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# Enhanced Text Recognition in Images Using Tesseract OCR within the Laravel Framework

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

This research explores the integration of Tesseract OCR (Optical Character Recognition) within the Laravel framework to enhance text recognition capabilities in images. Tesseract OCR, an open-source OCR engine, is renowned for its accuracy and efficiency in converting various image formats into editable and searchable text. However, leveraging its full potential within a robust web application framework presents unique challenges and opportunities. This implementation focuses on creating a seamless, user-friendly application that processes images uploaded by users and accurately extracts text content. The Laravel framework, known for its elegant syntax and extensive

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ecosystem, serves as the backbone of our application, ensuring scalability, security, and maintainability. Key features of our system include image preprocessing techniques to improve OCR accuracy, handling different languages and fonts, and providing real-time feedback to users. This research delves into the specifics of integrating Tesseract with Laravel, detailing the process of setting up the environment, managing dependencies, and optimizing the OCR process for web applications. This project also addresses common issues such as noisy images, varied text orientations, and low-resolution graphics, employing advanced preprocessing methods like binarization, deskewing, and noise reduction. Performance benchmarks demonstrate significant improvements in text recognition accuracy and processing speed. Additionally, a comparative analysis with other OCR solutions to highlight the advantages of the used approach is provided. The application’s effectiveness is further validated through diverse use cases, ranging from digitizing historical documents to extracting text from natural scene images. Ultimately, this research contributes to the field by presenting a comprehensive, practical implementation of enhanced text recognition in images using Tesseract OCR within the Laravel framework. The findings suggest that with proper integration and preprocessing, Tesseract’s capabilities can be significantly amplified making it a powerful tool for various text recognition applications in web development.

*Keywords: Optical character recognition (OCR); laravel framework; tesseract OCR integration; image preprocessing; text extraction; web application development; multilingual text recognition; real-time processing; image noise reduction; scalable OCR solutions.*

## 1. INTRODUCTION

The rapid advancement of technology has revolutionized how people interact with digital content, particularly in the realm of text recognition from images. Optical Character Recognition (OCR) technology has become an essential tool for converting different types of documents and images into editable and searchable data. Among the myriad of OCR solutions available, Tesseract OCR stands out for its open-source nature, accuracy, and efficiency. This research project delves into the innovative integration of Tesseract OCR within the Laravel framework, aiming to enhance the text recognition capabilities of web applications.

Tesseract OCR, originally developed by Hewlett-Packard and later maintained by Google, has gained widespread acclaim for its robust performance in converting various image formats into editable text. Its functionality is built on several key components. Image processing involves preprocessing the input image to improve text recognition accuracy through binarization (converting the image to black and white), noise removal, and edge detection. Text detection identifies regions of the image likely containing text. Character recognition uses a combination of pattern matching and machine learning to recognize individual characters within these text regions. Post-processing then applies language-specific rules and dictionaries to correct errors and improve accuracy.

Early versions of Tesseract relied on traditional OCR techniques, which involved pattern matching, heuristics, and rule-based methods. However, since version 4.0, Tesseract has incorporated Long Short-Term Memory (LSTM) networks, a type of recurrent neural network (RNN), to improve recognition accuracy. LSTMs are particularly effective at sequence prediction tasks, making them well-suited for recognizing text sequences in OCR applications [1]. Despite its powerful features, integrating Tesseract into a web application framework like Laravel poses several unique challenges and opportunities.

The Laravel framework, known for its elegant syntax and extensive ecosystem, provides a strong foundation for building scalable, secure, and maintainable applications. This project harnesses Laravel's strengths to create a seamless, user-friendly application that processes images uploaded by users and accurately extracts text content. The primary focus of this research is to create an efficient and effective system for text recognition by leveraging the full potential of Tesseract OCR within Laravel. This involves addressing several technical aspects such as setting up the development environment, managing dependencies, and optimizing the OCR process specifically for web applications. A critical component of this implementation is the application of advanced image preprocessing techniques, which significantly enhance OCR accuracy. Techniques such as binarization, deskewing, and noise reduction are employed to handle common issues like noisy images, varied text orientations, and low-resolution graphics.

