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Offline MODI script character recognition using deep learning techniques

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Abstract—The MODI script, historically used for writing Marathi and other languages in Western India, holds immense historical importance. It is essential for maintaining and comprehending this cultural legacy to recognize characters from ancient MODI texts. A major obstacle, which frequently affects the accuracy of character recognition, is the restricted availability of MODI script datasets. With the goal of achieving the maximum accuracy while minimizing noise interference, this paper presents an extensive study of MODI script character recognition using modern Machine Learning (ML) and Deep Learning (DL) techniques. To identify characters in the MODI script, we use a variety of ML and DL models, such as Convolutional Neural Networks (CNNs), VGG 16, ResNet, KNN, and SVM.The dataset contains a lot of similar characters so distinguishing them and increasing the accuracy of the algorithm used in order to get the best result. These models are trained on the dataset, enabling them to learn and distinguish between similar-looking characters effectively. The models are evaluated based on their accuracy.

Keywords—Offline character recognition , Modi Lipi , Deep Learning , Machine learning

INTRODUCTION

In ancient era, to write the documents in Marathi, MODI Lipi script was used **The** Marathi verb moḍaṇe (Marathi: मोडणे), which meaning "to bend or break," may be the source of the name "Modi." Several features of the Modi script make writing easier, such as the reduction of the need to take the pen from the page to dip it in ink when switching between characters. Many characters have a more circular shape, and some are "broken" copies of their Devanagari counterparts. Modi is a Marathi writing style that resembles cursive because of these features.

Before Devanagari was formally recognized, the 19th century saw the widespread use of the antiquated MODI script. For around 600 years, MODI was used for written communication in various forms.

It evolved over several centuries, and its development can be broadly categorized into different eras. The early form of the Modi script is believed to have evolved from the Nāgarī script and was primarily used for administrative and bureaucratic purposes, such as maintaining records and writing official documents. In the 12th century Modi was called "Adykalin" ("proto-modi"). It evolved and then in the 13th century it was called "Yadavkalin" . During the 16th to 18th century script was in widespread use under the Maratha Empire, 'Chatrapati Shivaji Maharaj' and 'Peshwas'. It was used for writing extensive legal documents, treaties, and letters. Various versions of modi script evolved during this period- 'Bramhkalin'(14th-16th century), 'Shivkalin'(17th century) , 'Chitnis' and 'Peshvekalin' (18th century). The 19th century saw the usage of this writing style. It was called the 'Anglkalin' script. Then, in the 20th century, Devanagari script started to take the place of MODI script.

Table 1: Eras of MODI script

Sr No.	Styles of MODI Script	Time Period
1	Adya kalin (proto-MODI)	12th century
2	Yadav Kalin	13th century
3	Bramhkalin	14th to 16 th century
4	Shivkalin	17th Century
5	Chitnis	18th Century
6	Peshvekalin	Till 1818
7	Anglakalin	1818 to 1952

Many historical documents written in Modi script are in physical form, which are susceptible to damage and degradation over time. Digitization of these documents will ensure their preservation for future generations. To digitize these documents offline character recognition is an important and preliminary task. Digitized texts can be made available to more audiences, including researchers, students, and the general public, through online databases and different digital libraries (1-3).

Fig 1: Various documents of different eras The need for character recognition of Modi script is driven by the goals of preserving cultural heritage, facilitating research, enhancing education, and improving access to historical documents. Despite the challenges, advancements in technology and collaborative efforts can significantly contribute to achieving these objectives, ensuring that the rich legacy of the Modi script and the Marathi language is preserved and appreciated.

