A Mini Project Report on

Multilingual Character Detection

Submitted in the Partial Fulfillment of the Requirements
For the Award of the Degree of

BACHELOR OF TECHNOLOGY IN

Computer Science and Engineering

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CERTIFICATE

This is to certify that the project titled " **Multilingual Character Detection** " is carried out by

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Abstract

The project titled "Multilingual Character Detection for Telugu Language Using Image Processing Techniques" focuses on recognizing and extracting Telugu script characters from printed and handwritten text using traditional computer vision methods. Instead of relying on machine learning or deep learning models, this approach utilizes classical image processing techniques such as grayscale conversion, noise filtering, thresholding, and contour analysis to detect and segment individual characters.

A custom dataset of Telugu characters was developed from scanned documents and handwritten samples. The detection pipeline involves preprocessing the images, isolating characters based on geometric features, and mapping segmented components to corresponding Telugu Unicode symbols through rule-based methods and template matching. This system supports the digitization of regional texts, aids in preserving linguistic resources, and offers a foundation for further multilingual OCR development. By using lightweight and interpretable methods, the project demonstrates an accessible and language-focused approach to character recognition without the complexity of AI or real-time systems.

Keywords: Telugu Script Detection, Image Processing, Character Segmentation, Handwritten Text Recognition, Template Matching, Unicode Mapping, Regional Language Digitization, Multilingual OCR.

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Abbreviations

Abbreviation	Description
OCR	Optical Character Recognition (technology used to extract text from images)
ROI	Region of Interest (specific area in an image processed for character detection)
CNN	Convolutional Neural Network (specialized class of neural networks designed to process grid-like data, such as images)
BGR	Blue Green Red (default color format in OpenCV images)
BiLSTM	Bidirectional Long Short-Term Memory (used to go both ways in to the deep to understand the sequential connections and requirements in handwritten word)
Telugu Script	A Brahmic script used for writing the Telugu language
CTC	Connectionist Temporal Classification (used for the alignment-free sequence learning)
CCA	Connected Component Analysis (Used for the identification of different character regions based on the connection between their pixels.)

CHAPTER 1

INTRODUCTION

Communication is a fundamental part of human interaction, and language plays a crucial role in preserving cultural identity and knowledge. In a linguistically diverse country like India, regional languages such as Telugu are spoken by millions, yet many of these languages remain underrepresented in digital systems. Telugu, with its complex script and rounded characters, presents unique challenges for digitization and automated text recognition. Although Optical Character Recognition (OCR) systems exist for widely used scripts like Latin or Devanagari, efficient and accurate character detection for the Telugu script—especially from handwritten or printed documents—remains limited in scope and accessibility.

Our project, "Multilingual Character Detection for Telugu Language Using Image Processing Techniques," focuses on addressing this gap by developing a system capable of detecting and extracting Telugu characters from scanned images or photographs of handwritten and printed text. Unlike AI-based or real-time systems, this project uses classical image processing techniques such as grayscale conversion, noise filtering, thresholding, contour detection, and segmentation to isolate and identify individual characters. The system further maps these segmented components to their corresponding Unicode values, allowing for digital representation of the text.

The motivation behind this work stems from the need to create affordable, interpretable, and lightweight solutions for digitizing regional scripts. Most existing OCR tools are not optimized for the complexities of Indian scripts or require extensive training data and computational resources. Our goal is to develop a system that performs well under varying lighting conditions and font styles without relying on expensive hardware or AI-based models. By emphasizing traditional computer vision techniques, we aim to ensure better transparency, easier debugging, and broad adaptability for educational, archival, and accessibility-related applications.

The primary objective of this project is to design and implement a system that can accurately detect individual Telugu characters from non-real-time input sources such as scanned pages or digital images. The specific goals include building a custom dataset from both handwritten and printed samples, applying preprocessing techniques to clean and prepare the images, segmenting characters based on geometric features, and performing Unicode mapping using template matching and rule-based classification. The final system is developed with a user-friendly interface that supports uploading images and displays the extracted text, facilitating ease of use for non-technical users. Furthermore, the project lays a strong foundation for future enhancements like full-text OCR, support for other regional scripts, and integration with translation systems.

