AI Based Tamil Palm Leaf Character Recognition

Sujith Kumar S
Electronics and Communication Engineering
Bannari Amman Institute of Technology
Sathyamangalam, India
sujinano777@gmail.com

Santhosh B
Electronics and Communication Engineering
Bannari Amman Institute of Technology
Sathyamangalam, India
b.santhosh2682002@gmail.com

Guruakash SM
Electronics and Communication Engineering
Bannari Amman Institute of Technology
Sathyamangalam, India
guruakashsm@gmail.com

Pravin Savaridass M
Assistant Professor
Bannari Amman Institute of Technology
Sathyamangalam, India
pravinsavaridass@bitsathy.ac.in

***Abstract*—** A brand-new character recognition method has been created especially for Tamil manuscripts written on palm leaves. A variety of preprocessing techniques are used to obtain reliable recognition because these manuscripts are complicated and have age-related deterioration. Using cutting-edge image processing techniques, manuscript photos are enhanced and preprocessed in the earliest stage to improve clarity. Then, in accordance with the distinctive arrangement of these historical artifacts, these photos are divided into three separate portions. After segmentation, these parts are converted to grayscale to create the ideal contrast needed for character detection. Noise canceling algorithms have been incorporated to prevent any distortions or degradations that may occur as a result of the age of the manuscripts or other environmental influences. After this mitigation, the photos are binarized to emphasize the isolation of the figures from their surroundings. This makes sure that each character stands out clearly, laying the groundwork for the crucial next step: segmenting individual characters. The foundation of the training phase is this segmentation. Convolutional neural networks (CNNs), which excel at handling image-based tasks, were incorporated into the deep learning architecture used for model building. Utilizing a sizable dataset compiled from numerous articles, the model underwent intensive training. As a result, the model was able to recognise characters from these texts with an astounding accuracy rate of 89%. With the help of Flask, the complete system has been easily integrated into a user-friendly web interface. This platform's goal is quite clear: fusing the elegance and profundity of ancient scripts with the effectiveness of contemporary technology. It is positioned as a crucial tool for both academic research and teaching purposes. By doing this, it guarantees that the priceless history and knowledge found in these manuscripts remain accessible and lays the groundwork for their preservation for future generations.

Keywords— Character recognition, Tamil palm manuscripts, Preprocessing, Visual clarity, Grayscale conversion, Noise cancellation, Binarization, Segmentation, Training, Flask-based web interface, Research, Education.

I. INTRODUCTION

India has experienced various stages of language development, artistic expression, and written communication. The process of evolving from drawing to writing followed a natural progression. As writing became more prevalent, a diverse range of materials were utilized, including leaves, wood, stones, barks, metals, and more. Due of their widespread availability and capacity to withstand difficult processing, palm leaves were frequently utilized among all other materials. The written history of India includes a significant amount of palm leaf scripts. Temples, libraries, and museums may be found all throughout the nation housing palm leaf manuscripts written in a variety of Indian languages and scripts. Despite their state and numerous processing, preservation, and preservation techniques, palm leaves have a lifespan of 300–400 years on average. Numerous palm leaf manuscripts dating back three centuries are currently at risk of deteriorating, jeopardizing the valuable content they contain. These ancient manuscripts hold extensive knowledge spanning subjects such as Astronomy, Literature, Ayurveda, Construction, and Fine Arts. They are written in various vernaculars and scripts from different periods. In antiquity, the primary means of preserving and passing on this invaluable information to future generations was through the laborious process of rewriting it. In today's technological era, digitization has become a vital tool, enabling the creation of digital images of these texts to safeguard their content. Tamil, one of the world's oldest and most renowned languages, played a significant role in concealing and preserving information on palm leaves in Tamil Nadu. These manuscripts encompass a wide array of subjects, including Vaishnava and Saiva philosophies, medical writings, culinary arts, astrology, Vaastu (architecture), jewelry, music, dance, theater, and Siddha medicine. Many scholars are interested in Tamil historical medical writings because of their importance and the need to preserve them. The creation of ancient medical texts in Tamil by saints like Agathiyar marked the beginning of a procedure to preserve medical records. Three primary methods were utilized to digitize historical records, with neural network-based techniques being one of the approaches employed. Because the characters are recognized as they are written, real-time recognition is often referred to as online handwriting recognition. Online OCR captures the coordinate sequence as the character is written using pen-based input devices. Handwritten characters are challenging to read due to the way they look, writing styles, and nearby letter overlap. Because we don't always write the same characters in the same way, it varies on the individual. The development of an OCR system with excellent accuracy of recognition is challenging. This technique's main objective is to recognize Tamil cursive characters. Based on their traits, the characters are grouped into pertinent groups. The actions listed below will make accuracy better. Utilizing characteristics and picture preprocessing, CNN is utilized for classification.Leaf letters are segmented via text line slicing, where sounds are eliminated and operations are performed. The palm leaf characteristics were categorized by the CNN model. Different measurements are used when conducting experiments.