LITERATURE SURVEY:

In this paper, various deep learning algorithms are utilized. Character recognition falls under the umbrella of pattern recognition tasks. CNN is an efficient neural network architecture for image processing tasks. It is one of the best for character recognition, having been implemented. Author has used deep learning algorithms for implementation. Character recognition can either be used directly or employed for extracting features. The text details certain aspects involved in character recognition. Implementation The author had proposed a method for extracting features using a CNN autoencoder. The paper handles MODI script character recognition. Support Vector Machines are employed to process the extracted features. SVM functions as a classification machine and to introduce variability, data augmentation is employed. The text calls for expanding the existing data set. The text primarily focuses on character recognition. MODI manuscripts are housed in multiple libraries. The proposed method, employing CNN, exhibits satisfactory performance. An autoencoder can function as both a feature extractor and an SVM classifier. The classifier achieves an exceptionally high accuracy and outperforms others. The most precise MODI text character recognition technique is used. (1-3)

Efforts to develop HOCR systems for different foreign languages remain ongoing, including those for Indian scripts. The unique writing styles of individuals pose a critical challenge for HOCR in recent decades. The world recognized India for its togetherness despite its diversity. Given the vast geographical and cultural expansion of the country, different spoken languages and writing scripts exist and were used in day-to-day life. Lots of efforts were made towards the HOCR implementation for different Indian scripts. Due to the complex structure of Indian

scripts, research on the development of the HOCR system was actively pursued, with MODI Script being older than most other Indian scripts. To preserve and explore the vast array of historical documents, it's essential to focus on MODI script. This paper explores contemporary advancements in Handwritten Optical Character Recognition systems for the MODI script. (4-5)

In this paper, the author has focused on deep learning technologies. In Pattern Recognition and Image processing, handwritten character recognition is a commonly employed technique. Ancient script handwritten characters pose greater recognition challenges. Analysing and identifying offline handwritten characters manually is a time-consuming task. Human errors are a potential risk during manual recognition processes. This error could alter the meaning of ancient texts. Precise analysis and transliteration/translation are crucial for preserving ancient documents. This study utilizes the ancient MODI script for handwritten character recognition. A Classification algorithm of machine learning, specifically a most accurate Convolutional Neural Network (CNN), serves as the overall recognition mechanism. This paper is divided into four sections. This study's initial part outlines the use of Ancient MODI Lipi and the Deep learning model AlexNet. The second section outlines the dataset preparation, preprocessing, and data augmentation processes for the proposed system. The following section details the experimental setup and outcomes of the proposed study, while the concluding section presents the system's final assessment. (6-8)

This study aims to evaluate and contrast the findings of various research on a particular topic.
Methods for recognizing Modi script are diverse. The author used various methods. For feature extraction and classification, distinct methods are utilized. The different methods used for feature extraction and classification Also various datasets are used for their comparison. The significance of virtual currencies, like bitcoin, is the subject of this talk. Employing suitable feature extraction and classification algorithms is crucial for accurate image classification. This text offers comments on methods tailored to distinct applications. The number of MODI translators is minimal. Historically, fewer numbers of people have migrated compared to the current trend. The Convolutional CNNs have achieved success in MODI recognition. The present study reveals that the author's findings surpass those of all previous studies. In this paper, the authors concluded with the comparison to all methods, CNN achieves a maximum accuracy of 99.78%. CNN is identified as the most effective approach for recognizing characters. (9-11)

In this paper, the author had discussed and implemented advanced deep learning models ResNet101, InceptionV3, and Xception. This research reveals the intricate cultural history of the "MODI LIPI" script. Among the three algorithms, ResNet101, renowned for its deep learning capabilities, delivered the best results, with a training accuracy score of 77.25% rising to a validation accuracy score of 90.36%. InceptionV3 achieved a training dataset accuracy of 86.62% and a validation accuracy of 80.99%, while Xception demonstrated superior performance with a training dataset accuracy of 90.87% and a validation accuracy of 85.94%, thanks to its utilization of depth wise separable convolutions. The use of deep learning, particularly transfer the learning via ResNet101, InceptionV3, and Xception structures, significantly improves the MODI script's recognition accuracy and efficiency. In character recognition tasks, these algorithms' success proves MODI more accessible and comprehensible to modern audiences, especially the youth. This research helps preserve and revitalize the historically significant MODI script by unlocking its untapped potential as a cultural and educational resource.(12-13)In this research, a CNN model was created for character and data augmentation techniques were used to expand the MODI script’s dataset. The Maharashtrian script, MODI, is an ancient Indian one. During Chhatrapati Shivaji Maharaj's reign, this script was used for drafting official papers. Character recognition in MODI is challenging due to its complex structure and the absence of a dedicated image database. For character recognition in this research, we expanded the MODI script's dataset using data augmentation techniques and designed a CNN model. We augmented the MODI script's limited dataset of 4140 images and used it to train the CNN model. The Handwritten MODI characters recognition accuracy of the trained model is approximately 91.62%. While the algorithm works admirably for picture modifications, it can be further expanded to distinguish noisy and unclear data as well. (14)