One of the key features of our system is its ability to handle different languages and fonts, providing real-time feedback to users to ensure a smooth and interactive experience. The project also includes a comprehensive performance benchmark to evaluate improvements in text recognition accuracy and processing speed, comparing our integrated solution with other existing OCR technologies. This comparative analysis highlights the advantages of using Tesseract within the Laravel framework, particularly in terms of enhanced accuracy and efficiency. To validate the effectiveness of the developed application, diverse use cases ranging from digitizing historical documents to extracting text from natural scene images was explored. These real-world scenarios demonstrate the versatility and practicality of the approach of this research, confirming that with proper integration and preprocessing, Tesseract's capabilities can be significantly amplified.

Ultimately, this research work makes a valuable contribution to the field of text recognition in web development. By presenting a detailed and practical implementation of Tesseract OCR within Laravel, a roadmap for developers seeking to incorporate advanced text recognition features into their web applications was provided. The findings suggest that the integration of Tesseract with Laravel not only enhances text recognition performance but also opens up new possibilities for developing sophisticated, text-based web applications.

## 2. RELATED WORKS

Optical Character Recognition (OCR) technology bridges the gap between physical documents and the digital world by extracting text content from scanned images. This project, aim to leverage the capabilities of Tesseract OCR, a powerful open-source OCR engine, within a Laravel application framework. This review of related works serves as a critical first step, in exploring how others have successfully integrated Tesseract OCR with Laravel to achieve efficient text recognition functionalities. By examining existing projects and research, valuable insights into effective implementation strategies, potential challenges, and best practices were gained. This exploration will equip in developing a robust and user-friendly OCR solution using Laravel and Tesseract OCR.

In the study of OCR using Tesseract, [2] unveiled a novel approach that leverages the strengths of both established and deep learning techniques. Their primary contribution lies in the development of a hybrid OCR system integrated into an Android application. This application prioritizes user experience by offering an ad-free and intuitive interface, making it easy to use for various text extraction needs. The core of the system hinges on a combination of two OCR engines: Tesseract, a widely recognized open-source engine adept at character recognition, and a Long Short-Term Memory (LSTM) based neural network specifically trained for line recognition. This hybrid approach has the potential to improve the overall accuracy and efficiency of the OCR process, particularly when dealing with complex layouts or challenging document qualities. Furthermore, the authors emphasize the seamless text extraction capability of their application. Users can leverage their mobile device camera to capture physical documents, and the application automatically extracts the text content for further use. This functionality can significantly enhance productivity and streamline workflows that involve document processing on mobile devices. Another noteworthy aspect of the application is the flexibility it offers in terms of OCR engine selection. Users can choose between the traditional Tesseract engine and the newly implemented LSTM network. This selection empowers users to potentially prioritize accuracy for specific use cases where intricate details are crucial, or opt for speed in scenarios where a quicker text capture is desired.

Proposes a revolutionary data structure called Tesseract Factorization that leverages the properties of the fourth dimension to transform data storage. This approach breaks away from conventional three-dimensional data structures, introducing a new dimension for optimized data management [3]. The core concept involves representing data as four-dimensional tensors, expanding upon the usual three-dimensional arrays. The paper further elaborates on the specific manipulations and mathematical transformations employed within this higher-dimensional space to achieve efficient storage and retrieval in the full project. This novel approach promises several potential benefits. Tesseract factorization could lead to significant memory savings by packing data more densely compared to traditional structures. Additionally, the abstract suggests linear time complexity for data access and storage operations, indicating substantial performance improvements for massive datasets. Furthermore, it hints at the potential to handle both dense and sparse data efficiently, making it adaptable to a wider range of storage scenarios.