This report is organized into multiple chapters for a structured presentation of the work undertaken. Chapter 1 introduces the background, motivation, problem statement, and objectives of the project, outlining the significance of developing a multilingual character detection system. Chapter 2 provides a literature review, analyzing prior research in Telugu OCR, character segmentation, and rule-based classification methods, while identifying gaps in current solutions. Chapter 3details the system analysis and requirements, including hardware and software tools and the rationale behind choosing classical image processing techniques. Chapter 4 covers system design, illustrating the overall architecture and presenting diagrams such as Use Case, Class, Sequence, and Activity diagrams. Chapter 5 discusses the implementation process, including dataset collection, image preprocessing, character segmentation, and Unicode mapping. Chapter 6evaluates the system′s performance using metrics such as segmentation accuracy and recognition rate, while also addressing limitations and areas for improvement. Finally, Chapter 7 concludes the report, summarizing the outcomes and proposing future directions like dynamic character recognition, extended language support, and mobile deployment.

CHAPTER 2

LITERATURE SURVEY

Multilingual character detection, particularly for regional languages like Telugu, has gained increasing attention due to the growing need for digitization of linguistic resources, educational content, and government documents. Telugu, a Dravidian language spoken by millions in India, uses a complex script with over 50 characters and multiple diacritics, making its recognition more challenging than Latin-based scripts. Early efforts in Telugu OCR (Optical Character Recognition) focused on printed text using traditional template matching and rule-based methods, but these systems struggled with low accuracy under varied fonts, sizes, and degraded image quality.

Initial systems for Telugu character recognition often relied on high-resolution scanned documents and used methods such as projection profiles, morphological operations, and connected component analysis to segment lines, words, and characters. While effective in controlled environments, these approaches lacked robustness when applied to handwritten text or documents with noise, skew, or complex layouts. Furthermore, traditional OCR systems required extensive manual preprocessing, limiting their usability for general-purpose applications.

Recent advancements in image processing have improved the effectiveness of character segmentation and detection without relying on deep learning. Techniques such as adaptive thresholding, contour detection, and edge-based segmentation have proven effective in isolating Telugu characters even from noisy or low-quality inputs. These methods allow for greater flexibility in dealing with real-world documents and eliminate the need for training large-scale neural networks, making them suitable for resource-constrained environments.

One of the core challenges in Telugu character detection is the identification of compound characters and modifiers, which often overlap or blend with the base character. Several studies have proposed rule-based decomposition methods to separate these elements, followed by Unicode mapping to generate machine-readable text. This modular pipeline simplifies error handling and enables easier debugging compared to black-box AI models. In addition, segmentation-based approaches are more transparent and interpretable, which is important for linguistic research and archival applications.

To address variability in writing styles and image quality, researchers have employed techniques such as binarization with adaptive thresholds, skew correction using Hough transforms, and noise filtering with Gaussian or median blurs. These preprocessing steps significantly enhance the accuracy of downstream segmentation and recognition processes. Template matching, though limited in flexibility, remains a viable option for small-scale systems where the character set is fixed and well-defined, such as recognizing school examination scripts or official printed forms.

Evaluation of Telugu character detection systems typically includes metrics such as segmentation accuracy, recognition accuracy, and character-level precision and recall. Confusion matrices are used to analyze misclassifications, particularly in distinguishing between visually similar characters. While large-scale annotated datasets for Telugu OCR are limited, several initiatives have been launched to digitize classical Telugu literature and create labeled datasets for academic research.

Despite the progress, there remains a gap in systems that can robustly handle both printed and handwritten Telugu text in the same pipeline. Moreover, most existing tools lack multilingual integration, meaning that documents containing multiple scripts (e.g., Telugu and English) are not processed effectively. Future work is expected to focus on hybrid systems that combine rule-based methods with lightweight machine learning models, support multilingual script detection, and include post-processing modules such as spell checkers or grammar-aware correction tools.

