KJMS 2025 VOL 7 (2): 116-124

KDU Journal of Multidisciplinary Studies (KJMS)
Volume 7. Issue 2 Nov 2025
DOI: https://doi.org/10.4038/kjms.v7i2.210

AUTOMATED DETECTION AND RECOGNITION OF SINHALESE INSCRIPTIONS USING YOLOV5

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ABSTRACT

This study proposes to recognize words in Sinhalese inscriptions using computational techniques as inscriptions form a foundational element of Sri Lanka's historical record and cultural heritage. Computational Archaeology plays a vital role in fields of Archaeology, Linguistics, and Anthropology. There is a significant advancement in using computational techniques to recognize text on inscriptions since manual interpretation and transcription are highly effort intensive, resource demanding and prone to inaccuracies. The model trained and evaluated on a curated dataset of 300 tokenized Sinhalese inscription images. The performance of You Only Look Once (YOLO); a deep learning model, was analyzed based on standard evaluation metrics—accuracy, precision, recall, and F1 score. Results indicate promising average accuracy of 90% and demonstrates YOLOv5's superiority in handling the unique challenges of ancient Sinhalese epigraphy such as irregular layouts, paleographic variations, and surface degradation compared to Optical Character Recognition systems. This research not only seeks to preserve and enhance access to Sri Lanka's rich cultural heritage but also provides a wider scope for linguistic and scholarly inquiry by facilitating more efficient analysis of ancient texts through automated recognition of Sinhalese inscriptions.

KEYWORDS: *words, deep learning, Sinhalese inscriptions, computational archaeology, YOLO*

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1. INTRODUCTION

Inscriptions are records created by our ancestors in ancient times, carved onto stone surfaces. Numerous unearthed Sri Lankan inscriptions shed light on the nation's historical, cultural, and linguistic evolution. As noted in scholarly sources, approximately 4,000 stone inscriptions have been discovered, with approximately 1,500 of them documented (Bandara and Warnajith, 2012). The study of inscriptions is called Epigraphy. Inscriptions belong to different categorizations based on eras (Heenkenda and Fernando, 2023). Steps have been taken by the Central Cultural Fund, the Department of Archaeology, and other pertinent institutions in Sri Lanka to conserve and protect inscriptions.

Currently, the content of each inscription is translated into contemporary Sinhala/English languages manually by archaeology experts who have specialized knowledge to understand the ancient scripts. However, the process of manually deciphering these texts is time-consuming, subject to human error, and often hindered by the weathering and degradation of the material over time (Karunaratne et al., 2017). Future archaeological studies are impeded due to resource demanding processes that weigh heavily on human expertise. Moreover, tourists cannot understand text on inscriptions, which directly impacts tourism. Thus, Computational Archaeology plays a major role in digitizing them.

There have been few studies conducted related to this research. Two major studies have focussed on recognizing Brahmi and Sinhalese inscriptions in the Sri Lankan context, both utilizing Optical Character Recognition (OCR) techniques. One research group developed a computational framework to accurately identify characters from early Brahmi scripts found in Sri Lankan inscriptions (Heenkenda and Fernando, 2020). The study was conducted in four main steps. Initially, photographic data was created from Brahmi scripts. Brahmi characters were identified using this data, and the identification findings were used to establish a database. The photos were scanned using an optical image scanner that has a resolution of 300 pixels per inch. MATLAB and Adobe Photoshop CS3 were utilized for further processing and primary image processing, respectively. The Majority algorithm was suggested as a way to determine the best shape for the Brahmi characters. The system successfully presents the accurate alphabet fonts of early Brahmi scripts found in Sri Lankan inscriptions. The second group developed a computerized system to detect inscription characters and location of the inscription sites. The system consists of two databases: one supports OCR which contains images and Sinhala interpretations of inscriptions, while the other stores geological information about inscription sites. The system is composed of two main modules: OCR and Geological Information System (GIS). In the preprocessing phase, binarization, boundary detection, segmentation, and thinning were performed. After the binarization phase, Ostu's method was applied. Next, feature extraction and classification carried out, with the K-means algorithm used for clustering.

