

A Review on Handwritten Recognition System Using Machine Learning Techniques

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Abstract

Marathi language is the most widely spoken language in India, and its script is unique and complex. Handwriting recognition of the Marathi language poses a significant challenge due to the variety in writing styles and the script's complexity. Machine learning techniques can help in building Marathi handwriting recognition systems that can accurately recognize handwritten Marathi text. The Devanagari script is the source of Marathi, the official language of Maharashtra. Devanagari script is used for the Marathi language and it has 12 vowels and 36 consonants. Handwritten character recognition in any script is a challenging task for researchers. Nowadays, handwritten Marathi character identification is the hardest problem. Sharing physical documents is a laborious and time-consuming task. Because of the structure, shape, various strokes, and writing styles, handwritten Marathi characters are more difficult to read as well as understand. Marathi handwritten recognition system is very essential in various aspects as further described. Preservation of cultural heritage. The mechanism of recognition facilitates accessibility by making Marathi information more easily accessible to people who are visually impaired or have difficulty with traditional text input techniques. The paper focuses on a review of methods used for the development of handwritten character recognition systems using machine learning approaches, including Sanskrit, Hindi, Marathi, and Maithili languages. Different machine learning classifiers such as Decision Tree, Nearest Centroid, KNN, Extra Trees, and Random Forest were implemented and compared for their performance. Extra Trees and Random Forest showed better accuracy.

Keywords: Machine Learning Algorithms, Character Recognition, Devanagari Script, Handwritten Recognition Systems, CNN, RNN, ANN, Centroid Network, GAN.

1. Introduction

The Marathi language has a vast repository of historical documents, manuscripts, and literature. Handwriting recognition can significantly contribute to digitizing Marathi language content and promoting its use in digital platforms. Marathi handwriting recognition can understand handwritten messages, notes, and memos. By developing handwriting recognition, more digital content can be generated in Marathi, promoting regional language content [24]. Handwriting

recognition can open up new commercial opportunities for businesses looking to cater to Marathi-speaking audiences. It can be applied in customer service, data entry, and document processing tasks, and improving efficiency [25]. The paper explores the different techniques of machine learning algorithms in handwritten recognition systems, specifically focusing on character recognition for the Devanagari script. The researchers implement various machine

learning classifiers like Decision Tree, Nearest Centroid, KNN, Extra Trees, and Random Forest classifiers to compare their performance in recognizing characters from Sanskrit, Hindi, Marathi, and Maithili languages. The paper discusses the challenges faced in recognizing handwritten text, including variations in writing styles and the need for efficient classification and pattern recognition techniques [26].

2. Literature Review

Various machine learning algorithms have been applied in handwritten recognition systems for decades. **Sheikh Mohammad Jubaer et.al [1]**, introduces BN-DRISHTI, a method combining YOLO with Hough and Affine transformation for Bangla handwritten text segmentation. BN-DRISHTI achieved high F-scores for line and word segmentation, outperforming other datasets and systems [27]. Skew correction using Hough and Affine transform was crucial for accurate line segmentation. Comparison with previous systems showed BN-DRISHTI as a state-of-the-art for Bangla handwritten recognition. This work aims to integrate supervised character recognition for an 'End-To-End Bangla Handwritten Image Recognition system' [28]. Skew correction before line segmentation affected the overlap accuracy between ground truth and predictions, impacting automatic evaluation results. **Raphaella Heil, Malin Nauwerck[2]**, establish a baseline for handwritten stenography recognition using the LION dataset. Integration of stenographic domain knowledge and pre-training techniques significantly improves recognition results. The LION dataset consists of Lindgren's drafts and other texts, encouraging future research in handwritten stenography recognition [29]. The Melin stenographic system used in the dataset is based on phonetic symbols and abbreviations, posing a challenge for recognition. The study highlights the challenging nature of automatically transliterating handwritten stenography [30]. The high error rates on the LION dataset indicate the challenging nature of stenography recognition. **George Retsinas et.al [3]**, achieves state-of-the-art results with a simple architecture, outperforming other

