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# Handwritten Character Recognition from Ancient Inscriptions: A Comprehensive Literature Review

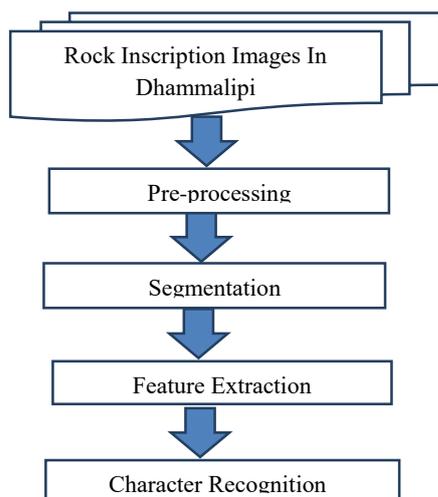
<sup>1</sup>Vasundhara R. Fegade, <sup>2</sup>Dr. G.R.Wani<sup>1,2</sup>Department of Computer Science, Bhusawal Arts, Science, and P.O. Nahata Commerce College, Bhusawal.

Peer Review Information	Abstract
<p><i>Submission: 05 Dec 2025</i></p> <p><i>Revision: 25 Dec 2025</i></p> <p><i>Acceptance: 10 Jan 2026</i></p> <p><b>Keywords</b></p> <p><i>Handwritten Character Recognition (HCR); DhammaLipi; Brahmi Script.</i></p>	<p>This paper provides a comprehensive review of the literature on handwritten character recognition, especially for Dhammalipi(Brahmi script) written on ancient inscriptions. There is a necessity to modernize old images and documents. The ancient times of stone inscriptions reveal the culture and assist in preserving and highlighting our nation's heritage. Handwritten Character Recognition (HCR) involves identifying and translating handwritten characters into digital text.HCR is a topic with extensive research, but there is still an opportunity for improvement in terms of accuracy and efficiency. Digitizing handwritten text is extremely important in today's world since it makes information available at any time and from any location. Digitized text is safer and environmentally friendlier than manual text, making it suitable for commercial use. This document examines multiple approaches and methods for obtaining, organizing, and deriving information from historical inscriptions in diverse languages. This literature will help many researchers to get the current and past position of work done on handwritten character recognition.</p>

### Introduction

Next to the Indus script, the second Indian writing system to emerge was Dhamma Lipi (Pali language script). It is also known as the Brahmi script. It serves as the foundation for all modern Indian scripts, as well as hundreds more scripts throughout South and East Asia. Dhammalipi originated in the third century BCE. Ashoka, the Indian ruler, distributed the Ashokan Inscriptions throughout North and Central India. Our main research work is to develop a character recognition system that recognizes the Dhammalipi character written on the rock inscription by Emperor Ashoka in the third century. Before that, we studied all the research work that has been done in the past on various scripts.

The following figure depicts common steps in the character recognition process. First, we use a camera to obtain an image of the rock inscription. Since the rock inscriptions date back to the third century, atmospheric effects have lowered their quality. To increase the quality, we need to run a series of noise-removing filters. For this goal, we developed a GUI application. We carried out character segmentation after improving the image quality. The separated character is stored in a new image file. In the feature extraction process, we extracted structural and geometrical features from the character and stored them in a .csv file for the future character recognition stage. Before we begin character recognition, we must first learn the various methods of character recognition used by previous researchers.



### Literature review

This section will address research contributions and strategies used to improve systems. Some of the significant works include:

The research "AI-inspired Preservation and Recognition of the Brahmi Script" by Jain et al. (2025) introduces a state-of-the-art deep learning solution to recognize ancient Brahmi alphabets. The authors utilized a combination of Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN), specifically Long Short-Term Memory (LSTM) models, for better recognition performance. Besides, Natural Language Processing (NLP) tools were utilized to correct context-related errors and thus improve recognition of noisy or faded text[1].