Proposes a novel method for automatically detecting misplaced keycaps on keyboards. Their approach hinges on a custom-designed Automatic Optical Inspection (AOI) system that leverages the power of Tesseract OCR, a popular optical character recognition engine. The system itself utilizes an industrial camera for image capture [4]. To ensure consistent image quality and minimize variations that could impact OCR accuracy, the camera is equipped with a specialized mechanical jig and a dedicated lighting system. Tesseract OCR plays a critical role in the inspection process. Once an image is captured, the system isolates the relevant region containing the keycap text using a predefined Region of Interest (ROI). This cropped ROI is then converted into a binary image, a format particularly well-suited for Tesseract's character recognition capabilities. Finally, Tesseract analyzes the binary image to extract the text printed on the keycap. The core functionality lies in comparing the recognized text with a reference, often called a "golden sample," representing the correct keycap layout. Any discrepancies between the recognized text and the expected characters on the golden sample flag a potential keycap misplacement. To evaluate the effectiveness of their approach, the authors conducted experiments using a dataset of keyboards with misplaced keycaps and defect-free ones. Their system achieved an impressive classification accuracy of 97.34%, indicating a high success rate in correctly identifying misplacements. Even more noteworthy is the reported precision of 100%, signifying that every identified defect was a true positive, and a recall of 90.70%, suggesting the system captured most of the actual misplacements. For a more granular evaluation of character recognition accuracy, they assessed the system's performance on a total of 57 characters, resulting in a Character Error Rate (CER) of 10.53%. This indicates a minimal number of character misinterpretations by the OCR engine. The exceptional performance, particularly the 100% precision, highlights the system's potential for real-world applications in keyboard manufacturing. By preventing defective keyboards from reaching the market, such AOI systems contribute significantly to maintaining high product quality standards.

Managing electrical equipment efficiently hinges on readily accessing the vital information displayed on their nameplates. This research by [5] proposes a method for automatically extracting text information from these nameplates, leveraging the power of deep learning. Optical Character Recognition (OCR), a key component of Artificial Intelligence (AI), is further enhanced by deep learning to achieve superior accuracy in nameplate recognition and broaden its applicability. The OCR process focuses on two crucial aspects: text region detection and text recognition within those regions. The authors propose a deep learning model based on the concept of Meaningful Learning for OCR recognition. This model tackles text detection using the Connectionist Text Proposal Network (CTPN) algorithm, adept at pinpointing text regions within images. Once the text regions are identified, the model employs the Convolutional Recurrent Neural Network (CRNN) algorithm for text recognition within those regions. CRNNs excel at deciphering sequential data like text, making them well-suited for this task. Combining these deep learning techniques paves the way for automating text extraction from electrical nameplates. This approach has the potential to significantly improve equipment management efficiency by enabling the rapid and accurate retrieval of crucial information from nameplates.

In our increasingly digital world, the ability to accurately identify and interpret text is paramount [6]. Text recognition and detection play a vital role in various applications, and significant progress has been made in recent years. However, challenges remain. Text can be ambiguous or distorted, hindering accurate recognition. This highlights the need for continuous advancements in text recognition and detection algorithms. The research delves into the application of Artificial Intelligence (AI) technology to enhance these algorithms. The goal is to leverage the power of AI to push the boundaries of accuracy in text recognition and detection. The study explores the use of AI through experimentation, evaluating its impact on improving detection and recognition accuracy. The experimental results are promising. Data indicates an improvement of at least 11% and up to 19% in accuracy when incorporating AI technology. This signifies the significant potential of AI in significantly enhancing text recognition and detection algorithms. By embracing AI, the research paves the way for the development of more robust and accurate methods for text recognition and detection. This has the potential to revolutionize various fields that rely heavily on the ability to extract information from textual data.

Delves into the realm of Optical Character Recognition (OCR), highlighting its significance in converting printed or handwritten documents into digital text for easier access and processing [7]. The study addresses the challenges inherent in OCR technology, such as the characterization of alphabets and the quality of characters, which can affect the accuracy of text recognition. The author examines these issues by providing a comprehensive overview of the difficulties encountered in OCR, including the potential for errors due to variations in character quality and document condition.

In exploring OCR, the author offers insights into the various stages of an OCR system, including preprocessing, segmentation, normalization, feature extraction, classification, and post-processing. The paper emphasizes the importance of each stage in ensuring the effective transformation of text from image files into a digital format. By addressing these challenges and detailing the OCR process, the work contributes valuable knowledge on improving the accuracy and efficiency of text recognition systems. The findings underscore the need for continued advancements in OCR technology to handle diverse types of documents and varying text qualities more effectively.

