languages and cultures. Numerous academic institutions and research centers have set up sections specialized to manuscript studies and maintenance, frequently collaborating together on restoration strategies.

II. LITERATURE REVIEW

The scope of Indian manuscript research is continuously changing and expanding, with the use of technology and multidisciplinary methods. It is important for protecting India's cultural heritage and expanding our understanding of its

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literature, philosophy, and history. Recent years have seen a rise in the study of Indian manuscripts, with a focus on a variety of disciplines including historic significance, linguistics, textual analysis, and maintenance methods. There are a lot of manuscripts which are in distorted form. A lot of work has been done on background restoration. Restoration of the foreground can be done by completing the incomplete characters in torn places of manuscript through restoration techniques. The background restoration, Otsu binarization threshholding method is used [3].

Wafa et al proposed a method in order to separate foreground and background from a manuscript image, for that they have presented a system comprising of a hybrid method which combines two algorithm together namely background light intensity normalization algorithm and k-means clustering algorithm with maximum likelihood estimation [4]. The foreground and background have been separated using background normalization algorithm. The work is performed such a way that firstly they have applied background normalization algorithm that separates foreground and background, than they focused on improving luminance and suppressing the distorted contrast.

Ntogas et al proposed a Binarization method that is based on pure thresholding and filtering in order to discriminate and categorize the text and background in a manuscript image with a help of using some image processing algorithms with it [5]. The main focus of their work were on text image binarization, that is been considered one of the most innovative and new method for acquisition of historical digital images. The plus points given by them are that they gave a method that is robust and simple. The binarization method they have used are applied on pre- filtered historical image and then the simulation is done on them in order to produce a result from it. The data set contains all characters that are made from manuscript images. There are some of the constraints while making a data set because the manuscripts are handwritten Devnagri manuscripts so every manuscript image is having a different data set, containing all characters of Devnagri.

The image processing methods are applied on the restoration of foreground as well as background of the deteriorated manuscript images[6]. The proposed methodology primarily focuses on foreground restoration of a manuscript image written in Devnagri. The main aim of the proposed work is to remove the yellowish background, crushes and restore the characters of manuscript which will help in improving the quality of content in Devnagri manuscripts. The results shows that only those characters can be completed in which the deterioration rate is 50% or less than 50%.

A collection of a large corpus of annotated Latin characters has been described along with the design of a novel deep convolutional network for the classification work [7]. The described system is a key component in the Codice Ratio project, whose aim is to fully transcribe a large corpus of documents contained in the Vatican Secret Archives. Some preliminary results with the entire system have shown that the framework is able to reach around 80% of word-error rate on the pages under consideration. Leveraging over recent progresses in deep learning, we designed and trained a deep convolution network achieving an overall accuracy of 96% over the entire dataset.

A customized CNN model has been used to classify the manuscript's character images efficiently. The CNN model achieved recognition accuracies of 88.67%, 90.91%, and 98.86% in the cases of resampling 1, resampling 2, and resampling 3, for the Beowulf manuscript's data [8]. The CNN model achieved the benchmark recognition accuracy of 99.03% for the MNIST dataset. The model was trained with the MNIST dataset for 100 epochs with a batch size of 256. MNIST dataset achieves recognition accuracy of 99.83% by EnsNet model, 99.87% by the Branching or Merging CNN model, 99.84% by the Efficient-CapsNet model, 99.83 by the SOPCNN model, 99.77% by the MCDNN model, 98.90% by the Convolutional net LeNet-4 model, and 99.05% by the Convolutional net LeNet-5 model. The proposed CNN model in this study achieved a recognition accuracy of 99.03%, when tested on the MNIST test dataset, and a training recognition accuracy of 100.00%.

A CapsNet-based method was used to identify the handwritten Devnagari characters from the manuscripts. The complete dataset was divided into 399 classes for the recognition of basic, modifiers, and conjunct characters from the manuscripts. The proposed model was run with varying test-train character ratio. The number of epochs was also varied for better recognition accuracy. The recognition accuracy of 94.6% was achieved to recognize the Devnagari characters using CapsNet based model [9]. The proposed model had a significant impact on the character recognition model overall performance which includes precision, recall, and accuracy. This study throws light on how CapsNet handles the spatial links between isolated characters. Isolated characters including conjuncts and modifiers were used as input. This model is found effective for single character recognition. The capsule keeps all of the required spatial characteristics of the Devnagri character by wrapping them in vector form. The maximum accuracy of 94.6% was attained after 30 epochs of operation.