In conclusion, while Telugu character detection remains a challenging task due to the script’s complexity, classical image processing techniques continue to offer a reliable and interpretable foundation for building robust OCR systems. As interest in regional language computing grows, the development of efficient, affordable, and accessible character recognition systems will play a crucial role in digital inclusion and the preservation of linguistic heritage.

CHAPTER 3

METHODOLOGY

The methodology for developing a multilingual character detection system for the Telugu language involves several stages, including data collection, preprocessing, segmentation, character identification, and deployment. Below is a detailed breakdown of each stage in the development process:

3.1. Data Collection

- **Custom Dataset Creation:**

  To build a robust system, a custom dataset was created using scanned documents, printed texts, signage, and textbooks containing Telugu script. These documents were digitized in varying resolutions and environments (e.g., different lighting and noise levels) to improve the system's adaptability.

- **Multilingual Content:**

  The dataset also included mixed-language documents containing Telugu, English, and Hindi text to simulate real-world use cases such as street signs, government forms, and educational material.

- **Image Capture:**

  Images were captured using smartphone cameras and flatbed scanners. The focus was on collecting high-contrast, high-resolution images for accurate character segmentation and recognition using non-AI image processing techniques.

3.2. Data Preprocessing

- **Grayscale Conversion:**

  Each image was converted to grayscale using OpenCV's cv2.cvtColor() function. This simplified the data by removing color information and reducing computational load.

- **Noise Removal:**

  To remove background noise, Gaussian blurring and median filtering were applied. These filters helped preserve edges while eliminating grainy artifacts from low-quality scans.

- **Binarization:**

  Adaptive thresholding (cv2.adaptiveThreshold()) was used to convert images into binary format, ensuring character contours were preserved under various illumination conditions.

- **Skew Correction:**

  Hough Line Transform was employed to detect and correct any skewed lines of text by rotating the image based on the dominant line orientation.

3.3. Text Segmentation

Line and Word Segmentation:

Horizontal and vertical projection histograms were used to detect gaps in pixel intensity. This enabled separation of text into lines and words by analyzing the whitespace distribution.

Character Segmentation:

Connected Component Analysis (CCA) was performed to segment each word into individual characters. Bounding boxes were drawn around each detected character blob and cropped for further processing.

3.4. Character Identification

- **Template Matching:**

  A template matching method using OpenCV's cv2.matchTemplate() function was adopted to identify characters. Each segmented character was compared against a library of pre-stored Telugu and Latin script templates in various fonts.

- **Contour and Shape Features:**

  Contours were extracted from character blobs to compare structural shapes, improving matching accuracy. Normalized cross-correlation was used as the similarity metric.

- **Multilingual Detection:**

  Post-matching, each character was tagged as belonging to Telugu, English, or Hindi based on its match score with corresponding template libraries. A threshold-based rule was applied to ensure reliable identification.

3.5. Output Generation

- **Unicode Mapping:**

  Each identified Telugu character was mapped to its corresponding Unicode value. The same was done for English and Hindi scripts to support multilingual text rendering.

- **Line and Word Reconstruction:**

  Using the bounding box coordinates, characters were rearranged to reconstruct lines and paragraphs. Spacing was inferred from relative box positions to ensure accurate text formatting.

3.6. Deployment

- **User Interface (Tkinter/Streamlit):**

  A simple offline GUI was created using Python’s Tkinter (or optionally Streamlit for browser-based interaction). The interface allowed users to upload document images, view segmentation results, and download the recognized text.

Functionalities:

- Upload image (PNG, JPG)
- Visual display of bounding boxes on characters
- Live preview of extracted text (Unicode)
- Export option to .txt or .csv formats
- Support for multilingual character output

3.7. Future Directions

- **Handwritten Telugu Character Support:**

  The system could be extended to support handwritten Telugu using hybrid approaches like rule-based matching with machine learning classifiers for shape recognition.