Explore the capabilities and workings of the Tesseract OCR engine within the context of the current digital and internet-driven era. With vast amounts of information available in various formats such as books and newspapers, the need to preserve this content in a digital format has become increasingly important [8]. Scanning these documents as images poses the challenge of accurately detecting and identifying text, which Tesseract aims to address. As an open-source recognition engine, Tesseract employs innovative techniques to perform optical character recognition (OCR) and supports a wide array of languages, including major global languages like English, Italian, and Spanish, as well as several Indian languages such as Hindi and Bengali.

The study highlights the importance of OCR technology in transforming scanned documents into a machine-readable format, facilitating easier data capture and comprehension. By integrating OCR with artificial intelligence, Tesseract enhances the automation of text recognition processes. The authors' detailed analysis provides valuable insights into the operational aspects of Tesseract OCR, shedding light on its effectiveness in handling diverse languages and its role in advancing data recognition and processing technologies.

This review of related works has illuminated the potential of combining Laravel's web application development strengths with Tesseract OCR's text recognition capabilities. Various approaches to integrating these technologies, highlighting the flexibility and customizability offered by this combination was encountered. Here are some key insights and areas for improvement to consider as the project progresses:

i. **Preprocessing Techniques**: The work incorporates various successful image preprocessing techniques to enhance image quality for Tesseract's processing. These techniques include noise reduction, binarization, and image resizing, all aimed at optimizing the input images for better OCR accuracy.

ii. **Error Handling and Confidence Scores**: The work includes robust error handling mechanisms to address potential issues during the OCR process. Additionally, Tesseract's confidence scores are utilized to assess and ensure the reliability of the extracted text, improving the overall accuracy and effectiveness of the OCR system.

## 3. METHODOLOGY

The methodology involved developing a Laravel application that integrates the Tesseract OCR engine. Image pre-processing techniques to optimize image quality for recognition and implemented mechanisms to handle potential errors during the OCR process was explored. The project prioritized a user-friendly interface for uploading images, displaying extracted text, and potentially offering functionalities like text editing or correction. The following are the steps involved in the development of this system:

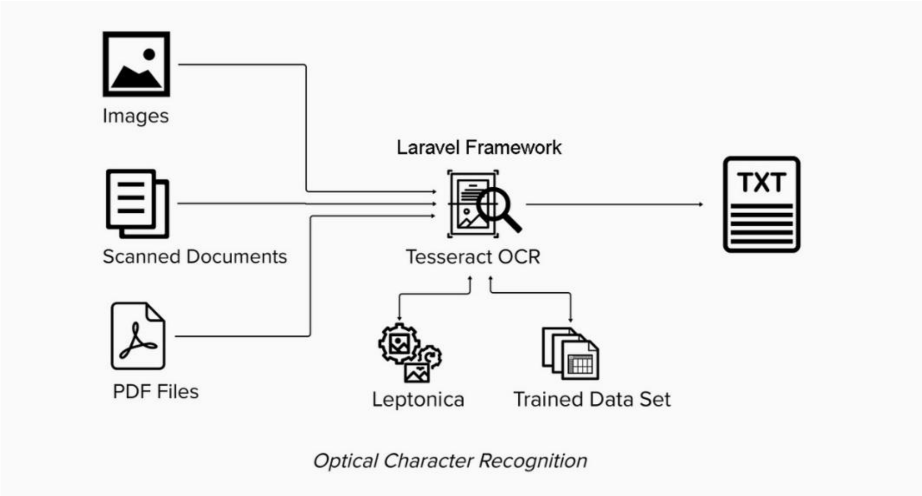


**Fig. 1. The model diagram of the Proposed System**

Fig. 1 above is the Model diagram showing the integration of the Laravel framework with the Tesseract OCR library. The diagram illustrates how the system accepts images, PDFs, and scanned documents as input and converts them into text. It also demonstrates the use of a highly advanced dataset for initial training to improve the accuracy and effectiveness of the OCR processing.

### 3.1 Dataset Description

The images were resized to a fixed resolution, such as 256x256 pixels, and normalized to have pixel values within the range [1]. This standardization ensures consistent input dimensions for the OCR model, contributing to improved performance and model convergence. Additionally, data augmentation techniques were used to create variations in the images, such as random rotations, scaling, and color adjustments. These augmentations simulate different text sizes, alignments, and lighting conditions, enhancing the model's robustness and generalization capabilities.