A deep learning model was proposed both as a feature extractor and a classifier to recognize 33 classes of basic characters of Devnagari manuscripts. The experiment was carried out with a dataset containing 5484 characters. The accuracy achieved using CNN as a feature extractor was found to be better than many other standard techniques. The recognition accuracy of 93.73% was achieved by using the model proposed in this paper for Devnagari character recognition [10]. Individual characters taken out from the ancient Devnagari manuscripts act as input. Deep learning with CNN has been used successfully for the recognition of the handwritten Devnagari ancient manuscripts. Maximum accuracy of 93.73% was achieved with 75% train data and 25% test data after 30 epochs.

The MNIST dataset having distorted digits with irregular shapes, incomplete strokes, and varying skew in both the training and testing datasets is used for the experiment [11]. This distortion causes less accuracy in digit recognition. To

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overcome this problem, a two-step deep learning methodology was used. The distorted and misleading images were detected and filtered out within the available training set using a simple neural network. These identified images were excluded from the training dataset and the model is retrained using the filtered dataset. This is done with a purpose to improve the accuracy of classification and confidence levels as well as decreasing the issues related to under fitting and over fitting. This experimental result achieves an accuracy rate of 99.5% on the testing dataset. This study demonstrates that removing distorted images can lead to a significant increase in classification accuracy and confidence level. The deep network model improved the validation accuracy from 99.44% to 99.72%

The performance of some standard deep CNN techniques to recognize the handwritten digits is tested by working on four different deep CNN architectures namely AlexNet, MobileNet, GoogLeNet, and CapsuleNet models [12]. The dataset used with these four CNN was NumtaDB dataset. Out of the four models, AlexNet showed the best performance in terms of accuracy and computation time. This research is reported on the implementation of four state-of-the-art deep CNN architectures on NumtaDB dataset. After investigating the individual performance, it was observed that among the four models, AlexNet provides the highest recognition accuracy of 99.01% over both the normal and augmented data. The implementation is much-time consuming process, requiring high configurable machine with GPU.

A detailed survey was carried out related to the work done in the various phases of an OCR with special focus centred around the OCR of ancient text documents. This paper provides a study of the various phases, namely, segmentation, feature extraction and classification techniques implemented in an OCR system especially for ancient documents. Convolution is implemented with overlapping Filter (Kernel) of Size 5*5 and stride 1 on both directions. The mini-batch size is 200 and the network was trained for 50 epochs [13].

A handwritten Devnagri ancient manuscripts recognition system which works only on basic characters of the Devnagri script is presented. It uses a statistical features extraction technique. Various feature extraction and classification techniques are used to recognize the basic characters segmented from Devnagri ancient manuscripts. A data set containing 6152 pre-segmented samples of Devnagri ancient documents, is chosen for experimental work [14]. A total of four features are extracted for the recognition of these characters. These features include intersection and open endpoints, centroid, horizontal peak extent and vertical peak extent. All the possible combinations of these features along with classifiers, namely, MLP, Neural Network, CNN, RBF-SVM and Random Forest are used. A simple majority voting scheme with different combinations of these classifiers is used. The recognition accuracy of 88.95% is achieved using a combination of all features and a combination of all classifiers.

A comprehensive review of various machine learning techniques used for recognizing handwritten Devnagari characters, which are commonly used in scripts like Hindi is presented. The paper emphasizes the challenges unique to Devnagri script, such as variations in stroke order and the presence of half consonants [15]. CNNs achieved the highest accuracy among the tested algorithms, with an average recognition rate of 94.2%**.** SVMs showed good performance with an average accuracy of 89.5%. Combining CNNs with other techniques, such as HOG and PCA, resulted in improved accuracy, reaching up to 96.1%. Using a dataset with over 50,000 images increased the accuracy of CNNs by 3.5% compared to smaller datasets.

The study on Handwritten Devanagari Character Recognition using deep learning—Convolutional neural network (CNN) model achieved an impressive 94.84% testing accuracy on the new dataset [16]. The model had a training loss of 0.18. A second fine-tuned model required fewer trainable parameters and less training time, achieving a higher testing accuracy of 96.55% with a training loss of 0.12**.** The proposed model was tested on four different benchmark datasets of isolated characters and digits of Indic scripts, showing promising results across all datasets.