The study concluded with the development of a highly accurate character recognition system that follows the established method of the Modi Script character recognizer system (MCR). The study focuses on creating a character recognition system for MODI language also known for its intricate character identification difficulties. The system, consisting of CNN and VGG16 algorithm, identifies MODI characters (printed or handwritten) from scanned papers with high accuracy, irrespective of their quality. The training dataset consists of 48 distinct MODI script characters and are continuously updated using handwritten samples. This study shows that an extremely precise character recognition system can be developed based on the MODI Script Character Recognizer System (MSCR) methodology. The CNN algorithm’s training phase shows a loss of 1.0773, a validation loss of 0.8074

and a validation accuracy of 87.25%.(15-17)

In this paper the author had discussed that Modi is difficult due to its structural features and the lack of an image database. In the research, we created a CNN model for character recognition and used data augmentation. The Maharashtrian ancient Indian script is called MODI. Chhatrapati Shivaji Maharaj's reign saw extensive usage of this script for drafting official records. The lack of an image database and MODI's structural complexities present challenges for character recognition. We built a CNN model for MODI script character recognition and expanded its dataset using data augmentation techniques. To address the insufficient number of images in the low-resolution MODIS dataset, we supplemented it with additional data and trained the CNN model on the expanded dataset. 91.62% of the time, the model identifies Handwritten MODI characters accurately. Using CNN, the accuracy achieved here is somewhat less. More epochs could be added [18-19].

Identification of gap:

Previous research shows that methods usually fail at identifying similar keywords in the script. Accuracy was found to be decreasing drastically when conjoined words were present in the document. The dataset needed for the training and testing also was not readily available. Also, it is used on scripts from different eras which has never been done before. UI has also been made available which makes it easier for the researchers to easily find the most accurate solution.

Challenges:

1. Modi script's cursive nature and variations in handwriting styles present challenges for character recognition technology. Advanced algorithms and machine learning techniques are needed to accurately recognize and interpret the script.
2. Developing effective character recognition systems requires large datasets of Modi script documents for training and testing. Collaborative efforts are needed to compile and share these resources.