Jain et al., 2025 - AI-Inspired Algorithm for Automated Identification of the World's oldest Script "Brahmi". This latest research presents an exhaustive literature survey of CNN-based approaches applied to Brahmi script images so far. It presents an integrated model where in hyper hyperparameters of a CNN are optimized using Genetic Algorithms (GA), achieving a higher recognition accuracy of 97%[2].

Jain et al. (Mar 2025)-Brahmi Script Recognition Using Optimized Convolutional Neural Network with Random Forest Classifier: The paper at hand suggests a hybrid system: Brahmi script image features are learned by a CNN-based autoencoder; the features are later classified employing a Random Forest model. Hyperparameters of both the parts are optimized using a Genetic Algorithm, achieving a peak accuracy of 97% and outperforming CNN-only (92%) and CNN + Random Forest without GA (94%) models. This research is novel in that it integrates feature extraction, ensemble classification, and GA-based optimization for Brahmi OCR[3].

J. A., S. B., T. M. Thiyagu, et al. (2025) Deep Learning Handwritten Text Recognition from Ancient Manuscripts with Hybrid CNN Transformer and PARSeq Model. The work in this study remedies the drawbacks of the conventional CNN- or RNN-based Handwritten Text Recognition (HTR) for ancient manuscripts, which are prone to failure due to degradations, noisy annotation, and variations in scripts. The Hybrid CNN-Transformer model with the PARSeq framework (Permutation-augmented recurrent sequence model) is suggested by the authors. Their model is 98.5% accurate on clean manuscripts and 92% on deteriorated texts, which is better than previous approaches[4].

Malashin et al. (2025) tackle the task of handwritten character recognition in medieval Novgorod birch-bark manuscripts with an object detection strategy. Contrary to classical OCR techniques, which are challenged by degraded and irregular scripts, the authors utilize YOLO-based models backed by a synthetic dataset of 2,500 glyphs generated through autoencoder-based denoising and augmentation. Comparison with SSD and Faster R-CNN, YOLOv10 performed the best with an mAP of 0.89 on synthetic images and 0.79 on real manuscripts. The contributions of the research are an error taxonomy and recommendations on how to incorporate language models and multimodal imaging for further improvements in accuracy. This research proves the potential for object detection frameworks for scalable and accurate transcription in paleography and digital humanities[5].

The research "A Hybrid CNN-RNN Model for Automated Recognition of Kannada Characters in Ancient Inscriptions" by Rajithkumar et al. (2024) proposes a new hybrid model that combines the power of Convolutional Neural Networks (CNNs) for spatial feature learning and Recurrent Neural Networks (RNNs) for sequence prediction. Tailor-made for stone inscriptions with their erosion, rough surfaces, and stylistic heterogeneity, the model was trained on a painstakingly compiled dataset of images from Karnataka's monuments. It attained a whopping recognition accuracy of 95%[6].

Murugan & Visalakshi et al. (2024)-This research proposes the DR-LIFT (Detect, Recognize, and Labelling Interpreter Framework of Text), particularly for third-century Tamil inscriptions, including Brahmi and Vattezhuthu styles. To address erosion complications, varying fonts, and surface deterioration, the process comprises:

Preprocessing with DnCNN denoising, Alphabet

detection through DBNet, FCENet, and TextSnake. Word recognition through ABINet, MASTER, and SAR; Efficiency gained with high precision: 99% accuracy in character recognition and 98.8% recognition rate[7].

Gunasekara et al. (2024), Deep Learning-Based Mobile Application for Early Brahmi Script Deciphering in Sri Lanka This paper proposes "GranoScan," a mobile app to identify and transliterate early Brahmi script inscriptions incised on stone in Sri Lanka. The system utilizes transfer learning-based deep learning along with a channel attention module to improve character-wise feature extraction, with a human-friendly interface for real-time in-field applications. GranoScan provides a critical niche, as there were no previous mobile-based solutions in place for Brahmi script reading in the region[8].