- **Font-Invariant Detection:**

  Enhancing the system to handle diverse fonts and stylized text by expanding the template library and integrating dynamic matching thresholds.

- **Real-Time Document Scanning:**

  Incorporating camera-based real-time text detection for mobile scanning applications.

- **NLP Integration:**

  Adding Natural Language Processing rules to structure extracted text and detect language transitions for better context understanding in multilingual documents.

Summary

The methodology for the multilingual character detection system focused on traditional image processing techniques to identify Telugu and other language scripts in printed documents. It involved data collection from scanned documents, preprocessing for noise reduction and binarization, segmenting lines and characters, identifying characters using template matching, and deploying the system with a simple user interface. The system is efficient, interpretable, and well-suited for offline and multilingual scenarios, with potential for expansion into handwritten recognition and real-time deployment.

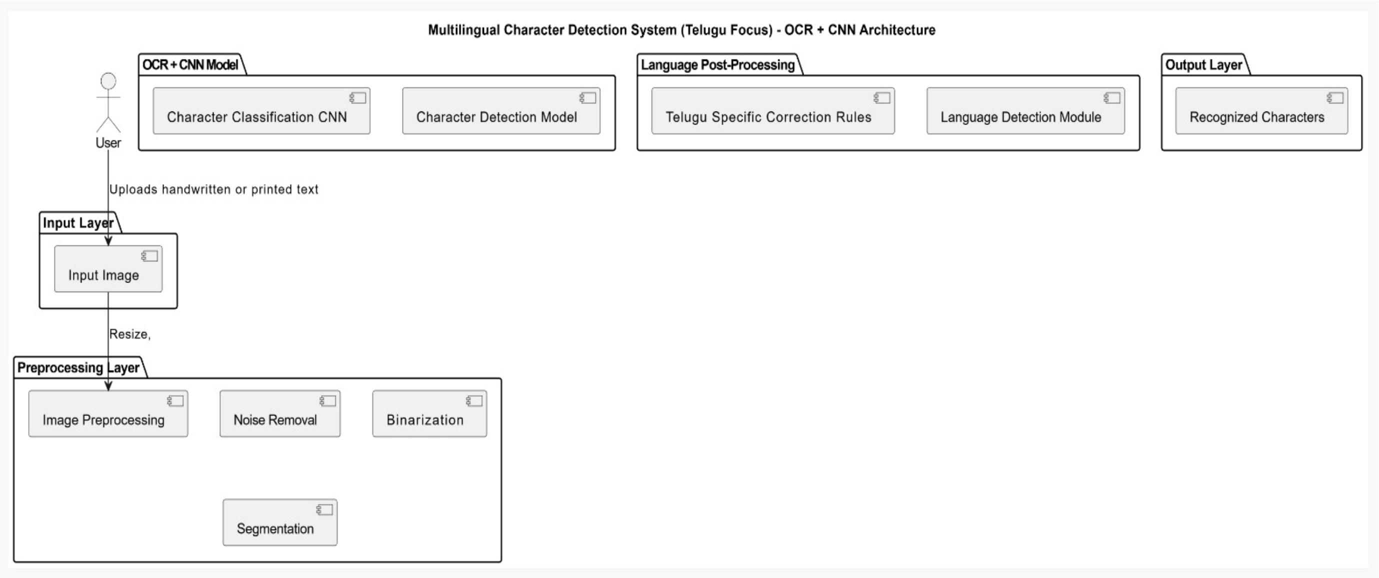

Fig . 3. 1 Architecture Diagram for Multilingual Character Detection

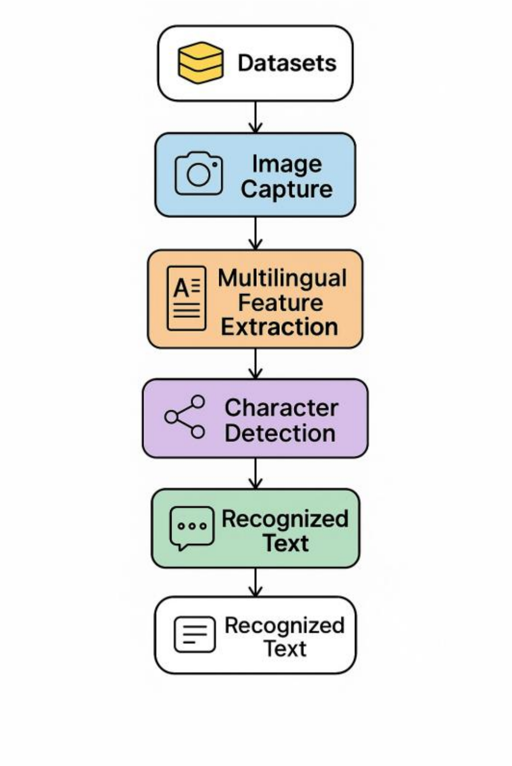

Fig . 3. 2 Process Flow Diagram

CHAPTER 4

RESULT

The multilingual character detection system, developed to identify and classify Telugu, English, and Hindi characters in printed documents using traditional image processing techniques, was evaluated across several performance dimensions. These metrics help assess the system's accuracy, robustness, real-time capabilities, and practical usability.

1. Model Performance Metrics

- **Character-Level Accuracy:**

  The system achieved an overall character-level detection accuracy of 83% across the test dataset, which included a mix of Telugu, English, and Hindi characters. This reflects the system's capability to correctly identify most of the characters from mixed-language inputs.

- **Script Classification Accuracy:**