Two major studies utilized Optical Character Recognition (OCR) techniques to recognize Sri Lankan Brahmi and Sinhalese inscriptions. One research group developed a computational framework to accurately identify characters from early Brahmi scripts found in Sri Lankan inscriptions. The research was carried out in four distinct phases. Initially, photographic data was created from Brahmi scripts. Brahmi characters were identified using this data, and the identification findings were used to establish a database. The photos were then scanned using an electro-optical image scanning device that could capture at 300 pixels per inch. MATLAB and Adobe Photoshop CS3 were utilized for further processing and primary image processing, respectively. The majority algorithm was suggested to determine the best shape for the Brahmi characters. The system successfully rendered authentic typographic forms of ancient Brahmi scripts found in Sri Lankan inscriptions. The other research group developed a digital framework for character recognition and geographical detection of inscription sites. The system consisted of two databases: one supported OCR which contains images and Sinhala interpretations of inscriptions, while the other stored geological information about inscription sites (Heenkenda and Fernando, 2020). The system was composed of two main components: Geological Information System

(GIS) and OCR. The preprocessing phase consisted of binarization, boundary detection, segmentation, and thinning, followed by Ostu's method. Feature extraction and classification were then fulfilled using K-means algorithm for clustering.

Hussein et al. (2023) presented a new approach to translate the cuneiform writing by employing artificial neural network technique. Effectively, a Multi Layer Perceptron (MLP) neural network has been adapted for translating the Sumerian cuneiform symbol images to their corresponding English letters.

Surasinghe and Thanikasalam (2024), developed an automated system for predicting the period of Sinhala epigraphical scripts using ensemble CNNs and attention modules. A dataset of 7,012 letter images was created from 175 estampage images, covering five evolutionary periods; Early Brahmi, Later Brahmi, Transitional Brahmi, Medieval Sinhala and Modern Sinhala. Estampage images are converted to grayscale, denoised using Non-Local Means, smoothed with Gaussian blur, and binarized. Letters are segmented using contour detection and resized to 64x64 pixels. Three pre-trained CNNs; VGG16, Xception, and ConvNeXtBase are fine-tuned with channel-spatial attention modules to enhance classification.

The detection and recognition of text in historical artifacts have been enhanced by computer vision and machine learning. With the capacity to attain high accuracies in a variety of classification and detection issues, deep learning techniques have demonstrated impressive performance in automating tasks (Rustam et al., 2021). The YOLO object detection algorithm has garnered considerable attention for its precision and efficiency in image based object identification, making it a strong candidate for text detection in challenging environments.

The detection and deciphering of Sinhalese and Pali inscriptions into the English language present a complex challenge due to the environmental concerns. Existing OCR systems are not optimized for recognizing eroded or damaged ancient scripts, limiting their applicability. Sinhalese inscriptions exhibit significant script variations and linguistic evolution over time, which are not well documented or standardized for computational analysis.

A quantitative analysis was carried out with the support of archaeological experts to identify mostly occurring words on Sinhalese inscriptions based on collected images. "ශ්‍රී (sri)", "රජ (raja)", "ගල (gala)", and "විහාර (vihara)" were identified as four of the mostly occurring words in Sinhalese inscriptions. As an extended work of the previous study, authors utilized a deep learning approach called You Only Look Once (YOLO) version five (YOLOv5) for detecting words in Sinhalese inscriptions. By training the YOLOv5 model on a customized dataset of Sinhalese inscriptions, this research aims to provide an efficient solution for text detection, facilitating the digitization and preservation of Sri Lanka's rich historical records. The productivity and efficiency of the model was analyzed according to established evaluation standards - precision, recall, Mean Average Precision (mAP), and F1 score. The subsequent sections covered in this paper discuss the methodology of the research findings in section 2, establishes the experimental results along with the discussions in section 3, and summarizes the model's performance and suggests directions for future research in section 4.

2. METHODOLOGY

2.1 Dataset

The dataset is composed of 300 images of tokenized Sinhalese inscriptions which belong to the Modern era. The dataset consists of on-site images of stone inscriptions, slab inscriptions, and pillar inscriptions. These images illustrate the original Sinhalese inscriptions taken from the inscription sites (Heenkenda and Fernando, 2023). Figure 1 presents sample pieces of original Sinhalese inscriptions.

A quantitative analysis was carried out with the support of archaeological experts to identify mostly occurring words in Sinhalese inscriptions based on collected images. As per the pilot model, the words separated in a meaningful way. Word separation was difficult due to various reasons such as partial deletion or damage of words as shown in Figure 2, text conjoinment in between lines as shown in Figure 3, moss growth as presented in Figure 4, and letter erasure due to surface engravement as seen in Figure 5.