An OCR-based system for Brahmi script recognition that makes use of the Tesseract OCR engine is presented by Kimothi et al. (2024). Because Tesseract can handle multi-language recognition, various font styles, and handwritten inputs, it has become one of the most popular OCR systems. The authors bridge the gap between ancient writings and contemporary script usage by incorporating Tesseract into an Android application that not only identifies Brahmi characters but also translates them into Devanagari. The method trained on a sizable dataset of 69,000 images that were carefully selected from a variety of sources. The study places itself within the larger context of digital heritage preservation, The work exhibits both practical usability and scalability by integrating Tesseract OCR into a mobile application, enabling the general public and researchers to interact with Brahmi inscriptions without the need for specialist computing knowledge[9].

Jayanthi et al.(2024) focus on the digitization and transliteration of Brahmi inscriptions, which are at risk of deterioration. The study applies image preprocessing and segmentation (OpenCV, binary conversion, bounding box methods) to extract characters from stone engravings, achieving 88% segmentation accuracy. Recognized Brahmi characters are then transliterated into Tamil using Tesseract OCR, with 85% accuracy. This work highlights the importance of digital preservation and accessibility of ancient scripts, addressing unique challenges such as low contrast between text and background[10].

Swaroop et al. (2024) introduce a handwritten Brahmi script recognition using deep learning techniques by comparing pre-trained models like Vision Transformer (ViT), MobileNetV2, VGG16, ResNet50, DenseNet, and EfficientNet

with a standard CNN. The paper points out the shortcomings of standard CNNs in dealing with the intricacies of handwritten Brahmi characters and demonstrates that MobileNetV2 provides the best accuracy among tested models. The project shows the efficacy of transfer learning in recognition of ancient scripts and highlights its potential for cultural heritage preservation via digital transcription[11].

Agrawal et al. (2024) suggest an OCR system that uses Convolutional Neural Networks (CNNs) with

transfer learning for Ashokan Brahmi inscriptions. Preprocessing, noise reduction, segmentation, and data augmentation are all included in the comparison of LeNet, VGG16, and MobileNet. MobileNet outperformed the other models in identifying old scripts, achieving the greatest accuracy of 95.94%.

The study highlights how deep learning based OCR can preserve and digitize historical inscriptions, opening up old texts for epigraphic research[12].

Poornimathi et al. (2024) introduce a new preprocessing method for Tamil Brahmi inscriptions to enable automated recognition and preservation. The research accentuates the need to improve image sharpness prior to applying deep learning algorithms. Based on CNNs and RNNs for recognizing letter patterns, the authors evaluated various methods of preprocessing such as image blurring, binarization, and edge detection. The Median filter with Canny edge detection produces the highest accuracy of inscription images proven by experiment. It is a critical indication of how important preprocessing can be in enhancing feature recognition and extraction performance, which renders the method extremely valuable for linguistic preservation, cultural heritage research, and digital archiving[13].

An enhanced method for identifying Tamil Brahmi characters and notations is presented by Narsh Kumar and Geetha (2024), utilizing the Extreme Learning Machine with Improved Spider Monkey Optimization (ELM-ISMO) algorithm. The approach uses ELM-ISMO for classification, K-Means clustering for segmentation, and histogram equalization for preprocessing. The ELM-ISMO model is a reliable solution for ancient script recognition,

as demonstrated by experimental comparisons with ELM, CNN, and ANN. It achieves superior accuracy, sensitivity, specificity, and F1-score.

This demonstrates the possibility of hybrid optimization-driven machine learning models for digital inscription archiving and cultural heritage protection[14].