The effectiveness of transfer learning in enhancing the performance of handwritten Devnagri character recognition systems was presented using CNN [17]. The fine-tuned model achieved an accuracy of 96.55% on the test dataset. he fine-tuned model required fewer trainable parameters and less training time, making it more efficient. The model was tested on four different benchmark datasets of isolated characters and digits of Indic scripts, showing consistent and promising results across all datasets.

The transcription of medieval manuscripts using machine learning techniques was studied [18] where the use of Handwritten Text Recognition to automate the transcription process was discussed. The emphasize was given on the importance of designing transcription schemes tailored to specific research questions and scholarly needs. The transcription guidelines aim to capture abbreviations and orthographic variations between different textual witnesses, which are crucial for downstreaming machine learning tasks.

The use of deep learning techniques for Optical Character Recognition (OCR) in various challenging environments was tested. It discusses the architecture of deep learning models used for OCR, highlighting Convolution Neural Networks and Recurrent Neural Networks as essential components [19]. The paper provides examples of practical applications, such as reading text from street signs, license plates, and documents in different languages and fonts. Deep learning-based OCR models are shown to achieve high accuracy, even in challenging conditions like low lighting, distorted text, and varying backgrounds.

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Machine learning classifiers like SVM, ANN, k-NN for recognizing Devnagari and Gurmukhi characters were evaluated in this paper. Feature extraction techniques like zoning and projection profile were used to represent the characters in a form suitable for machine learning models [24]. The recognition accuracy for the Devnagari script was reported to be around 95% using SVM and for the Gurmukhi script, the recognition accuracy achieved was 92%.

The application of CNN for recognizing handwritten Bangla characters in an online setting, applying deep learning techniques to improve the recognition process was carried out successfully [20]. The study focused on 209 Bangla characters, including letters and numerals, and successfully recognized all characters within the dataset. The proposed model performed better than SVM and k-NN classifiers and was found suitable for real-time applications.

A study where transcription of Ancient Indian Manuscripts was achieved through Artificial Intelligence highlights that deep learning models, particularly Convolutional Neural Networks, have shown promising results in accurately transcribing ancient Indian manuscripts. The challenges faced in transcribing manuscripts written in various languages and scripts, with a focus on Sanskrit, Pali/Prakrit, and Tamil was also discussed [21]. The paper mentions a deep learning model developed by Nanonets, which is user-friendly and can transcribe thirteenth/fourteenth-century Sanskrit and Tamil manuscripts without extensive training or visual enhancements.

The current AI-based techniques being used for manuscript transcription, such as Optical Character Recognition (OCR), machine learning, and deep learning models were highlighted in this paper. The error rates in AI-driven transcription systems were found to be lower than traditional manual transcription processes. The paper emphasized that AI models trained on large datasets of well-preserved manuscripts may achieve higher accuracy in transcription, while models trained on more diverse datasets can handle variations in handwriting and styles [22]. The study emphasized on multilingual models, contextual understanding, and collaborative AI-human transcription efforts for handling multiple Indian languages and scripts simultaneously.

The process of automation of the transcription process was carried out which significantly reduced the labor and time needed for manual transcription. It was pointed out that machine learning models must be trained on high-quality annotated data for accurate transcription. The challenges of data scarcity were explored using data augmentation methods [23]. It was observed that the transcription accuracy improved with better-quality manuscripts and larger annotated datasets.

III. MATERIAL AND METHOD

The distortion in images of devnagri characters is a concern that affects the accuracy of identification of images. Many times the images are torn and masked which makes them unreadable and unidentifiable. There exist some algorithms that reduce these type of distortions but may produce inaccurate results. The rate of success of pre-processing and feature extraction is dependent on the quality of the image. Image recognition is directly dependent on the method used for feature extraction which is again dependent on the image quality and acquisition factors. In this experiment, the effect of distortion on devnagri script images is investigated using a dataset downloaded from Kaggle. The script images included in dataset are handwritten character images which captures distinct attributes that enhance its usability for research and analysis. Each character image is identified using a detailed label.