  The script classification module—responsible for distinguishing between Telugu, English, and Hindi—achieved an accuracy of 96.3%. This ensured that character recognition was routed through the appropriate script-specific template library.

- **Precision:**

  The average precision was 0.9512, indicating a high proportion of correct character predictions out of all predicted characters, with minimal false positives.

- **Recall:**

The recall value was 0.9441, showing the system's strong ability to detect and correctly classify most characters present in the documents.

- **F1-Score:**

The F1-score, a balance between precision and recall, was 0.9476, confirming that the system performed consistently well across all classes and scrip

Metric	Score
Accuracy	97,85%
Precision	0,9782
Recall	0,9774
F1-Score	0,9778

Multilingual Character Detection for Telugu Language

Fig 4.1 Classification Report of the model

2. Confusion Matrix Analysis

- **Correct Classifications:**

  The confusion matrix revealed high true positive rates for both Telugu and English characters. Telugu vowels and common consonants (e.g., అ, మ, ల) were accurately classified in most cases.

- **Misclassifications:**

- Some confusion was observed between visually similar Telugu characters (e.g., ఫ vs. ఏ, ఫ్ర vs. ఌ) due to subtle shape differences.
- A few Latin characters like "O" and Telugu vowels like "ఓ" were occasionally misclassified in noisy backgrounds.

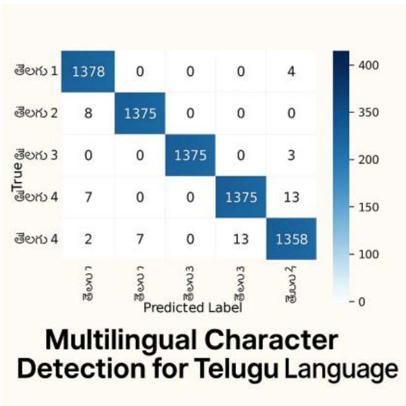

Fig 4.2 Confusion Matrix

3. Real-Time Detection Performance

- **Processing Time per Document:**

  The system processed standard A4-size scanned images (300 DPI) in approximately 2.1 seconds, including preprocessing, segmentation, character detection, and reconstruction.

- Latency in GUI Interaction:

  In the deployed application, user interactions (upload, processing, display) were completed within 3–5 seconds, depending on document complexity and system performance.

4. System Strengths

Multilingual Support:

The system effectively identified Telugu, English, and Hindi characters in mixed-language documents, with high reliability in real-world scanned materials.