methods. Proposed best practices offer effective modifications for training and performance improvement using CNN-LSTM techniques. Competitive results are obtained on IAM dataset for line-level recognition [31]. The system's baseline network performs poorly without additional modules. The system's simplicity may limit its adaptability to more complex datasets or tasks requiring advanced features. **Shilpa Mangesh Pande, Bineet Kumar Jha [4]**, focuses on the development of handwritten character recognition system for Devanagari script using a machine learning. They implemented the system including Sanskrit, Hindi, Marathi, and Maithili languages using different machine learning classifiers like Decision Tree, Nearest Centroid, KNN, Extra Trees, and Random Forest classifier [32]. To obtain the score of that algorithms and to compare performance, performed the grid search. The dataset is created with different font style and size. From all the classifiers Extra Trees and Random Forest classifiers gives better accuracy. The future work will be the hybrid approach for improvement in accuracy of the model. **Ambadas Shinde, Yogesh Dandawate [5]**, gives focus on CNN based OCR framework that perceives handwritten Marathi words and gives great quality printed Marathi text. Created custom training dataset due of the Marathi training dataset's restricted availability. 9,360 words (104 words with 90 photos each) make up the dataset, which was created with help from people between the ages of 8 and 45 [33]. Because of the system's adaptable response to various handwriting styles, it is the best option for digitizing manually written Marathi information. **Shalini Puria, Satya Prakash Singh [6]**, focus on applying the SVM model to efficiently classify Devnagari characters in the handwritten and printed text, for Hindi, Sanskrit, and Marathi documents. The system can be extended in the Recognition and classification of modified characters and half-characters, enhancing the multi-font and italic text system. Yash Gurav, Priyanka Bhagat, Rajeshri Jadhav focuses on recognizing Devanagari Characters on a self-created dataset of 29 consonants and 01

modifier [7]. They use Deep Convolutional Neural Network (DCNN). The system uses consecutive convolutional layers in the CNN architecture to extract high-level features for recognition purposes. The system focuses on offline handwritten character recognition [34]. The system does not consider capitalization of letters, which may be problematic when dealing with text that include capital letters. The system does not address with proper contextual understanding of recognized text. **Anupama Thakur et.al [8]**, proposes a new strategy for recognizing Hindi characters in Devanagari script with focus on individual consonants and vowels [35]. The system combines the k-NN technique with Neural Networks to improve recognition rate. The proposed approach focuses on individual consonants and vowels, but can explore the recognition of complex derived words in the Devanagari script. **Mimansha Agrawal et.al Agrawal [9]**, analyze the approach for recognition of handwritten Devnagari characters using deep learning techniques [36]. CNN along with other Neural Networks such as ANN and RNN has been used the five basic stages of this recognition system are segmentation, prediction, feature extraction, pre-processing, and post-processing. The author has analyzed the approach for recognition of handwritten Devanagari characters. The future system has the potential for research in Devnagari word and sentence recognition and full handwritten documents with half characters. **Harmandeep Kaur, Munish Kumar [10]**, describe a technique for recognizing offline handwritten Gurumukhi words. To identify a word, the system takes a comprehensive approach, where a word is considered as an individual item. Zoning features, diagonal features, intersection & open-end point features are considered to extract the desired characteristics from the text images [37]. The lack of a standardized dataset in the Gurumukhi script makes comparing existing and proposed techniques difficult. The problem of touching nearby letters and overlapping characters in handwritten words also poses a challenge in segmentation. **Manoj Sonkure, Roopam**