The overall methodology for proposed character identification is shown in Figure 1. The reference input images are subjected to different types of synthetic distortions. In this experiment, images are purposefully distorted by masking them in a systematic way. Each input image is masked row wise and column wise with 8 numbers of masks in row and column making the total count of masks in a single image to be 64. Each masked image is differentiated and identified by using a suitable label. The process of application of masks in the first row of an image is shown in Figure 2. In the same way, masks are applied in the reference image up to 8 rows with 8 number of columns in each row. A mapping function is applied to reference image in each batch to convert the string labels into corresponding numerical values as a part of pre-processing. The input image is further pre-processed using transformation pipelining which helps in image classification process. Here the image is resized to proper height and width as per specifications in pre-trained models. The processed image is further cropped, converted to a PyTorch Tensor and normalised with the specified mean and standard deviation for RGB channels. The data is loaded with a proper batch size for test dataset under consideration. The attention mechanism is implemented using the forward method which applies the convolution layers to the local as well as global features to compute the attention map. The local and global features are passed to the attention block during forward pass. The number of convolution layers applied is 3. The dimensions of the local features are matched to the unsampled global features using bilinear interpolation. The local and global features are combined to compute attention map which is then normalised using softmax function. The final output is obtained by applying attention map to the local features. The local features are re-weighted by multiplying them with the computed value of attention map. The model is trained for 105 epochs, with train and validation losses and AUC scores printed for each epoch. The output includes both the attention map and the aggregated features.

The VGG based model is decomposed into multiple blocks which facilitate the processing of features at different levels. The output of different convolution blocks is integrated in attention block. The output of the attention block is pooled, flattened and is forwarded to a fully connected layer for classification purposes. The classification outputs as well as the attention map are obtained from the forward model. The attention blocks are applied in the forward pass followed by

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pooling and concatenating of outputs for the classification layer. The over fitting is prevented by using dropout. In this model, two attention blocks are added where different convolution blocks provide input to different attention blocks. The weights for the classification and attention layers are initialized using Kaiming Normal Initialization which is best suited to layers with ReLu activation. The predictions, labels and additional information are stored in proper dictionaries. The models output is passed through a sigmoid function to get probabilities.

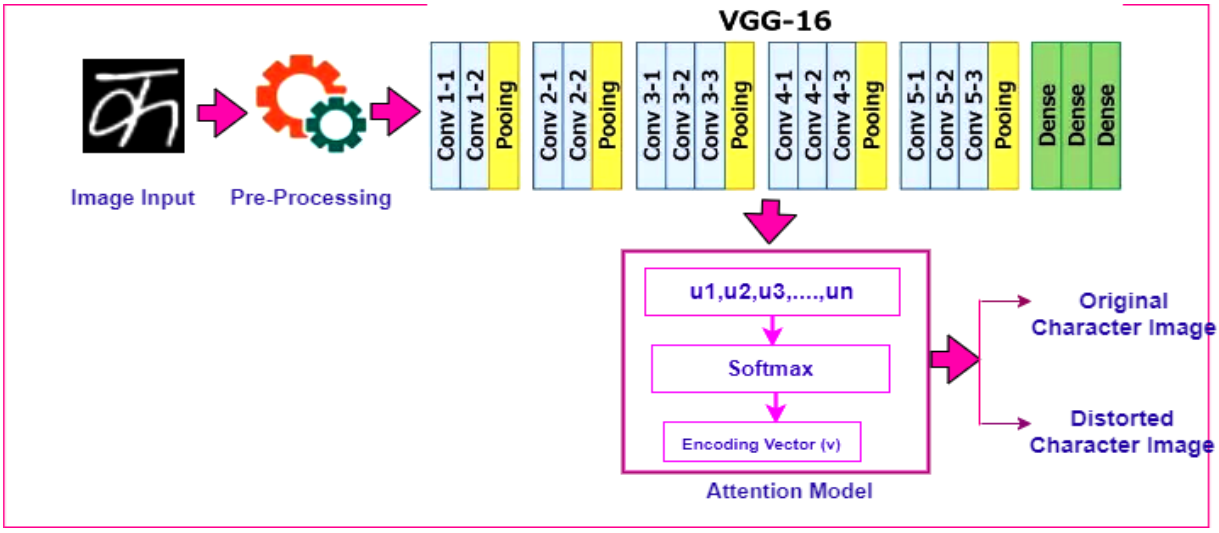

Fig. 1. Schematic of the methodology employed for proposed character identification