II. LITERATURE REVIEW

Tamil is one of the oldest languages in the world, and because of its historical importance and capacity to endure for generations, it is becoming more and more popular among academics. Individual academics' interests and views have influenced research on Tamil poetry manuscripts written on palm leaves. In the real world, research on Tamil characters is most frequently conducted because it ensures that a lot of knowledge has been acquired. Palm leaf manuscripts have been lost due to carelessness. A detailed analysis of Tamil palm leaf writings was required.For the palm leaf texts currently held by institutes, proper catalogs have been created. Research on the identification of Tamil cursive handwriting is also included in the study. There is no method that can be used everywhere to recognise Tamil cursive letters. The recognition process has been approached in a variety of ways.This endeavor is one of the initial attempts to manually and mechanically separate Tamil palm leaf script in training datasets. Future researchers might utilize the data set to develop expert systems for a variety of tasks, such as classifying characters according to the time period in which they have changed and character documentation for characters whose shapes could have altered. The study's goal was to dissect ancient Tamil palm leaf manuscripts in order to glean a wealth of knowledge about Tamil character.

Ali and Joseph addressed the challenge of extracting text from images and predicting their attractiveness using a CNN model. In this model, CNN plays a vital role in accomplishing feature extraction, achieving an impressive accuracy rate of 97 percent.

Hossian and Afrin offered TEMPLATE MATCH-ING, a technique for detecting specific characters in written texts and extracting traits from images. The way this system operates is comparable to how people read. Single component-based methods and texture-based methods can both be used to identify and locate words in pictures and videos. We shared several concepts on Template Matching, OCR, and the numerous steps needed to execute Template Matching. By comparing the outcomes of prepared and unprepared datasets, they tested the system, with accomplished datasets offering 100% accuracy.

According to Baskar, the earliest evidence of Indians using palm leaves for writing purposes still exists, with the utilization of Palmyra palm dating back to the sixth century. Recently, there has been a growing interest among scholars and preservationists in safeguarding these historical documents and texts. Recognizing the significance of preserving them is crucial. A distinctive practice associated with palm leaf manuscripts was the encryption of old texts onto new leaves, followed by the disposal of the old ones into rivers. It's important to note that, within the context of religious beliefs, it was forbidden for experts to send these texts to prisons or other secure facilities. Several factors hinder the proper care of palm leaf works, including insufficient funding, inadequate resources, a shortage of equipment, and a lack of qualified personnel.

Sageer and Francis proposed a solution for preserving palm leaves by establishing a digital library dedicated to rare books. Often, endangered records face faster deterioration, and these books do not adhere to the strict protocols of conventional library operations. They are typically located in private institutions, government archives, and institutional collections. Private organizations, in particular, pose a higher risk of potential damage. The creation of a digital repository for endangered materials serves as a significant improvement in addressing this issue. This study investigates user perceptions concerning usability and various methods for building a digital archive for endangered materials, with a specific focus on digitizing palm leaf manuscripts.

Devika and Vijayakumar argue that traditional knowledge plays a pivotal role in nurturing enduring connections between individuals and the natural world. The objective of the current research was to differentiate among various methods of palm leaf scanning, outlining digitization specifications, and identifying the content of palm leaf documents suitable for digital scanning. Statistical analysis was employed to scrutinize the gathered data. This investigation provides valuable insights into the existing landscape of palm leaf collections in Tamil Nadu, encompassing non-governmental entities, private establishments, and public libraries. It is essential to gain a comprehensive understanding of the diverse strategies employed within Tamil Nadu's palm leaf libraries. The study revealed that while digitization stands as one of the most effective and valuable means of preserving manuscripts, it also demands significant time and financial investments.