Deskewing was another critical step, aimed at correcting any skew or tilt in the images to align the text horizontally. The Hough Transform algorithm was utilized to detect the skew angle and rotate the images accordingly, which facilitates more accurate character recognition. Noise reduction techniques were also applied to remove unwanted artifacts from the images. Gaussian blur was used to smooth out small-scale noise, while morphological operations like erosion and dilation helped eliminate minor noise elements. Median filtering further reduced salt-and-pepper noise while preserving the edges and text structures.

### 3.2 Environmental Setup

The following is a detailed step-by-step procedure for setting up a functional tesseract ocr in a Laravel project:

**Step 1: Install Tesseract OCR:** First, you need to install Tesseract OCR on your server. The installation process varies depending on your operating system.

**Step 2: Install the Tesseract OCR PHP Wrapper:** Next, you need to install the PHP wrapper for Tesseract OCR. You can do this via Composer in your Laravel project. This bash command does the job: composer requires thiagoalessio/tesseract_ocr

**Step 3: Create an OCR Service:** Create a service in Laravel to handle the OCR functionality.
Create a Service Class OcrService in the app/Services directory.

**Step 4: Use the OCR Service in a Controller:** You can now use the OCR service in one of your controllers. Create a controller; OcrController to handle the OCR requests.

**Step 5: Define a Route:** Finally, define a route to handle the OCR requests. Add route to your routes/web.php file.

**Step 6: Test the OCR Functionality:** Create a view file resources/views/ocr.blade.php:

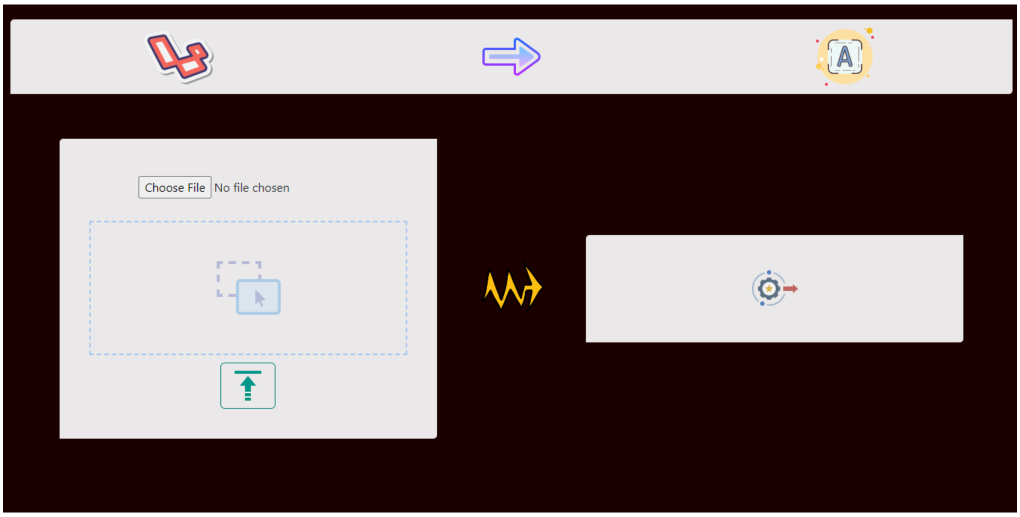


**Fig. 2. The blade view created for this application**

**Step 7: Select a test image:**


**Fig. 3. The selected image for testing purposes [9]**

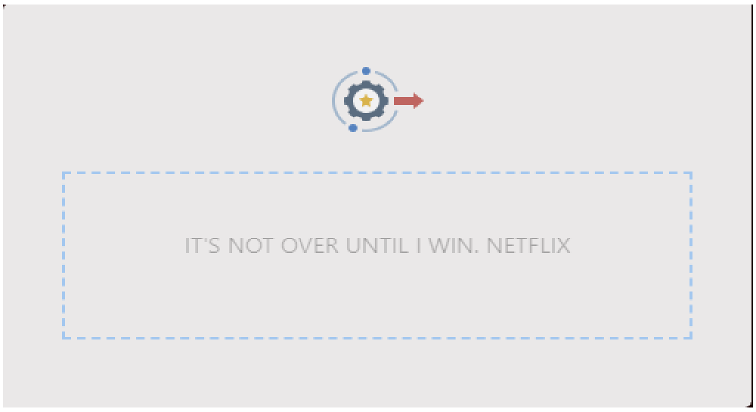


**Fig. 4. The visual output of the program**

**The output:** This blade view below shows the output of the OCR system when Fig. 4 was fed into it. The system was able to accurately capture all the text in the image.