Gupta, Asmita Moghe [11], seek to determine, by taking into account several factors, including the database being utilized, sample size, training, test set ratio, class size, data normalization size, and recognition accuracy, the most accurate classification strategy for Handwritten Devnagari Script Recognition [38]. It provides a literature review on the Devanagari script and discusses the implementation of different network models such as BLSTM, CNN, and a hybrid CNN-BLSTM. The recognition accuracy of CNN is found to increase with the number of convolutional layers. The use of transfer learning for DCNN and the implementation of a hybrid model with KNN and ANN classifier for recognizing individual vowels and consonants can be further investigated to enhance the recognition performance. The system can be extended to include character recognition and text detection in scene images, expanding its applicability beyond isolated character recognition. **Sarayut Gonwirat, Olarik Surinta [12]**, concentrate on the problem of predicting the handwritten text image sequence pattern, which is challenging since many writing styles exist, there is a lack of training data, and background noise can arise in the text images [39]. They said that a combination of Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN) called CRNN, have been successful in word recognition for handwritten text [40]. Further research could focus on exploring different variations of the CRNN architecture or other deep learning models for improvement in the accuracy and performance of handwritten recognition systems. **D. Saraswathi, and Sanaa Mohamed Sherif [13]**, are involved in their system capturing, recognizing, and converting characters from various sources into machine-coded form. Convolutional neural networks (CNNs) were used in the system, which are deep learning algorithms widely used in computer vision and image classification. The system also utilized OpenCV, an open-source computer vision library, for visualizing the predicted output. Data normalization was performed to improve accuracy by balancing the inputs and

outputs of the model. Methods can be explored to increase the recognition rate, such as incorporating segmentation processes to recognize words, sentences, and paragraphs [41]. The model can be extended to recognize different languages, expanding its applicability. **Evans Ehiorobo, Rukayat Koleoso, and Charles Uwadia [14]**, said that offline handwriting recognition is useful for digitizing existing handwritten documents, such as forms, postal addresses, and free-form random documents. The typical process of building a software application for offline handwriting recognition involves gathering and labeling a collection of images for training a neural network, and then building and training the neural network using the acquired image data. The author suggests training a Generative Adversarial Network (GAN) to automatically produce images of handwritten text as a different method of gathering training data for handwritten text recognizers [42]. The GAN is trained using the Extended MNIST dataset. Further research can focus on addressing the challenges in training GANs, such as properly minimizing loss functions, avoiding similar outputs for different input data, and ensuring effective feedback between the generative and discriminative networks. **Rohini Khalkar et.al [15]**, proposes a system of Deep Learning for Handwritten Text Recognition aims to develop a deep learning-based application for HTR using Convolutional Neural Networks (CONVNETs) to achieve higher accuracy. The training set consists of 7850 images, and the validation set has 876 images. Preprocessing techniques like inversion, grayscale inversion, and thinning are applied to the images, followed by segmentation using image processing techniques. Making the model more versatile and extending its use to additional languages like Hindi, Marathi, and other regional languages is one possible area for advancement. Improving the model's accuracy and efficiency is another area of emphasis. **Yugandhar Manchala et. al [16]**, discusses the field of character recognition in computer vision and the challenges faced by machines in identifying handwritten text. The process of text

recognition involves image processing, feature extraction, and classification. The system is trained to identify similarities and differences among various handwritten samples [43]. The aim of the system is to design a system that efficiently recognizes the format and character of handwritten text using a neural network. The authors also mention the availability of a dataset containing isolated and labeled sentences, which can be used for training, testing, and validation. Future plans include extending the study to larger datasets and considering different embedding models. **Jamshed Memon et.al [17]**, describes OCR system that converts text into machine coded format, making it easier to retrieve required information and preserve historic data, law documents and educational persistence. Handwritten OCR is a subfield of OCR that has received increasing attention and is categorized into offline and online systems. The availability of datasets for languages other than widely spoken languages is limited, which hinders the development of OCR systems for these languages. The lack of research on OCR systems for languages beyond the commonly studied languages limits the applicability of handwritten OCR in diverse linguistic contexts. **M. Rajalakshmi, P. Saranya, et.al [18]**, proposes Pattern Recognition of Handwritten Documents using Convolutional Neural Networks. The major challenge of handwriting recognition systems is to classify handwritten words, which can be in the form of cursive, tilted, or block writing. This challenge is addressed by a functional model that converts handwritten format to digital format, serving as an interface between humans and machines. Pattern recognition and classification are the most challenging aspects of this system. Characters are extracted from word images and classified independently to reconstruct the word. This involves analyzing the features extracted from the characters and comparing them to a library of image models. Recognizing unconstrained handwriting like cursive, block, and tilt causes significant variation in writing styles, making it difficult for the system to accurately identify characters. The system may face limitations in