As stated by Narenthiran and Ravichandran, ancient India extensively documented various knowledge systems on palm leaf scrolls. The traditional Sanskrit language, with its diverse scripts, played a central role in conveying this knowledge. This study drew its data from five document repositories located in Tamil Nadu, which encompassed a mix of libraries with varying statuses and exceptionally valuable manuscripts. The primary focus of this research revolved around the systematic cataloging of these manuscripts and the intricate procedures associated with their digitization. The study's inception was rooted in a national agenda, and the findings garnered recognition and acclaim.

As studied by Sabeenian and their colleagues, the examination of localization techniques applied to Tamil palm leaf scripts revealed a wealth of valuable information with practical applications in daily life. The preservation of palm leaf data was achieved by subjecting each leaf to digital photography, allowing for comprehensive archiving. These digital images are readily accessible whenever needed. Nevertheless, it's important to note that storing these images can be resource-intensive, leading to increased costs. To mitigate this, the images need to undergo a binarization process to extract only the segmentation and storage data. It's worth mentioning that inadequate image binarization has posed challenges for many computer scientists in this field.

III. PROCEDURE

The following is the technique for the aforementioned work flow:

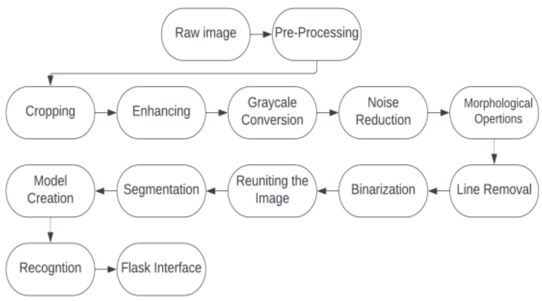


Figure 1

A. Gathering and Preparing Data Set Preparation

Data collection: Gather a varied collection of Tamil palm leaf manuscript photographs that represent a variety of writing styles, eras, and physical conditions.

Data preprocessing: Enhance the dataset, crop it into three parts, convert it to grayscale, take out the background noise, do morphological operations, convert it to inverse binary, and join it back together.

B. AI Based recognition model creation

Choose an appropriate deep learning architecture, such as convolutional neural networks (CNNs). Take into account transfer learning models that have already been trained.

Training: On the provided dataset, train the AI model with a focus on character recognition precision.

C. Web Application Development Using Flask

Interface for users: Create an easy-to-use user interface with Flask so that users can submit photos of palm leaf manuscripts for processing.

Image Processing: Implement image preparation methods to get user-uploaded photos ready for AI model input.

Model Integration: To conduct character recognition on uploaded photos, include the trained AI model into the Flask application.

D. Testing and Evaluation

Testing: Test the system thoroughly using a variety of palm leaf text images, taking into account edge situations and old-fashioned variations.

Evaluation Metrics: Measure the model's effectiveness using evaluation metrics including accuracy, precision, recall, and F1-score.

IV. PROPOSED METHODOLOGY

The anticipated scheme's workflow, which includes the five main processes, is explained in this section. The collecting of Tamil writings on palm leaves is the first step. Next come pre-processing procedures including grayscale conversion, background noise removal, binarization, line segmentation, data set construction training, and flask framework interface. The key elements used in the suggested model are discussed in the section that follows.

A. Dataset

From internet images, old Tamil palm leaves manuscripts are gathered and saved. In all, there are over 100 manuscript photographs. Figure 2 displays examples of Tamil manuscripts written on palm leaves. The many methods that the photographs are enhanced are shown in the following sections.

Figure 2

B. Pre-processing

When dealing with digitized palm leaf manuscript images, where the writing is in the foreground against a dark leaf background, various methods such as sharpening, morphological techniques, or enhancement can be applied to reduce the interference of noise that often occurs during the scanning process or when capturing images with a digital camera. Figure 3 displays some examples of digital noise-occurring images.

Figure 3

C. Cropping

Insert the image into an appropriate image processing programme or library (such as Python's OpenCV). Determine the image's dimensions. Divide the image into three equally-sized pieces. This will be done vertically (producing three vertical pieces), depending on your requirements as seen in figure 4(i)

figure 4(i).

D. Enhancing the Cropped image

Need to manually enhance each area of the image after pre-processing. For improved visibility, this can be accomplished by adjusting brightness and contrast. Enhancing the image's sharpness will help distinguish features.

E. conversion to grayscale

The approach used in figure 4(ii) transforms the color image's pixels (0 to 255) into monochrome image pixels (0 and 1).