Fig. 2. Application of mask in first row of a character image

IV. RESULTS

The original image and attention maps overlaid on attention maps are adjusted on different scaling factors. The original image and both the attention maps are displayed side by side for easy comparison. The input images along with the attention maps are visualized, saved and evaluated properly to check the behaviour of layers as shown in Figure 3. The top row displays a sequence of input images, which are grayscale representations of the character "क" in handwritten font. These images are fed into the model for processing, and they serve as the starting point for generating the attention maps. The middle row show attention maps after the model has processed the images through the third layer. The attention highlights which areas of the input image the model is focusing on to make decisions. The model is capable to identify key features, like curves and edges of the devnagri character. The bottom row shows attention maps after processing the images through the fourth layer of the model. The attention appears to be more concentrated in specific regions, particularly around the bottom of the character "क".

The total numbers of masked reference images included in the testing phase are about 20000. The rate of accuracy of the proposed algorithm is found to be 75% approximately. Figure 4 displays some character images which the model failed to identify accurately. Finally, the evaluation of performance of the algorithm is displayed by using well structured ROC curve as shown in Figure 5. The model represented in this curve has an AUC of 0.74, which suggests that the model is performing satisfactorily.

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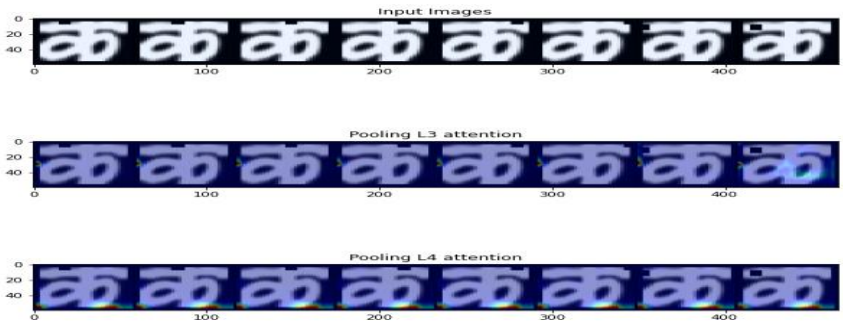

Fig. 3. Input images along with the attention maps

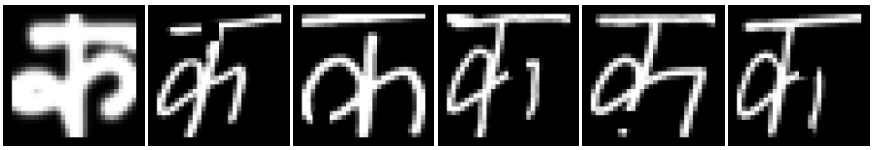

Fig. 4. Input images showing different actual and predicted value

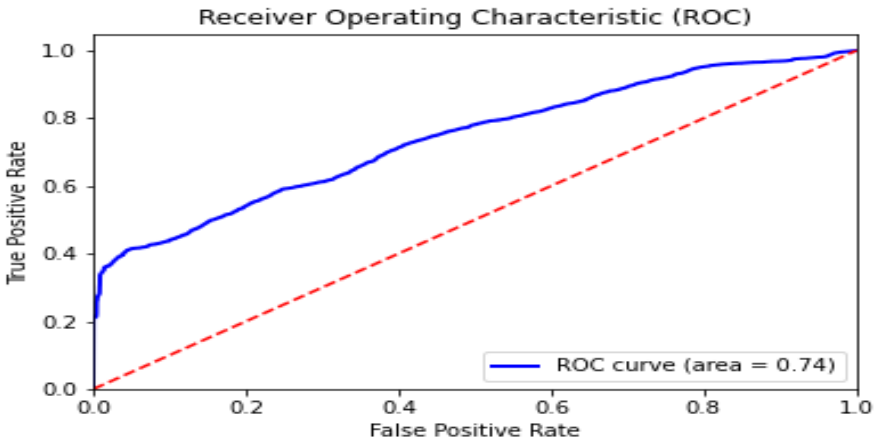

Fig 5 FPR-TPR-ROC Curve

V. CONCLUSION AND FUTURE SCOPE

The study on the automatic identification of devnagri characters using attention mechanism based on VGG-16 is carried out in this paper. The model represented in this curve has an AUC of 0.74, which suggests that it is much better than random model but not highly accurate and there exists scope of improving the model. The performance may be further improved by altering the batch size, number of layers and optimizer type.

Conflict of interest: The authors declare that they have no conflict of interest.

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