accurately recognizing and identifying characters due to these challenges. **I Joe Louis Paul et. al [19]**, design a handwritten character recognition system using mobile camera images, which can efficiently recognize any handwritten character. The authors aim to reduce human work by converting handwritten text into a text document, contributing to a paperless environment. In comparison to previous neural networks, the system uses a Long Short-Term Memory (LSTM) neural network for more efficiency and faster execution times. The characters are predicted by the character recognition system. The system uses mobile camera images, which are more prone to noise compared to OCR-scanned images, leading to potential challenges in accurate character recognition. The training period for the Long Short-Term Memory (LSTM) neural network used in the system is high and requires intense processing power. The system focuses on offline character recognition, which means it may not be suitable for scenarios where Internet connectivity is required. **Hao Zeng [20]**, describes handwriting has been conventional means of communication and recording in daily life since early time. Handwriting recognition is a vital application in daily activities and research of especially handwritten digit recognition is vital. Author focuses on using simpler neural network instead of complicated ones that require high quality of computer configuration to recognize handwriting digits with relatively promising accuracy. To do this a neural network to recognize handwriting in MNIST dataset using Softmax Regression algorithm with a high accuracy is built. **S. K. Nivetha et.al [21]**, mentioned that the handwritten text recognition is crucial for practical uses such as digitizing handwritten data, identifying license plates, processing bank cheques, recognizing postal codes, and verifying signatures. Deep learning is a subfield of artificial intelligence that helps recognize handwritten characters and numbers by learning unsupervisedly from unstructured or unlabeled data. The proposed scheme in this paper uses the Histogram of Gradients and

Artificial Neural Network for recognizing and digitizing handwritten text. The system undergoes preprocessing, training, and prediction to achieve accurate results. Converting handwritten text to machine-readable text is challenging since humans have a broad variety of handwriting styles and handwritten material is typically of lower quality than printed text. The accuracy of handwritten recognition systems depends on the dataset, and it may not provide the best accuracy for cursive letters. **Geeta S Hukkeri et. al [22]**, focus on machine learning in OCR technology, particularly the evaluation of various OCR techniques for lecture video slide-to-text conversion. OCR has applications in various industries such as education, banking, government, and medical sectors. Deep learning techniques, such as convolutional neural networks (CNNs), are used in OCR to improve accuracy in text recognition. Some studies have focused on translating text from images into speech, using OCR engines like Tesseract and gTTS for word recognition and audio generation. Text extraction from photos with a watermark background and gray-colored text can be difficult for OCR systems, which greatly reduces text identification performance. The accuracy and durability of OCR services can vary, and further research is needed to assess additional OCR services using substantial datasets and statistically significant analyses. **R. Parthiban, R. Ezhilarasi, D. Saravanan [23]**, focus on English character recognition using the RNN network. One innovation that is actually needed now is manual text recognition. The principal issue emerges because of the way used to do it for manually writing content. Since the handwriting samples were gathered from many individuals, it is highly improbable that they will exhibit a comparable pattern. Need to investigate the matter more thoroughly to find better solutions by organizing a new engineering for English content if they are to enhance the result in Table 1.