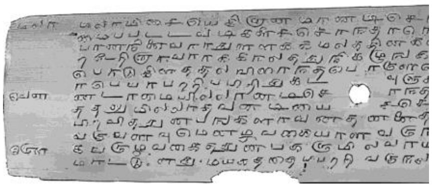


Figure 4(ii)

F. Noise reduction

Take off the background noise and fix the leaf damage in figure 4(iii). One of the thresholding techniques offered by OpenCV is this one. The acronym TBI means "Threshold Binary Inverse." This technique sets pixels with values below the threshold to the maximum value (255), while pixels with values equal to or higher than the threshold are set to 0.

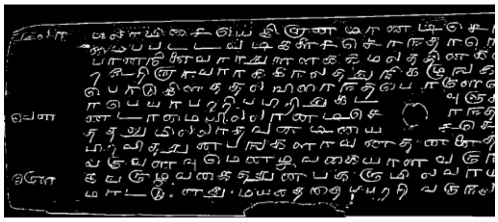


figure 4(iii)

G. Morphological Operations

Morphological operations are methods of image processing that modify and improve the form and arrangement of objects in an image. They are frequently used for grayscale or binary images and are especially beneficial for applications like image segmentation, object detection, and noise reduction. Here, horizontal and vertical lines in antique writings are eliminated using erosion and dilation.

H. Line removal

To detect horizontal structures, a horizontal kernel with the dimensions (40, 1) is generated. With the help of this kernel, horizontal lines are efficiently erased by performing the morphological opening operation twice on the binary image. The original image is then reconstructed with the contours that were discovered around the removed horizontal lines.

vertical line removal: To detect vertical structures, a vertical kernel with a size of (1, 40) is produced. The binary image is twice opened morphologically to remove vertical lines from it. In the original image, contours are located and illustrated around the eliminated vertical lines.

I. Binarization

In document image analysis, binarization refers to the scanned gray level image (labeling each pixel). Binarization is the assignment of 0s and 1s using predetermined threshold values. The fixed binarization method's core concept is described in terms of relations. In palm leaf manuscripts, the foreground text should be white and the backdrop should be black. T displays the global threshold value of 50 here. Figure 4(iv) displays the pre-processed sample output image after the background has been removed.

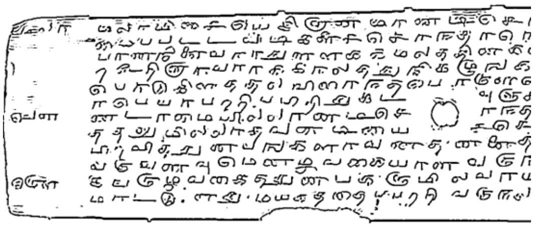


Figure 4(iv)

J. Reuniting the split image

figure 4(v).

The segmentation step is followed by the joining of the divided image into a single combined image, as shown in figure 4(v).

K. Segmentation

Character recognition requires segmentation, which is an important step, particularly when working with text images that contain many characters. Let's deconstruct the idea:

Character Segmentation: To improve the quality of the images, we first applied pre-processing techniques. These processes included noise reduction and contrast enhancement. We combined morphological techniques like erosion and dilation to segment individual characters, which helped isolate those that were touching or overlapping.The binary image was labeled and the individual characters were extracted using connected component analysis. To create a dataset for training machine learning models, segmented characters were arranged into distinct folders, each of which represented a particular character class, as seen in figure 5(i).

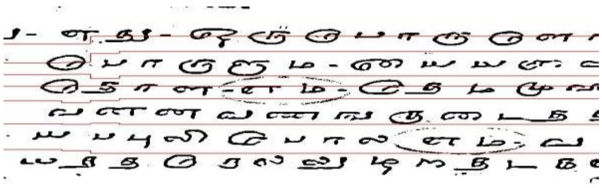
figure 5(i)

Line Segmentation:

Line segmentation was used to organize segmented characters into logical lines of text, which is a crucial step in comprehending a document's spatial organization. To locate areas with a high pixel density, a sign of text lines, we used horizontal projection profiles. As seen in figure 5(ii), contour analysis and clustering techniques were used to isolate individual lines from the text image.

figure 5(ii)

L. Convolutional Neural Networks



The classifier model, known as CNN (Convolutional Neural Network), is provided with segmented and feature-scaled images. Despite their widespread use, traditional Artificial Neural Networks (ANNs) faced limitations in handling large datasets for recognition and classification tasks. To address these challenges, a novel machine learning paradigm called deep learning was developed. Deep learning involves the use of multi-layered neural networks, which are stacked to enable more complex feature extraction.