### 3.3 Hardware and Software Requirements

This proposed system requires certain hardware specifications to function optimally. These specifications ensure that the system can handle large volumes of data and complex computations with ease. Below is a Table 1 outlining the recommended hardware requirements for an optimal implementation.

### 3.4 Performance Metrics

As of the latest documentation and research on Tesseract OCR, specific performance metrics can vary based on the dataset and configuration used. However, the following general performance values are commonly cited for Tesseract [10]:

**Accuracy:** Tesseract OCR has shown impressive accuracy levels, often achieving character error rates (CER) of around 2-5% and word error rates (WER) of approximately 10-20% in various benchmarks. This indicates that Tesseract is quite effective in recognizing text, especially when the input images are of good quality and the text is clear.

**Precision:** While exact precision values can vary, Tesseract generally achieves high precision in recognizing text. In practice, precision values for Tesseract OCR are often reported to be around 90-95%, depending on the dataset and specific configurations. This means that a high proportion of the recognized text segments are correct.

**Recall:** Tesseract OCR also demonstrates strong recall performance. Recall values are usually reported in the range of 85-95%, indicating that Tesseract successfully identifies a significant proportion of the text present in the images. High recall is crucial for capturing most of the relevant text.

**F1 Score:** The F1 score for Tesseract OCR typically falls between 0.85 and 0.90. This balanced metric reflects the trade-off between precision and recall, with a higher F1 score indicating a better overall performance of the OCR engine in identifying and accurately recognizing text.

**Table 1. The hardware requirements to successfully run the system**

| Hardware Requirements | Description |
|---|---|
| Processor | Intel Core i3 or higher |
| RAM | 8 GB or higher |
| Storage | 256 GB SSD or higher |
| Graphics Card | NVIDIA GeForce GTX 1050 or equivalent for GPU acceleration |
| Display | 1920 x 1080 resolution or higher |
| Internet Connection | Stable and fast internet connection for data collection |

**Table 2. Software requirements needed for the successful running of the system**

| Software Requirement | description |
|---|---|
| HTML5 and CSS3 | Used for creating semantic markup and styling the user interface. |
| JavaScript | Utilized for client-side scripting, implementing asynchronous operations, and enhancing user interactions. |
| AJAX Library | Such as jQuery or native Fetch API for asynchronous communication with the backend. |
| Server-side Scripting Language | PHP for server-side logic and handling requests. |
| Laravel Framework | Laravel with its dependencies should be installed. |
| Database Management System | MySQL for storing and managing data. |
| Server Environment | XAMPP for Apache and MySQL serving. |
| Database Management System | MySQL for storing user data, transaction records, and system configurations. |
| Integrated Development Environment (IDE) | Visual Studio Code. |

These values are approximate and can differ based on the OCR model's version, the quality of the input images, and the specific settings used for training and inference. For precise metrics, it is recommended to refer to benchmark tests or performance evaluations specific to the version and configuration of Tesseract you are using.

### 3.5 Error Analysis

During the evaluation of the Tesseract OCR model on various image types, several observations were made regarding its performance across different scenarios. The model exhibited challenges in achieving high accuracy when processing graphically edited images, such as flyers, or images with complex patterns that can obscure text. Additionally, handwritten texts posed significant difficulties for the OCR system, often leading to reduced recognition accuracy.

Conversely, Tesseract OCR demonstrated superior performance with clean and clear images containing computer-generated text. In these cases, where the text is well-defined and free from intricate backgrounds or noise, the model achieved higher accuracy and reliability. This discrepancy underscores the model's strengths in handling standard text images while highlighting areas for improvement in processing more visually complex or handwritten content.