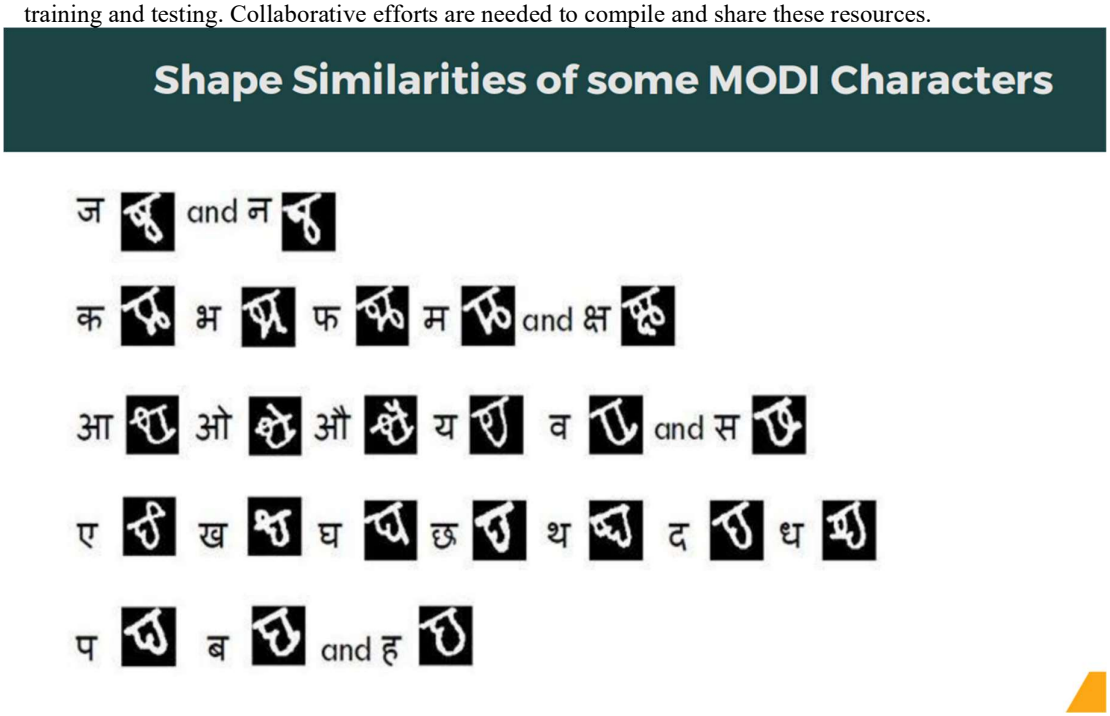

Fig 2: Shape Similarities of some MODI characters

METHOD

Although the world has evolved technologically today, still many people tend to use the traditional method of writing using pen and paper. However, there are drawbacks with respect to this. Physically handwritten data takes up more physical storage space and accessing it also becomes difficult. It is difficult to search through them effectively. Chances of data loss is very high in these cases as the information does not get transferred to digital format at all. Handwritten Character Recognition is also used in signature identification in several government organizations and banks where the characters and the patterns are recognized by the system to identify its originality. This is also used in Research related activities where the old documents and manuscripts found are recognized using Handwritten Character Recognition and the information is transferred to digital format. Handwritten Character Recognition can also be used in converting a handwritten application form to a digital

form. Here, the filled form is recognized using the model and the characters are converted into their respective digital characters which helps in easier understanding and faster processing of the forms.

In the training step, segmented characters are matched with the dataset. If the match is found, then the character recognition is successful. We have trained multiple modules.(20-21)
Fig 3 describes the system architecture of the Handwritten Character Recognition. The initial step involves capturing the image of handwritten text in Modi script from the dataset. Ensuring high-quality image capture and preprocessing is crucial for the accuracy of subsequent steps. Noise removal and thresholding help in creating a clear distinction between text and background. So, the captured image is converted from color to grayscale to simplify further processing. In order to better distinguish the text from the backdrop, thresholding is done, which turns a grayscale image into a binary image by changing all pixels above and below a given threshold value to white. Filters are applied to remove any noise or unwanted variations in the image to enhance the clarity of the text. Extracting the right features is critical as it directly impacts the model's ability to recognize characters accurately. Specific features of the characters in the Modi script are identified and extracted in the feature extraction step.
These features could include edges, corners, curves, or other distinctive characteristics of the characters. In the Neural network models, it is done automatically. A dataset of Modi script images with labelled characters is used to train a machine learning model. The model learns to recognize and differentiate between various characters based on the features extracted. Then the trained model is applied to new images of handwritten Modi script to identify and recognize the characters. The output from the recognition step is further refined to correct any errors or ambiguities. A well-trained model with a robust dataset ensures high accuracy in character recognition. The quality and size of the labelled dataset are key factors here.(22-23)