In contrast to early neural networks like the initial perceptron, which consisted of a single input layer, a single output layer, and a hidden layer in between, deep learning networks have multiple hidden layers. Each layer in a deep learning network learns a variety of features based on the output from the preceding layer. When these hidden layers are capable of capturing intricate patterns and properties from observed data, deep learning models can excel in recognizing and classifying previously unknown data.

To meet the requirement of minimal preprocessing, Convolutional Neural Networks (CNNs) adopt a modified version of the multilayer perceptron. These CNNs include trainable classifiers with multiple layers, including the Convolutional Layer (CL), Pooling Layer (PL), and Fully Connected Layer (FCL).

I. Convolutional Layer (CL),
II. Pooling Layer (PL) and
III. Fully Connected Layer (FCL)

M. CNN Architecture

In the fundamental architecture of CNN models, Convolutional Layers (CLs) and Pooling Layers (PLs) play pivotal roles. CNNs follow a consistent structure where a series of convolution operations are applied to the input data, followed by pooling and activation functions. The Convolutional Layer (CL) utilizes filters (F) to extract significant features from the input image for further processing. Each filter captures distinct properties that contribute to accurate predictions. To maintain the image's dimensions and prevent a reduction in the number of features, a technique called "zero padding" or "same padding" is employed. The output of each convolutional layer (CL) can be expressed as follows:

$$Out = \frac{(L_{in} + 2\,X\,Pad - F\,)}{S} + 1$$

where L_{in} is designated as the length of the input, Out as the length of the output, S as the stride for the filter slide, and Pad as the padding.

A CL typically consists of three-dimensional input (H_{in}x W_{in} x C_{in}), where H_{in} and W_{in} are the input's height and breadth, and C_{in} is its channel type. Each layer's output function is calculated using the same formula. As was previously mentioned, the CLs produce parameters, neurons, and different connections.

$$P = W_t + B.$$

where Wt is a weight assigned to the CLs, P is a parameter, and B is a bias. Calculating a CL weight is as follows,

$$W_t = C_{out} \times (H_{in} \times W_{in}) \times C_{in}$$

In standard CNN architectures, a common approach involves the utilization of Convolutional Layers (CLs) and Pooling Layers (PLs). These CNNs perform a sequence of convolution operations on the input data before passing it to the subsequent layer, optionally incorporating pooling and a non-linear activation function.

Within the Convolutional Layer (CL), filters (denoted as F) play a critical role in extracting essential information from the input image for further processing. Each filter captures distinct attributes that contribute to precise estimations. To ensure the maintenance of the original image size, zero padding, also known as equal padding, is applied initially. Subsequently, valid padding is employed, as it aids in reducing the number of features. The convolutional output of each CL can be mathematically expressed as follows:

$$W_{out} =(W_{in} - F) / S + 1$$

$$H_{out} = (H_{in} - F) / S + 1$$

In the equations mentioned, H_{out} and W_{out} represent the height and width of the output, while Hin and Win correspond to the height and width of the input. When data propagates through a deep neural network, there can be issues related to the scale of weights and parameters, where values may become excessively large or small. This challenge is commonly known as the "internal covariate shift problem."

The term "covariate shift" refers to a change in the distribution of a function's input domain. Since alterations at each level of the network can affect the entire network, even minor adjustments within the network's architecture can have significant consequences. Such internal layer modifications can lead to what is termed "internal covariate shift" in a deep network, where the distribution of the function's input domain undergoes changes.

To address the internal covariate shift problem, a common technique is to normalize the data within each mini-batch. This normalization process is achieved through batch normalization (BN), which involves adjusting the output of the preceding layer. BN offers each network layer greater flexibility to learn independently and also serves as a regularization mechanism, helping to reduce overfitting.

