

Abstract

In an era increasingly driven by digital information systems, vast collections of handwritten records such as historical archives, government documents, personal notes, and administrative forms remain locked in analogue form, inaccessible to modern digital processing tools. The manual transcription of these records is labor-intensive, time-consuming, and prone to errors, necessitating the development of reliable and automated systems for handwritten text digitization.

This project presents a comprehensive **Handwritten Character Recognition (HCR) System**, utilizing state-of-the-art machine learning and deep learning techniques to accurately identify and convert handwritten characters into machine-readable text. The proposed approach integrates a **hybrid deep learning model** combining **Convolutional Neural Networks (CNNs)** for spatial feature extraction with **Recurrent Neural Networks (RNNs)**, specifically **Long Short-Term Memory (LSTM)** networks, for capturing sequential dependencies within handwriting patterns. Further, the system incorporates the cutting-edge **Transformer-based OCR model, TrOCR**, which leverages attention mechanisms for superior recognition accuracy, especially in cursive and free-form handwritten texts.

To train and evaluate the system, standardized benchmark datasets such as **MNIST, Kaggle A-Z**, and **IAM Handwriting Database** were used, representing a diverse range of writing styles, character sizes, and image conditions. The project undertakes rigorous **preprocessing techniques** including image normalization, noise removal, and data augmentation to enhance model robustness. It further employs **post-processing methods** like beam search decoding and dictionary-based corrections to refine output accuracy.

The system's performance was assessed using standard evaluation metrics: **accuracy, precision, recall, and F1-score**. The hybrid CNN-RNN model achieved an accuracy of **93.8%**, outperforming standalone CNN and RNN architectures. However, the **TrOCR model significantly outperformed all other methods**, achieving a remarkable **97.5% accuracy**, confirming the superiority of attention-based models in complex handwriting recognition tasks.

This project not only demonstrates the feasibility of deploying advanced AI models for handwritten text recognition but also highlights their transformative potential for various real-world applications, including **automated form processing, document digitization, banking, medical record systems, and historical archive preservation**. The system's scalability and adaptability further suggest opportunities for future enhancement through **reinforcement learning, multi-lingual support, and deployment in mobile or embedded platforms** for real-time applications.