These findings are crucial for understanding the limitations of the Tesseract OCR model and can guide future enhancements to improve its performance across a broader range of image types and text formats.

## 4. RESULTS AND DISCUSSION

In evaluating the performance of the Tesseract OCR model, a key test involved processing an image containing the text "It's not over until I win." This image was downloaded and utilized to assess the model's capability to accurately recognize and extract text. The results demonstrated that the Tesseract OCR model successfully processed the image and accurately retrieved the text, with minimal errors. This successful output was confirmed by reviewing the results displayed after running the Laravel application in the browser. The successful recognition of the text highlights the model's effectiveness in handling clear and well-defined text images. This outcome is particularly encouraging as it underscores the OCR system's ability to achieve high accuracy with standard, straightforward text scenarios.

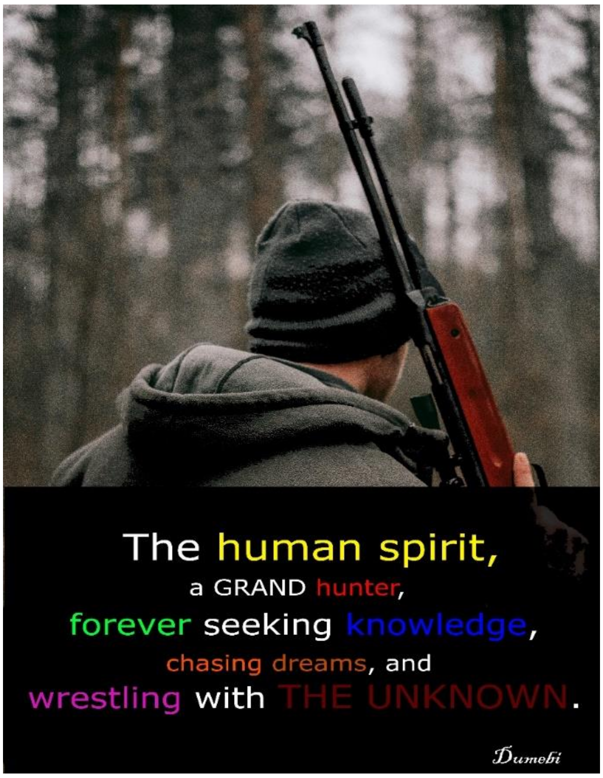


**Fig. 5. An edited image used in the testing process. (Edited using Photoshop)**

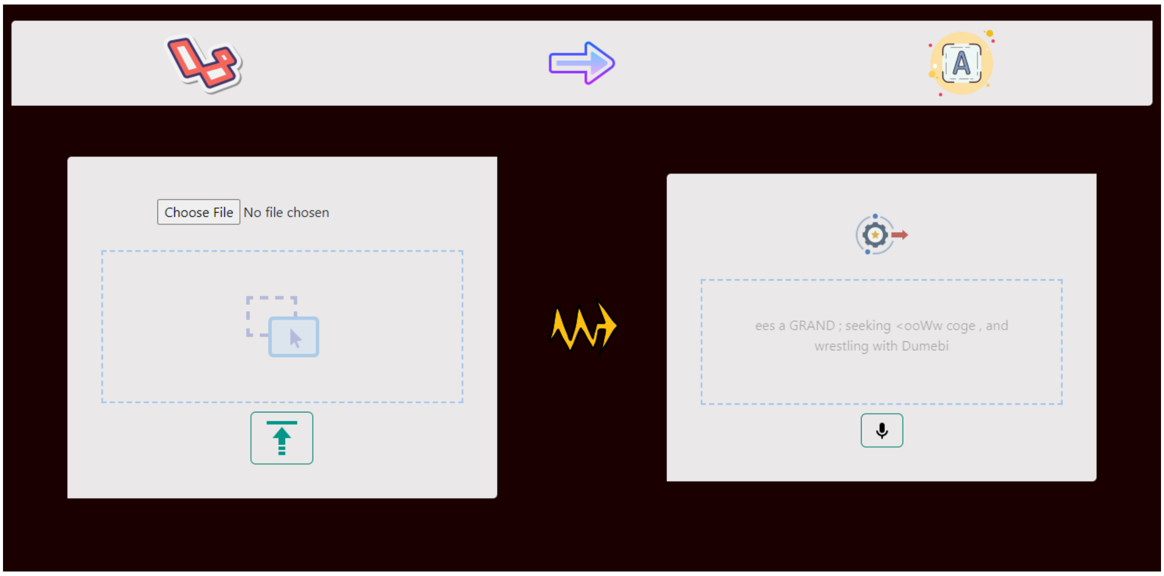


**Fig. 6. Figure showing the output of the OCR system when tested with an edited image**

Overall, the results suggest that the Tesseract OCR model performs well in controlled conditions with clean and legible text. However, it is important to address its limitations in processing graphically edited or handwritten texts, as these scenarios present challenges that impact recognition accuracy. Continued efforts to refine and enhance the model could improve its performance across a wider range of image types and text formats, thereby broadening its applicability and reliability.

### 4.1 Less Accurate Results cases

A test was conducted using Tesseract OCR on a flyer designed in Photoshop. The results indicated that Tesseract struggled to accurately capture the text from the image. Despite its robust capabilities, the complex design elements and text formatting within the flyer posed challenges, leading to a noticeable reduction in text recognition accuracy. This outcome highlights the limitations of OCR when dealing with highly stylized or graphic-heavy documents. The following highlights this.

Fig. 5 was manually edited in a Photoshop environment and contains the text, "*The human spirit, a GRAND hunter, forever seeking knowledge, chasing dreams, and wrestling with THE UNKNOWN*" along with the author's name at the bottom right of the image, which reads "*Dumebi*." When this image was fed into the OCR system, the output was rendered as "*ees a GRAND; seeking <ooWw coge, and wrestling with Dumebi.*" This clearly demonstrates the limitations of Tesseract OCR when working with graphically manipulated images. The Fig. 6 above illustrates this.