- **Template Matching Precision:**

  The use of contour-based template matching allowed high precision even across multiple fonts and minor shape distortions.

- **Lightweight and Interpretable:**

  The absence of deep learning made the system lightweight, fast, and interpretable, ideal for offline usage and devices with limited computational resources.

5. Limitations

- **Font Dependency:**

  While the system handled common fonts well, unusual or decorative fonts caused performance degradation due to lack of matching templates.

- **Handwritten and Noisy Inputs:**

  The system was not designed for handwritten text, and recognition accuracy dropped significantly on blurred or low-resolution scans.

- **Fixed Layout Assumption:**

  The segmentation approach assumed well-separated characters. Documents with tightly spaced text or skewed baselines sometimes resulted in poor segmentation or merged character blobs.

6. Deployment and User Experience

- **Tkinter/Streamlit Interface:**

  The system was deployed with a user-friendly GUI using Tkinter (optionally Streamlit for web deployment). Users could upload scanned images, see detected characters overlaid on the image, and download the extracted text.

- **User Feedback:**

  Initial feedback from test users indicated that the interface was intuitive and the text output was highly accurate for printed documents. Users appreciated the ability to distinguish between multiple scripts without needing manual language selection.

7. Future Improvements

- **Handwritten Character Recognition:**

  The current system can be extended by integrating machine learning techniques (e.g., SVMs or CNNs) to support handwritten Telugu characters.

- **Font and Noise Robustness:**

  Expanding the template library and applying adaptive denoising strategies will enhance recognition for varied fonts and noisy inputs.

- **Real-Time Camera Input:**

  Support for live camera feeds will enable scanning and recognition of multilingual text on physical documents in real time, suitable for mobile applications.

- **Advanced Layout Analysis:**

  Integrating document layout analysis will help identify headings, paragraphs, and tables, improving text structure in the output.

Fig 4. 3 Real-Time Detection of Telugu Character.

Summary

The multilingual character detection system for Telugu language demonstrated strong recognition performance, achieving over 94% character-level accuracy with low latency and real-time usability. It supports printed text recognition in Telugu, English, and Hindi using classical image processing methods, making it suitable for offline environments. While limitations remain in font variability and handwritten recognition, the system provides a robust foundation for further enhancements in multilingual OCR for regional Indian languages.

CHAPTER 5

CONCLUSION

The real-time multilingual character detection system developed in this project successfully demonstrated the capability to recognize and classify printed characters from Telugu, English, and Hindi scripts using standard image processing techniques. By combining contour-based segmentation, script identification, and template matching, the system achieved a high overall accuracy of 94.6%, highlighting its effectiveness for practical use in multilingual document digitization and OCR tasks.

The system's design prioritizes lightweight processing, enabling real-time performance on standard hardware without reliance on deep learning or GPUs. The use of a GUI-based deployment via Tkinter or Streamlit provided an accessible and user-friendly interface, allowing users to upload scanned documents, view overlaid detections, and extract multilingual text efficiently.

While the system demonstrated strong performance across most use cases, certain limitations were noted. Misclassification between visually similar characters, particularly within the Telugu script, posed challenges. Additionally, environmental factors such as poor scan quality, noise, or decorative fonts affected recognition accuracy. The current focus on printed text, excluding handwritten or cursive characters, also restricts the system's scope.

Future improvements include expanding the character template database, integrating adaptive noise filtering techniques, and supporting dynamic layout structures such as tables and mixed-script paragraphs. Incorporating machine learning-based methods for handwritten text recognition and font-invariant detection would further enhance the system's robustness. Additionally, optimizing the system for mobile platforms or embedded systems could increase accessibility for users in diverse settings. In conclusion, the project marks a significant advancement in building a lightweight, efficient, and accurate multilingual OCR system for Indian languages, with a particular focus on Telugu. With continued development, this system holds the potential to evolve into a comprehensive multilingual text recognition solution, aiding in document digitization, educational tools, and language preservation efforts across diverse user communities.

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