A. S. Nagane et al.(2024) state that (OCR) research has been extensive for contemporary scripts, but it has taken a limited interest in older Indian scripts such as Brahmi, which are of historical importance. Feature extraction techniques, Histogram of Oriented Gradients (HOG), have been extensively used in the detection of shape and edge information, while Support Vector Machines (SVMs) are still a robust classifier for multi-class recognition problems. With the combination of HOG features and an SVM-ECOC model, the authors obtain 92.09% accuracy[15].

The research by Kaur and Sagar(2024) adds a new multistage pipeline that combines SIFT and template matching. By taking the best of both SIFT for scale and rotation invariance and template matching for accurate structural verification, the system proposed in this work effectively screens out unwanted images while maintaining the target Brahmi script information. This blend of the two provides a scalable remedy to the long-standing issue of automated ancient script image retrieval and recognition[16].

P. Rajnish et al. (2023) found in their study that stone, metal, or copper plate inscriptions are essential histories of South Asia. However, throughout the course of several centuries, these inscriptions have significantly degraded and are now difficult to study. Many manuscripts and documents are also repositories of precious cultural information facing loss. To work around this, studies underscore the need to digitize inscriptions like Brahmi, not just enhancing their legibility and quality but also long-term preservation and access for researchers all over the globe[17].

Over the centuries, the historical inscriptions have deteriorated considerably, making them difficult to analyze. The work of P. P. and M. H. R. (2023) resolves this problem by creating a set of Brahmi characters and using both conventional machine learning and deep learning techniques. For conventional models, Hu-Zernike moments were employed, whereas transfer learning using CNN architectures such as AlexNet, GoogleNet, and Inception-V3 was more productive, with the best performance recorded by Inception-V3[18]. Identification of ancient inscriptions is difficult because the script gets degraded over time and the orientation may vary. To overcome this, Durga Devi et al.(2023) suggested an Image-based Character Pattern Identification (ICPI) system for ancient Tamil stone inscription character recognition. The procedure makes use of a Modified SURF Method with Bag of Grapheme (MSURF-BoG) approach to match patterns and extract unsupervised key point

features. Employing 11th-century Tamil inscriptions of 24 characters as samples, the system registered a highest recognition accuracy rate of 96% and proved the superiority of feature-based pattern matching for ancient script recognition [19].

The process of recognizing ancient inscriptions often faces challenges due to the slow and inconsistent nature of manual reading, as characters have evolved into different forms over hundreds of years. To address this issue, Ruwanmini et al.(2023) proposed an OCR-based system designed to identify ancient Sinhala inscription characters from the 10th to 12th centuries A.D. The study compared template matching, artificial neural networks (ANN), and convolutional neural networks (CNN), with CNN emerging as the most effective method. Furthermore, a GIS module was added to track inscription locations, which enhanced both character recognition and the preservation of cultural heritage[20].

Sriram(2023) presents a virtual reality-based system for the analysis of Tamilian non-Hellenic Brahmi inscriptions from the Ashokan era. The approach involves preprocessing, segmentation, and SIFT-based feature extraction, followed by the use of ensemble learning classifiers to translate characters into their contemporary Tamil forms. Furthermore, the incorporation of 3D visualization and VR/AR technologies enhances both recognition accuracy and interactive cultural engagement, illustrating how advanced digital platforms can aid in the preservation and interpretation of ancient scripts[21].

The research paper "Brahmi Word Recognition by Supervised Techniques" by Gautam et al.(2022) examines the problem of Brahmi word recognition, as it is more challenging than single-character recognition, as there are compound characters and complex structures involved. The research makes the field progress by fusing structural (zonal density) and statistical (HOG) features and using Support Vector Machines (SVM) for classification. With a big dataset of 6,475 training and 536 test samples in 170 word classes, the method proposed here has a high recognition rate of 95.17%, which is higher than previous models[22]

Research by Devi and Sathiyapriya (2021) emphasizes the significance of Tamil-Brahmi inscriptions in realizing ancient Indian civilization and cultural heritage. Deciphering these inscriptions traditionally used manual interpretation, which takes time and is prone to errors. Previous work in script recognition involved using classical image processing and

OCR-based methods, but they did not perform well with degraded inscriptions and non-availability of standardised datasets. Recent developments in deep learning, specifically convolutional neural networks (CNNs), have been used successfully on handwritten and ancient writings because they can learn intricate patterns. This research follows the trend by using deep learning and image processing to automatically translate Tamil-Brahmi inscriptions into readable modern Tamil[23].