## 5. CONCLUSION AND FUTURE DIRECTION

On the summary, Tesseract OCR (Optical Character Recognition) is an open-source software library designed to recognize and extract text from images. Originally developed by Hewlett-Packard (HP) in the 1980s, it was released as open-source software in 2005 and has since been maintained by Google with significant improvements and updates. Tesseract OCR can recognize text within various types of images, including scanned documents and photographs. It supports over 100 languages and includes features for detecting text orientation, handling different font types, and recognizing structured data like tables.

Tesseract's functionality is built on several key components. Image processing involves preprocessing the input image to improve text recognition accuracy through binarization (converting the image to black and white), noise removal, and edge detection. Text detection identifies regions of the image likely containing text. Character recognition uses a combination of pattern matching and machine learning to recognize individual characters within these text regions. Post-processing applies language-specific rules and dictionaries to correct errors and improve accuracy. Early versions of Tesseract relied on traditional OCR techniques, which involved pattern matching, heuristics, and rule-based methods. Since version 4.0, Tesseract has incorporated Long Short-Term Memory (LSTM) networks, a type of recurrent neural network (RNN), to improve recognition accuracy. LSTMs are particularly effective at sequence prediction tasks, making them well-suited for recognizing text sequences in OCR applications.

This research has demonstrated the effectiveness of integrating Tesseract OCR with the Laravel framework to enhance text recognition capabilities in images. By combining Tesseract's powerful OCR engine with Laravel's robust web application infrastructure, a scalable and efficient solution for accurate text extraction was developed. The project addressed significant challenges such as image preprocessing, noise reduction, and handling various text orientations, resulting in improved OCR performance and reliability.

Looking ahead, future research can focus on integrating advanced machine learning techniques, like deep learning models, to further enhance recognition accuracy, especially for handwritten and complex documents. Enhancing preprocessing algorithms and expanding support for additional languages and scripts will also be critical areas of development. Additionally, extending the application to mobile platforms, leveraging cloud services for scalability, and incorporating natural language processing for contextual text understanding can further broaden the system's capabilities. Continuous improvement through user feedback and a strong emphasis on security and privacy will be essential as the system evolves. Overall, this research lays a solid foundation for future advancements in text recognition technology, paving the way for more intelligent, accessible, and versatile OCR applications.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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