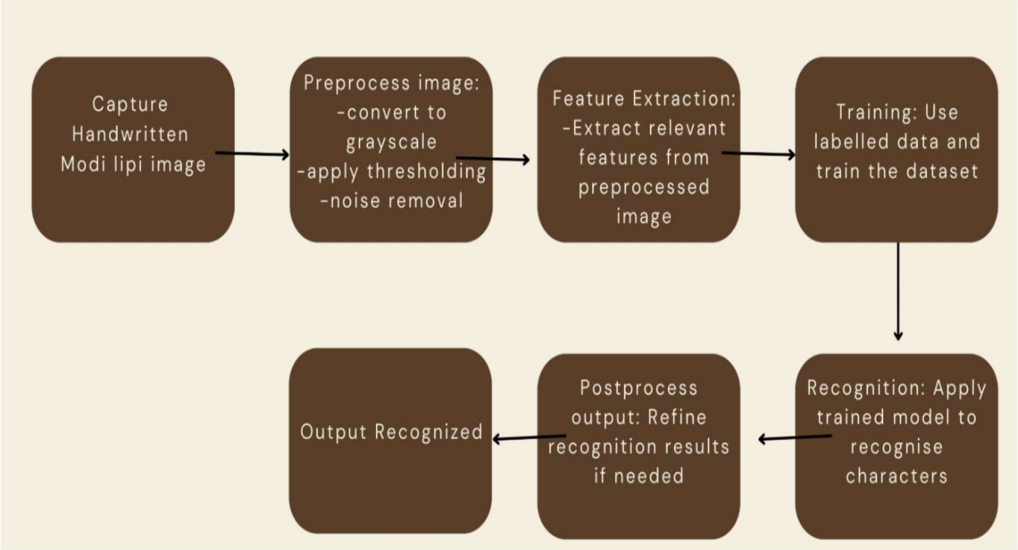

Fig 3: system architecture of the Handwritten Character Recognition We have employed a number of methods for character recognition, including ResNet, VGG16, SVM, CNN, and KNN.

Models:
1]CNN: CNN is a deep learning model. CNN is the most commonly employed in image recognition. They excel in character recognition by automatically learning hierarchical features, capturing local patterns, and exhibiting translation invariance. CNNs have proven effective in handling variability in font, size, style.

2]SVM: They are a type of supervised learning algorithm used for classification tasks. SVM functions in character recognition by determining the ideal hyperplane to optimally divide various character classes in feature space. SVMs are highly effective in high-dimensional spaces, making them well-suited for image data where each pixel can be considered as a separate dimension. SVMs can perform well even when the dataset is relatively small. This is advantageous where collecting a large, labelled dataset for training is challenging.

3] KNN: KNN is straightforward and easy to implement, and its adaptability makes it effective for recognizing characters with varied fonts, styles and sizes. It also makes localized decisions based on nearby data points, which can be advantageous for certain character recognition scenarios.

4] VGG-16: It is a convolutional net architecture. Visual Geometry Group-16 is utilized for image recognition. It is considered as one of the finest vision model designs and makes use of 16 layers with weights.

5] ResNet:
The issue of vanishing gradients is solved by residual connections in the ResNet architecture, which makes it possible to train very deep networks. ResNet presents the idea of residual learning, in which each layer or module learns the residual, or difference, between the layer's input and output, as opposed to learning a straight mapping. Use skip connections, also called shortcut connections, to transfer the input directly to the output of one or more layers while skipping one or more of them. Fig 4, outline the the ResNet architecture:**RESULTS AND DISCUSSION**
There are 46 vowels and consonants in the Devnagari script. We tested all these letters for all the methods. The input characters and predicted characters for it using each method are described in table 3. We applied 100 epochs, cross-validation during testing. From this table we conclude that the CNN provides better results as compared to all the other methods (24-25).

Table 2: Sample Predicted output

S.NO	INPUT CHARACTER	PREDICTED CHARACTER				
		CNN	SVM	VGG16	KNN	ResNet
1	अ	अ	अ	अ	द	अ
2	आ	औ	स	इ	आ	औ
3	इ	इ	इ	इ	द	द
4	ऊ	ऊ	ऊ	ऊ	ऊ	ऊ
5	ए	ए	ढ	औ	आ	ढ
6	ऐ	ऐ	ऐ	ऐ	घ	ढ
7	ओ	ओ	ओ	स	आ	स
8	औ	औ	औ	अं	आ	औ
9	अं	अं	अं	अं	द	घ
10	अः	अः	ऐ	फ	ख	फ
11	क	क	क	आ	घ	क
12	ख	ख	ख	ख	द	द
13	ग	ग	ग	द	ग	घ
14	घ	घ	घ	क	द	क
15	ङ	ङ	ट	ङ	ट	ङ
16	च	च	च	च	ड	च
17	छ	छ	छ	छ	द	छ
18	ज	ज	ज	ज	द	ज