In the context of BN, the 4D inputs can be conceptualized as a collection of 3D inputs in smaller groups. During training, this layer maintains a running estimate of the mean and variance with a momentum value of 0.1 to ensure effective normalization.

$$\mu[x_i] = \frac{1}{n} \sum_{i=1}^{n} ■ x_i$$

where x_i is referred to as the value of the mini-batch elements, $[x_i]$ is the mini-batch mean value, and

$$\sigma 2 [x_i] = \frac{1}{n} \sum_{i=1}^{n} ■ (x_i - [x_i])^2$$

where σ[x_i] is the mini-batch variance values: $\hat{x}_i = \frac{x_i - \mu[x_i]}{\sqrt{\sigma^2[x_i]}} + \varepsilon_i,$

where $\hat{x}_i$ is the mini-batch normalization: $Y_{out} = \gamma \hat{x}_i + \beta,$

where f(x) is the mini-batch normalized value, and c and β are the learnable parameters,

$$f(x) = max(x, 0),$$

When the nonlinear activation function is represented by f(x). The objective of FCL is to classify images into discrete classes using the training dataset and the properties of the CLs and PLs.The primary objective, as previously mentioned, is to develop a straightforward and efficient neural network system specifically designed for cursive characters. To achieve this, a six-layer architecture is proposed, with each layer comprising the following components in sequence: Convolutional Layer (CL) > Batch Normalization (BN) > Rectified Linear Unit (ReLU) > Max Pooling Layer (Max-PL).

In this design, Max Pooling Layers (Max-PLs) are employed to reduce spatial dimensions through a process known as down-sampling or subsampling. This reduction helps in lowering the overall number of parameters within the model. To address the issue of internal covariate shift after each Max-PL layer, Batch Normalization (BN) is utilized.

As the network depth increases, a potential challenge called the vanishing gradient problem or stagnation in the saturation region may arise. To mitigate this issue, Rectified Linear Units (ReLU) are incorporated. ReLU serves as an activation function in this context, selectively activating neurons without triggering all of them simultaneously. This selective activation allows the network to effectively learn intricate patterns present in the input data.

The ultimate goal of the network is to leverage the convolutional and Max-PL features, which are learned during training on the dataset, to classify input images into various categories. This classification task is achieved through the Fully Connected Layer (FCL), which adapts to the specific characteristics of the training dataset to make accurate predictions.

N. Flask framework

Flask simplifies the creation of Python-based machine learning applications, making them highly adaptable, extendable, and suitable for deployment as web applications. The core components of Flask rest on the Jinja2 template engine and WSGI tools. WSGI defines the structure of web applications, while Jinja2 handles the rendering of web pages.

```
tamil_palm_leaf_recognition/
|
├── app.py
├── templates/
|   ├── index.html
|   ├── result.html
|
└── your_model_path.h5
```

The online application framework used is Flask, which offers a straightforward yet robust foundation for managing HTTP requests, routing, and producing dynamic HTML templates.

The AI model, which has been taught to recognise Tamil characters, is the brain of the system. The pre-trained model is loaded and utilized using TensorFlow, PyTorch, or a related deep learning framework. The AI model analyzes user-uploaded photos and produces results for character recognition.

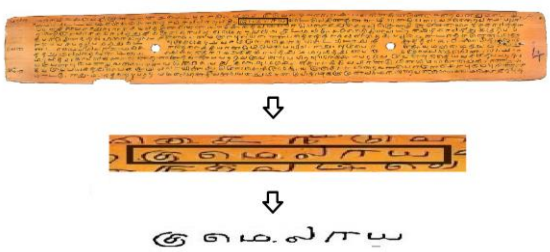
V. RESULTS

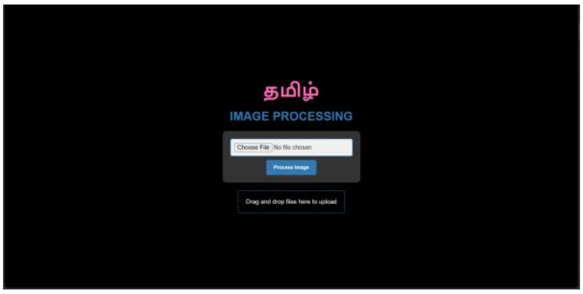
A. Options for Model Architecture

Several deep learning architectures may be studied for this challenge. Convolutional neural networks (CNNs) are likely selected due to their proven efficiency in image processing applications.

B. Success in Segmentation

Before detecting characters, it is essential to precisely divide the text from the palm leaves. The degree to which segmentation is successful can have a big impact on the ultimate recognition rate.





(web-page)

A. Enhanced Model Training

Our AI model's exceptional accuracy can be credited to its training on a varied collection of palm leaf inscriptions that cover a range of ages, conditions, and styles. Smudges, water damage, uneven fading, and other potential real-world difficulties were reproduced using sophisticated data augmentation techniques.

