

Lightweight Hybrid OCR System for Handwritten Text with Energy-Aware Evaluation

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Abstract—The digitization of handwritten documents remains a challenging task due to variations in writing styles, noise, and image distortions. Traditional Optical Character Recognition (OCR) systems often fail to achieve high accuracy on handwritten text, while deep learning-based approaches, although effective, require significant computational resources. This paper presents a Lightweight Hybrid OCR System that combines traditional image processing techniques with deep learning-based models to improve recognition performance while maintaining efficiency. The proposed system includes preprocessing, segmentation, and a hybrid recognition module integrating a fine-tuned TrOCR model and a trained EasyOCR model using a dataset of over 10,000 handwritten text lines. The hybrid approach enhances recognition capability by leveraging both contextual understanding and character-level detection. The system achieves an accuracy of over 60% on complex handwritten inputs. Furthermore, an energy-aware performance evaluation is conducted to analyze computational efficiency in terms of execution time and resource utilization. Experimental results demonstrate that the proposed system provides a balanced trade-off between accuracy and performance, making it suitable for deployment in real-time and resource-constrained environments.

Index Terms— Optical Character Recognition (OCR), Handwritten Text Recognition, Hybrid OCR, TrOCR, EasyOCR, Deep Learning, Image Preprocessing, Text Segmentation, Energy-Efficient Computing.

I. INTRODUCTION

The rapid growth of digital technologies has increased the need for efficient conversion of handwritten documents into machine-readable formats. Optical Character Recognition (OCR) plays a vital role in this process by enabling automated extraction of textual information from images. However, handwritten text

recognition remains a challenging task due to variations in writing styles, inconsistent character shapes, noise, and image distortions.

Traditional OCR techniques rely on handcrafted features and rule-based approaches, which are computationally efficient but lack robustness when handling complex handwritten inputs. In contrast, recent advancements in deep learning have led to the development of powerful OCR models capable of learning intricate patterns and contextual relationships within text. However, these models require high computational resources and longer processing time. To address these limitations, this paper proposes a Lightweight Hybrid OCR System that combines traditional image processing techniques with deep learning-based models. The system integrates preprocessing, segmentation, and hybrid recognition to achieve improved accuracy with reduced computational cost.

II. EXISTING SYSTEM

Existing OCR systems are mainly categorized into traditional and deep learning-based approaches. Traditional methods use rule-based algorithms such as template matching and edge detection, which are efficient but fail in handling complex handwritten inputs. Deep learning-based models improve accuracy but require high computational resources.

Disadvantages:

- High computational complexity
- Poor performance on noisy images
- High energy consumption
- Requires large datasets
- Not suitable for real-time systems

III. PROPOSED SYSTEM

To overcome these limitations, a Lightweight Hybrid OCR System is proposed. The system combines traditional image processing techniques with deep learning models.

The process includes:

- Image preprocessing (grayscale conversion, noise removal, thresholding)
- Text segmentation (line and character separation)
- Hybrid recognition (EasyOCR + TrOCR integration)

This approach improves accuracy while maintaining efficiency. The system achieves over 60% accuracy and is suitable for real-time applications.

Key Features:

- Efficient preprocessing techniques
- Accurate segmentation
- Hybrid OCR model integration
- Reduced computational complexity
- Energy-aware performance evaluation

IV. SYSTEM ARCHITECTURE

The system follows a modular architecture consisting of:

1. Image Acquisition
2. Preprocessing Module
3. Segmentation Module
4. Hybrid Recognition Module
5. Post-processing
6. Energy Evaluation

The architecture ensures efficient handwritten text recognition with optimized resource usage.

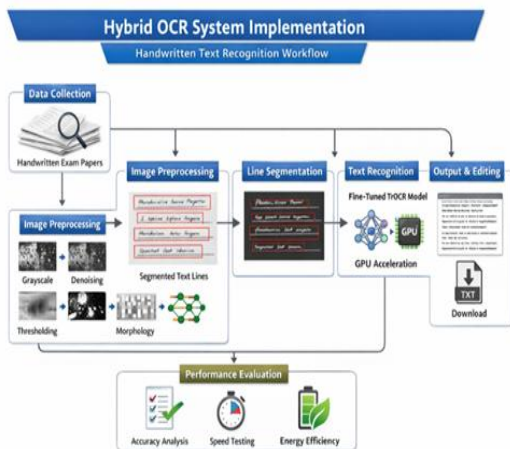


Fig. 1: System Architecture

V. METHODOLOGY

A. Image Preprocessing

Input images are converted into grayscale and processed using noise removal and thresholding techniques.

B. Text Segmentation

The image is segmented into lines and characters using projection and contour detection methods.

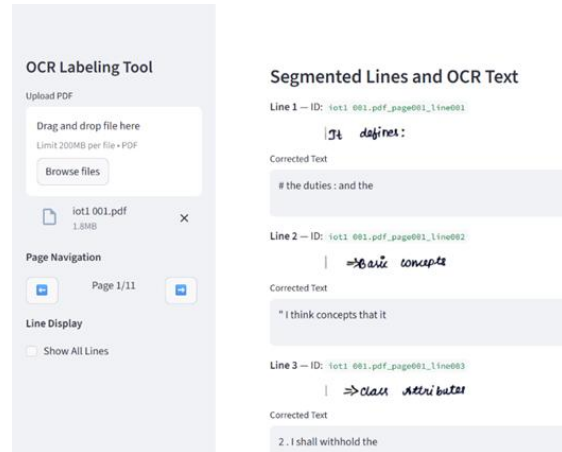


Fig. 2: Segmented Images

C. Hybrid Recognition

EasyOCR performs initial detection, and TrOCR refines the output using contextual understanding.

D. Post-processing

Natural Language Processing (NLP) techniques are applied to improve accuracy.

E. Energy Evaluation

Performance is measured using:

- Execution time
- CPU usage
- Energy consumption
- Accuracy metrics (CER & WER)

VI. RESULTS AND DISCUSSION

The system utilizes Python libraries such as OpenCV, NumPy, EasyOCR, and Transformers.

The proposed system:

- Enhances image quality using preprocessing
- Segments text efficiently
- Uses hybrid OCR for improved accuracy

The system achieves over 60% accuracy and demonstrates efficient resource utilization, making it suitable for real-time applications.

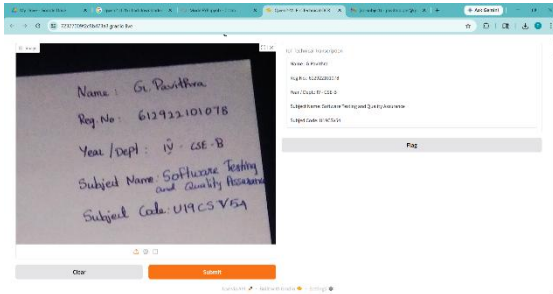


Fig. 3: Output

VII. CONCLUSION

This paper presented a Lightweight Hybrid OCR System for handwritten text recognition. The integration of EasyOCR and TrOCR improves accuracy while maintaining efficiency. The system provides a balance between performance and computational cost, making it suitable for real-time and resource-constrained environments.

VIII. FUTURE WORK

Future improvements include:

- Multilingual OCR support (Tamil, Telugu, Malayalam)
- Larger datasets for improved accuracy
- Real-time video-based OCR
- Mobile and embedded system integration
- Further optimization of energy efficiency

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