Figure 1: Sample pieces of original Sinhalese inscriptions (non-tokenized)

Figure 2: Sample image of partially damaged, but reconstructed inscription (occurrence of two colors in the same stone)

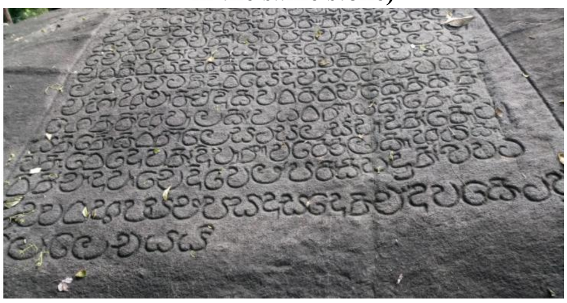

Figure 3: Sample image of unspaced phrases and words

Figure 4: Sample image of moss growth

Table 1: Summary of the dataset (most common words in Sinhalese inscriptions)

Most common words in Sinhalese inscriptions	Occurrence (from modern Sinhalese inscriptions)
ශ්‍රී (sri)	80
රජ (raja)	75
ගල (gala)	68
විහාර (vihara)	77

"ශ්‍රී (sri)", "රජ (raja)", "ගල (gala)", and "විහාර (vihara)" were identified as most common words in Sinhalese inscriptions. A balanced dataset of training and testing in ratios of 80% and 20% respectively was formulated. Figure 5 is an illustrative sample from the dataset.

Figure 5: Illustrative sample from the dataset

2.2 You Only Look Once (YOLO) based text detection

Unlike traditional OCR, which requires clean, preprocessed input and struggles with low resource ancient scripts, YOLOv5 processes raw field images directly, delivering a scalable, accurate, and practical solution for digital preservation and scholarly analysis of Sri Lanka's epigraphic heritage.

YOLOv5n, YOLOv5s, YOLOv5m, YOLOv5l, YOLOv5x, YOLOv5n6, YOLOv5s6, YOLOv5m6, YOLOv5l6, and YOLOv5x6 + TTA are ten distinct architectures that make up the YOLOv5 model (Jocher, 2020). Backbone, neck, and output are three main components of the YOLOv5 network. Figure 6 presents the architecture of YOLOv5. YOLOv5 supplies each batch of training data through the data loader while concurrently improving it. Mosaic enhancement, color space modification, and scaling are three sorts of data enhancements carried out by the data loader. A novel technique called "dynamic anchor box" method was formulated to create anchor boxes. The results demonstrated that mosaic augmentation effectively addresses tiny object detection problems in model training. The ground truth bounding boxes were grouped into clusters using a clustering method, and the anchor boxes acted as the centroids of the clusters. Based on the review, YOLOv5 was chosen for its superior speed and accuracy compared to other alternatives, making it the ideal choice for this study.

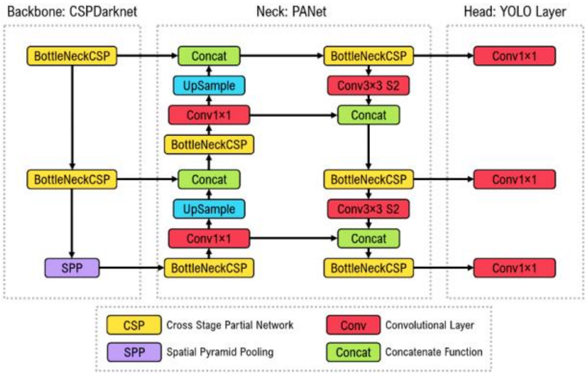

Figure 6: YOLOv5 Architecture (Katasamenis, 2022)

2.2.1 Data preparation

Data augmentation was carried out on the 'Roboflow' platform (Dwyer, 2020), which supports YOLO and facilitates both data augmentation and storage. The augmentation techniques, such as rotation, scaling, and zooming, were applied. In rotation, the image is rotated by angles within the range of 10° to 45°. This augmentation technique enables the model to learn from images with different orientations. To robustly handle variations in inscription scale due to differences, scaling and zooming augmentations were strategically applied. 0.5 to 2.0 range utilized for random scaling. Data annotation was done using Roboflow which supports YOLO. It facilitates data augmentation and subsequent data storage. Roboflow was allowed to auto update the label to new images after the augmentation process while small angled rotations and hue adjustments were also performed.