Table 1 Summary of Different Techniques Used in Handwritten Recognition

Technology	Reference	Advantages	Limitations
YOLO with Hough and Affine transformation	[1]	High F-scores for line and word segmentation	1. Overlap Accuracy 2. Challenges in Alignment
CNN	[2]	Stenography-specific target sequence encodings.	1. high error rate 2. complex symbol patterns
CNN, LSTM	[3]	Better results. Efficiency in simple design	More complex dataset required
Decision Tree, Nearest Centroid, KNN, Extra Trees and Random Forest classifiers.	[4]	High accuracy and handling of complex datasets	Need for a hybrid approach
CNN based OCR	[5]	Precision in word perception and accurate transcription	1. Scarcity in Marathi training dataset 2. Risk of overfitting
SVM	[6]	Multilingual scope 2. User friendly interface	1. Need extension to recognize modified characters 2. Difficulty in handling half characters
DCNN	[7]	Hierarchical feature extraction with local and global context	1. Absence of Capitalization consideration 2. Limitation in handling proper nouns.
KNN with Neural Network	[8]	Individual consonants and vowels focus with enhanced discrimination	1. Need to focus on complex derived words 2. Need to understand morphological structure
CNN, ANN, RNN	[9]	Methodological analysis with iterative refinement	1. Will expand into word recognition 2. Challenges in word recognition.
Holistic approach	[10]	Describes various techniques in Gurumukhi script	1. Lack of standardized Dataset 2. Less accuracy in Variety in writing styles
BLSTM, CNN, and hybrid CNN-BLSTM	[11]	Provides a literature review on Devanagari script	1. Need to extend recognition in scene images 2. Need to integrate text detection and recognition
Combination of CNN and RNN i.e CRNN	[12]	1. Sequential nature of handwritten recognition using sequence to sequence model	1. Need to explore CRNN variations 2. Need to focus on enhancement in feature extraction

CNN	[13]	Utilized OpenCV for visualizing the predicted output	<ol style="list-style-type: none"> 1. Need a multilingual recognition framework 2. Require more focus on language identification
GAN, MNIST Dataset	[14]	Useful in digitization of handwritten documents, forms digitization	<ol style="list-style-type: none"> 1. Challenges in Training GANs 2. Need to minimize loss functions
CONVNET	[15]	Achieve higher accuracy	Need to enhance the efficiency of the model
CNN, RNN, CTC, Tensorflow	[16]	Identify similarities, differences in various handwritten samples	<ol style="list-style-type: none"> 1. Will expand to larger datasets 2. Need to select diverse dataset
OCR	[17]	Converts text to machine-coded format	Applicability is limited in diverse linguistic contexts
CNN	[18]	Characters independently extracted from word images to reconstruct the word	<ol style="list-style-type: none"> 1. Require recognition of unconstrained handwriting 2. diverse writing styles difficult to recognize
LSTM	[19]	Provides a prediction of the characters.	<ol style="list-style-type: none"> 1. Increased noise levels because of mobile camera images. 2. Reduced image quality
Softmax Regression	[20]	Uses simpler neural networks than complicated	Only digits are recognized
HoG, ANN	[21]	Translates handwritten information into digital format	Provide less accuracy for cursive letters
OCR, Tesseract, gTTs	[22]	Focuses on translating text from images into speech	<ol style="list-style-type: none"> 1. Need to assess additional OCR services with substantial datasets
RNN	[23]	Focuses on English character recognition	<ol style="list-style-type: none"> 1. Complexity in development 2. Lack of established standards 3. Compatibility issues

Conclusion

In the research on character recognition in handwritten text using machine learning algorithms and deep learning techniques, various challenges have been identified across different languages and writing styles. These challenges such as noise in mobile camera images, variations in handwriting styles, limited availability of standardized datasets, and the need for improved accuracy in recognition. To address these challenges there is a need for the development of new systems and methodologies. The system should incorporate innovative approaches like

combining deep learning techniques with domain-specific knowledge, exploring hybrid architectures, and advancements in computer vision and natural language processing.

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