19	झ	झ	झ	झ	ब	ब
20	ञ	ञ	ञ	अं	च	अं
21	ट	ट	ट	आ	ट	ट
22	ठ	ठ	ठ	ठ	ट	ट
23	ड	ड	ड	ञ	ड	ड
24	ढ	ढ	ढ	ढ	ढ	ढ
25	ण	ण	ण	घ	घ	घ
26	त	त	त	च	ट	त
27	थ	थ	क्ष	ए	द	क्ष
28	द	द	द	ग	द	द
29	ध	ध	ध	ओ	ड	ड
30	न	ज्ञ	न	छ	ट	छ
31	प	प	औ	ख	घ	प
32	फ	फ	फ	ज्ञ	ट	ट
33	ब	ब	ङ	ज	घ	ब
34	भ	भ	भ	भ	च	भ
35	म	म	म	ए	ञ	ज
36	य	य	य	य	द	य
37	र	र	र	न	ट	न
38	ल	ल	ल	ज्ञ	द	ल
39	व	व	व	व	घ	व
40	श	श	श	ग	घ	स
41	ष	ष	ष	ष	घ	प
42	स	स	ऐ	ऊ	द	स
43	ह	ह	ण	ण	द	ण
44	ळ	ळ	ळ	न	ञ	ळ
45	क्ष	क्ष	क्ष	क्ष	द	क्ष
46	ज्ञ	ज्ञ	ज्ञ	ज्ञ	द	ञ

The highest accuracy achieved is 96% by using CNN. The algorithms are analyzed for various picture modifications as well**Table 3: Accuracy with different models**

Method	Accuracy
KNN	75%
CNN	96%
SVM	77%
VGG16	85%
ResNet	87%

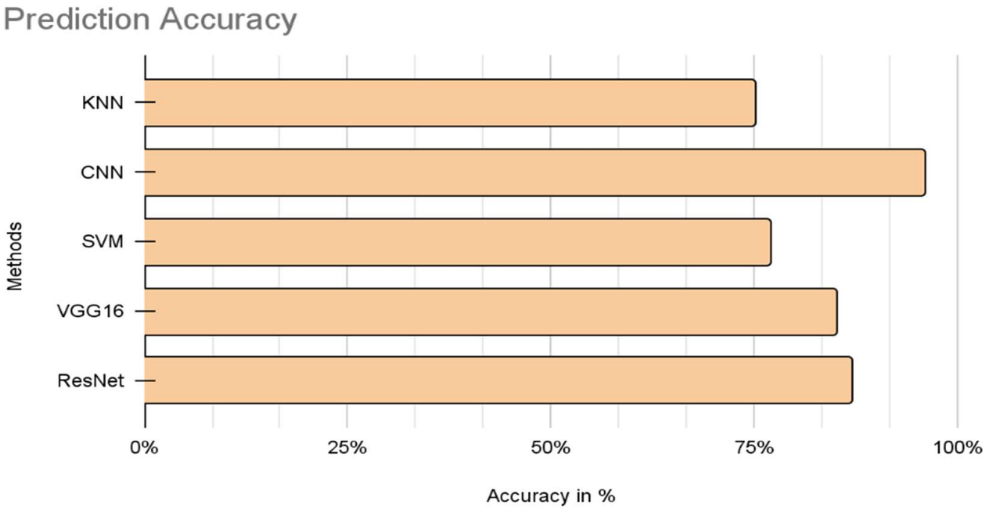

Fig 5: Accuracy related to each type of classification methodCONCLUSION

Due to data variability i.e. differences in an individual's handwriting style, it is difficult to include all variations. Obtaining the dataset to perform operations and getting a huge set of result data sets was a prominent challenge. So, there is a need to generate Standard dataset for handwritten MODI script. Creation of dataset according to various eras of MODI script evolution is now quite challenging. Because fairly thick brushes were employed for various eras and preparing those strokes is quite difficult.

Machine learning-based approaches have very poor accuracy rates and may need time-consuming feature extraction processes. The accuracy rate in deep learning-based techniques was adequate. Deep learning provides rapid attribute inference and suitable modification to achieve the intended outcome. That implies that attributes won't have to be extracted. VGG16 and ResNet are advanced techniques as compared to CNN, but due to the small size of the dataset their accuracy rate is low. Also, it is observed that due to computational complexity of these models it takes a long time to generate output. Preprocessing also plays an important role in character recognition. If the preprocessing is applied adequately then accuracy of VGG16 increases sufficiently.The initial step towards comprehending and translating documents written in MODI script is character recognition. Numerous applications can be developed if it takes less time and is highly suitable.

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