Figure 7: Augmented image using Roboflow

2.2.2 Model training and testing

The detailed hardware/software specifications utilized in this experiment are as follows: CPU - Intel(R) Core(TM) i7-8750H, RAM - 16GB, Graphics card - GTX 1050, OS - Windows 10 (64-bit), deep learning development platform – PyTorch 1.9, and Parallel computing framework - CUDA 10.0. The model was trained with 80% of images from the dataset. Augmented data were fed into the YOLOv5 algorithm, with initial learning rate set to 0.01, and batch size of 32 for 300 iterations. The rest of the parameters used in the model included Binary Cross-Entropy for loss and Adam for optimization. The model was tested with 20% images from the dataset. The model was evaluated by performance metrics—precision, recall, mAP (0.5), and F1 score. Evaluation was performed on the test set with detailed analysis of its ability to detect text in various environmental conditions.

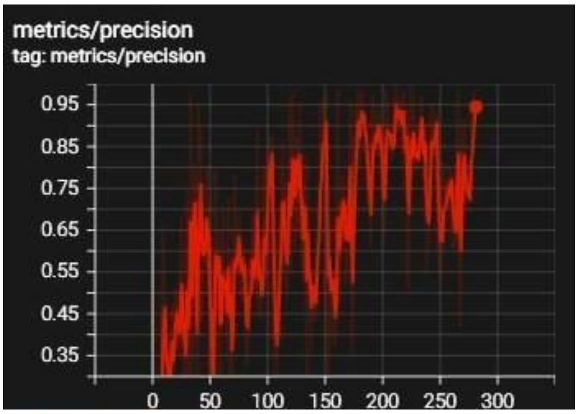

Figure 8: Precision metric of the model

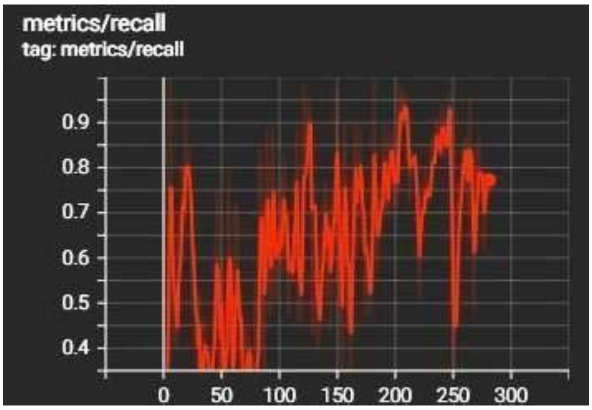

Figure 9: Recall metric of the model

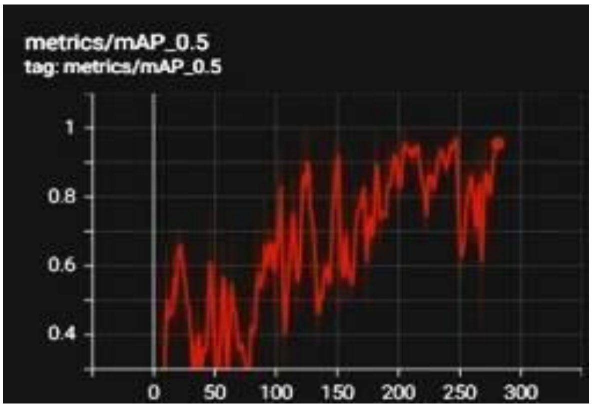

Figure 10: mAP(0.5) metric of the model

3. RESULTS AND DISCUSSION

3.1 Results

The model was developed, trained and validated using a configured dataset of Sinhalese inscriptions, and its performance was evaluated using conventional metrics including precision, recall, mAP (0.5), and F1 score. The results of the YOLOv5 method are presented in Table 2.

Table 2: Results of YOLOv5 model

Precision	Recall	mAP (0.5)	F1 Score
95.7%	90.7%	99.5%	90%

The testing results of words are shown as follows. Figure 9 reflects precision of the model, Figure 10 presents recall, and Figure 11 showcases mAP (0.5) of the model.

Sample detection results of segmented words in inscriptions are shown in Figure 11.