Brindha and Bhuvanewari(2021) emphasizes the difficulties of identifying ancient Tamil-Brahmi characters, which are far different from contemporary Tamil script. It presents a new feature extraction scheme along with chi-square testing to determine zoning feature independence and dependence. These extracted features are classified using neural networks via MATLAB's NNTool. With an accuracy of 91.3%, the research proves the viability of the integration of statistical feature extraction and neural networks[24].

The article "Recognition of Brahmi Words by Using Deep Convolutional Neural Network" by Gautam et al. tackles the intricacy of Brahmi

word recognition, especially in coping with compound characters and diverse word patterns. Based on the recent developments in deep learning, this research postulates a Deep Convolutional Neural Network (DCNN) using dropout, obviating the necessity for hand-crafted feature engineering. Compared against a standard Brahmi test set, the model has a recognition accuracy of 92.47%, which is among the best on word-level Brahmi recognition[25]. The article "Tamil-Brahmi Script Character Recognition System Using Deep Learning Technique" by Subadivya et al. introduces a CNN-based architecture for digitizing and translating ancient Tamil-Brahmi characters into contemporary Tamil script. Previous research in Brahmi recognition was mostly based on manual interpretation, statistical feature extraction, or shallow neural networks, which were short on scalability and accuracy. This project is based on progress made in deep learning through the use of Convolutional Neural Networks to extract character features automatically without relying on manual methods. With a recorded accuracy of 94.6%[26].

### Literature Summary:

**Table 1:** Literature Summary

Sr. No	Paper Title	Methodology	Accuracy
1	AI-Inspired Preservation and Recognition of the Brahmi Script	A combination of Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN),	~97 %
2	AI-Inspired Algorithm for the Automated Recognition of the World's Oldest Script "Brahmi"	It presents an integrated model where the hyperparameters of a CNN are optimized using Genetic Algorithms (GA),	97%
3	Brahmi Script Recognition Using Optimized Convolutional Neural Network with Random Forest Classifier	Optimized Convolutional Neural Network with Random Forest Classifier	97%
4	Deep Learning Handwritten Text Recognition from Ancient Manuscripts using Hybrid CNN Transformer with PARSeq Model	New hybrid CNN-Transformer model incorporating the PARSeq framework	98.5% -clean manuscripts 92% - degraded documents
5	Recognition of Handwritten Characters in Birch-Bark Manuscripts via Object Detection	Utilize YOLO-based models backed by a synthetic dataset of 2,500 glyphs generated through autoencoder-based denoising and augmentation.	mAP of 0.89 on synthetic images and 0.79 on real manuscripts
6	A Hybrid CNN-RNN Model for Automated Recognition of Kannada Characters in Ancient Inscriptions.	A new hybrid model that combines the power of Convolutional Neural Networks (CNNs) for spatial feature learning and Recurrent Neural Networks (RNNs) for sequence prediction.	95%