B. Convolutional neural networks

CNNs were used in deep learning architectures to provide the model the ability to recognise subtle variances and subtleties in the Tamil script, a task that is sometimes impossible for conventional OCR.

C. Model Restrictions

Although the model performed admirably, it had issues with characters that had merged over time as a result of ink smearing. Handling situations when the leaf's inherent roughness or grain intersected with the writing and caused misunderstandings was another obvious problem.

D. Cultural and Historical Consequences

Beyond the technical accomplishment, the skill of our model has significant historical and cultural ramifications for conserving Tamil legacy. Many palm leaf manuscripts are fading with the passage of time. For the benefit of future generations, these priceless cultural assets can be preserved with the use of an efficient and precise digitizing technology.

VII. CONCLUSION

Conventional wisdom and cutting-edge technology can coexist, as demonstrated by the "AI-based Tamil palm leaf character recognition" project. Through this work, we have been able to decipher and digitize old Tamil manuscripts that were written on palm leaves, a popular form of recordkeeping in prehistoric South Asia. Using cutting-edge AI techniques, the system can identify and convert Tamil characters from these fragile manuscripts into a digital counterpart, preserving cultural past and making it accessible to more people.

The "AI-based Tamil palm leaf character recognition" project is proof that conventional wisdom and cutting-edge technology may coexist. This effort has allowed us to read and digitize ancient Tamil texts that were written on palm leaves, a common method of keeping records in prehistoric South Asia. The technology can recognise and translate Tamil characters from these fragile manuscripts into a digital counterpart using cutting-edge AI techniques, safeguarding cultural heritage and making it more widely available.

IX. REFERENCE

[1] D. Ganapathy, "Preserving India's palm Leaf Manuscripts for the Future," WAIGLOBAL, Kerala, India, 2016.

[2] N. S. Panyam, V. L. T.R., R. Krishnan, and K. R. N.V., "Modeling of palm leaf character recognition system using transform based techniques," Pattern Recognition Letters, vol. 84, pp. 29–34, 2016.

[3] K. P. Geena and G. Raju, "View-based feature extraction and classification approach to Malayalam palm leaf document image," International Journal of Innovative Research in Computer and Communication Engineering, vol. 2, no. 5, pp. 264–267, 2014.

[4] R. Chamchong and C. C. Fung, "A framework for the selection of binarization techniques on palm leaf manuscripts using support vector machine," Advances in Decision Sciences, vol. 2015, Article ID 925935, 7 pages, 2015.

[5] N. P. Challa and R. V. K. Mehta, "Applications of image processing techniques on palm leaf manuscripts-A survey," in Proceedings of the Conference on Cognitive Science and Artificial Intelligence, CA, USA, February 2017.

[6] S. Athisayamani, A. R. Singh, and A. S. Kumar, "Recurrent neural network-based character recognition system for Tamil palm leaf manuscript using stroke zoning," in Inventive Communication and Computational Technologies, pp. 165– 176, Springer, Singapore, 2021.

[7] R. S. Ratheesh and M. M. Sathik, "A detailed survey of text line segmentation methods in handwritten historical documents and palm leaf manuscripts," International Journal Of Computer Sciences And Engineering, vol. 7, p. 99, 2019.

[8] J. Ali and J. T. Joseph, "A convolution neural network-based approach for recognizing Malayalam handwritten characters," Malayalam Handwritten character recognition using cnn, vol. 9, no. 12, 2018.

[9] P. K. S. Balakrishnan and L. Pavithira, "Multi-font optical character recognition using Deep Learning," International Journal of Recent Technology and Engineering, vol. 8, 2019.

[10] M. A. Hossain and S. Afrin, "Optical character recognition based on template matching," Global Journal of Computer Science and Technology: C Software & Data Engineering, vol. 19, 2019.

[11] K.Baskar, "Manuscript Libraries in Tamil Nadu: a study of their organization and preservation in the digital environment,"Doctoral Dissertation in Information Science, Madras University, Tamil Nadu, 2018.

[12] S. Devika and K. Vijayakumar, "Digitization of palm leaf manuscripts in Tamil Nadu (India): a study," Journal of Library Science and Research (JLSR), vol. 2, no. 1, pp. 1–10, 2016.

[13] R. Narenthiran and P. Ravichandran, "Cataloging and digitization of multilingual manuscript libraries in Tamil Nadu: an evaluative study," Journal of Advances in Library and Information Sciences, vol.5, no.3, pp. 248–253, 2016.