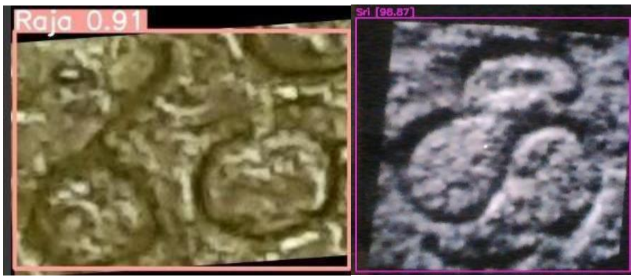

Figure 11: The detection results of Sinhalese inscriptions using YOLOv5

4. DISCUSSION

The experimental findings reveal that the YOLOv5 model is capable of reliably detecting text in Modern Sinhalese inscriptions, despite challenging conditions. The high precision value reflects the ability of the model to accurately identify text regions especially on intricate landscapes like stone and rock surfaces. However, the slightly lower recall suggests that damaged or partially eroded text regions were missed. Many inscriptions are subjected to notable weathering, causing characters to be faint or partially obscured. In these cases, the model occasionally struggled to detect faint text, leading to a lower recall. The stone surfaces often had textures of moss, cracks, roughness, and carvings, making it difficult to distinguish text from non-text elements. While YOLOv5 handled most cases well, prospective optimization in handling background and landscape complexity could further reduce false positives.

Compared to traditional image processing and OCR techniques, YOLOv5 provides several advantages. Traditional OCR systems often rely on clean, printed text and struggle with irregular, degraded, or historical fonts. In contrast, the YOLOv5 model, designed for object detection, excels in handling the diverse and irregular nature of Sinhalese inscriptions. The model's aptitude for real-time text detection, with a mAP of 99.5%, significantly outperforms the accuracy and efficiency of conventional methods that require substantial preprocessing and manual intervention.

This study encounters several limitations. One significant limitation is the availability and condition of inscriptions. Many inscriptions are weathered, damaged, or erased, which presents challenges in achieving accurate translations. Additionally, some pictorial symbols are encountered in ancient inscriptions. These symbols were excluded from the study.

5. CONCLUSION

The success of YOLOv5 in detecting text on Modern Sinhalese inscriptions opens new avenues for historical text analysis and preservation. Automated text detection can significantly reduce the time required for archaeologists to analyze inscriptions, enabling faster digitization of historical records. Moreover, the approach needs to be extended to other eras of Sinhalese inscriptions.

Subsequent research could seek to improve recall by optimizing the model's detection proficiency of detecting heavily degraded texts on inscriptions. Also, future study will focus on translating text in Sinhalese inscriptions to English and recognizing damaged or partially damaged text in Sinhalese inscriptions.

6. ACKNOWLEDGEMENTS

A sincere gratitude is extended to the following archaeological experts and organizations for providing historical information. Ven. Galkiriyagama Wimalananda Thero, Former Lecturer, University of Kelaniya, Ven. Maligathanne Susima Thero, Pali language expert, Maligathanna Purana Vihara, Gampaha, Ven. Kelagama Ginarathana Thero, Lecturer, Bhiksu University of Sri Lanka, Prof. Karunasena Hettiarchchi, Professor in Archeology, Department of History, University of Sri Jayewardenepura, Mrs. Sanuja Kasthuruarchchi, Director General, Department of National Museums of Sri Lanka, Mr. Pathum Paranawithana, Site Officer, Rajagala Archaeological Project, Mr. Isuru Madushanka, Education Promotion Officer, Department of National Museums, Mr. Gayan Baduraliya, Field Officer, Archaeological Zonal Office, Warakagoda, Ms. Dinethra Tharangani, Field

Officer, Department of Archaeology, Mr. Rajitha Namasinghe, Development Officer, Archaeology Office of Hambantota, Ravindu Lakshan, Field Officer, Central Cultural Fund, Rathnapura, Mr. Ranjith Hewage, Museum Keeper, National Museum of Colombo, Royal Asiatic Society of Sri Lanka. Further, grateful to the technical officers of the Software Laboratory of the Department of Information and Communication Technology, Faculty of Technology, University of Sri Jayewardenepura for facilitating access to high-performance computing facilities.

Funding Declaration

This study was conducted without external funding from governmental, commercial or non-profitable agencies.

Conflicts of Interests

The authors confirm that there are no potential conflicts of interest regarding the scholarly contribution and release of this paper.

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