7	Ancient Tamil inscription recognition using detect, recognize and labelling, interpreter framework of text method	Preprocessing with DnCNN denoising, Alphabet detection through DBNet, FCENet, and TextSnake. Word recognition through ABINet, MASTER, and SAR;	99% accuracy for character recognition and 98.8% for word recognition
8	Deep Learning-Powered Mobile App for Early Brahmi Script Decipherment in Sri Lanka	Deep Learning-Based Mobile Application "GranoScan," for Early Brahmi Script Deciphering in Sri Lanka.	-
9	Optical Character Recognition of Bhrami Script using Tesseract	Make an OCR system using Tesseract. It developed an Android application that not only identifies Brahmi characters but also translates them into Devanagari of a dataset of 69,000 images	~92.09 %
10	Digitization and Automated Transliteration of Ancient Inscription Scripts	Tesseract OCR,	85%
11	Hand-Written Bramhi Script Recognition using Deep Learning	Using deep learning techniques by comparing pre-trained models like Vision Transformer (ViT), MobileNetV2, VGG16, ResNet50, DenseNet, and EfficientNet with a standard CNN.	MobileNetV2 provides the best accuracy.
12	Optical Character Recognition using Convolutional Neural Networks for Ashokan Brahmi Inscriptions	Convolutional Neural Networks (CNNs)	95.94%
13	Preserving Tamil Brahmi Letters on Ancient Inscriptions: A Novel Preprocessing Technique for Diverse Applications	preprocessing techniques (median filter + Canny edge detection)	95.61 %
14	Recognition of Ancient Tamil Brahmi Symbols and Notations Using ELM-ISMO Algorithm	Extreme Learning Machine with Improved Spider Monkey Optimization (ELM-ISMO) algorithm.	Superior to ELM, CNN, and ANN
15	Classification of Brahmi script characters using HOG features and a multiclass error-correcting output codes (ECOC) model containing SVM binary learners	Combination of HOG features and an SVM-ECOC model	92.09%
16	Efficient Scalable Template-Matching Technique for Ancient Brahmi Script Image	Developed a new multistage pipeline that combines SIFT and template matching.	F1 score of ~61%
17	Improving the Quality and Readability of Ancient Brahmi Stone Inscriptions	CNN	-
18	Intelligent Recognition of Ancient Brahmi Characters using Transfer Learning	CNN architectures such as AlexNet, GoogleNet, and Inception-V3 & DNN	Inception-V3 is best
19	Pattern Matching Model for Recognition of Stone Inscription Characters	Use of a Modified SURF Method with Bag of Grapheme (MSURF-BoG) approach to match patterns and extract unsupervised key point features.	96%
20	Sinhala Inscription Character Recognition Model Using Deep Learning Technologies" by Shashika Ruwanmini, Kapila Dias, Clera Niluckshini, and Terrance Nandasara	Compared template matching, ANN and CNN. A GIS module was added to track inscription locations	CNN-based OCR has having accuracy 95%

21	Virtual Reality-Based Enhanced Brahmi Inscription Script Recognition	VR/AR technologies	-
22	Classification of Brahmi script characters using HOG features and a multiclass error-correcting output codes (ECOC) model containing SVM binary learners	Fusing structural (zonal density) and statistical (HOG) features and using Support Vector Machines (SVM) for classification.	95.17%
23	Brahmi Script Recognition System using Deep Learning Techniques	Convolutional Neural Networks (CNNs), Deep Learning	71.1%
24	Repossession and Recognition System: Transliteration of Antique Tamil Brahmi Typescript	Neural networks via MATLAB's NNTool.	91.3%
25	Recognition of Brahmi Words by Using a Deep Convolutional Neural Network	Deep Convolutional Neural Network (DCNN)	92.47%
26	Tamil-Brahmi Script Character Recognition System Using Deep Learning Technique	CNN-based architecture for digitizing and translating ancient Tamil-Brahmi characters	94.6%

### Conclusion

A thorough analysis of ancient character recognition methods is provided with an emphasis on ancient inscriptions (Brahmi Script). The survey examined recognition methods and accuracy for several models, including CNN-based OCR, ResNet, SVM, ANN, RNN, Tesseract, YOLO-based models, ABINet, MASTER, SAR, a Deep Learning-Based Mobile Application, a fusion model, and a hybrid model. As the inscriptions were written in the third century, their degraded quality affects the performance of the classifier. The report highlights potential research directions for enhancing the digitization of ancient scripts.

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