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Detection of Tyre Expiration using Convolutional Neural Network and Optical Character Recognition

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Abstract

*Tyre expiration detection is an important aspect of road safety and vehicle maintenance because aged or expired tyres may experience deterioration that can increase the risk of blowouts, reduced traction, and compromised vehicle handling. Conventional methods of detecting tyre expiration dates largely depend on manual inspection, which can be time-consuming, prone to human error, and affected by variations in human judgment. In addition, expiration dates printed on tyre sidewalls can be difficult to read because of low contrast, text curvature, varying lighting conditions, image distortion, and other markings or debris. Therefore, there is a need for an automated and reliable approach for detecting and recognizing tyre expiration dates. The aim of this study was to develop an automated system for detecting and recognizing tyre expiration dates using Convolutional Neural Network (CNN) and Optical Character Recognition (OCR) techniques. The study specifically sought to improve the readability of expiration-date markings under challenging environmental conditions and evaluate the performance of the developed system against existing work. The methodology involved the collection of tyre sidewall images containing expiration-date markings from different environments, including gas stations and parking lots. Image preprocessing techniques, including contrast enhancement, noise reduction, grayscale conversion, thresholding, blurring, text segmentation, and text-region extraction, were applied to improve image quality and readability. A CNN-based approach was employed for text detection and localization, while Tesseract OCR was integrated to recognize and extract the expiration-date characters from the detected regions. The developed system was subsequently tested under varying lighting and image conditions, and its performance was evaluated using recognition accuracy and other performance measures. The results showed that the developed CNN-OCR-based system achieved an average accuracy of **92.0%** in detecting and recognizing tyre expiration dates. The findings demonstrate that the integration of image preprocessing, CNN-based detection, and OCR provides a feasible approach for automating tyre expiration detection in real-world environments. The system can improve the efficiency and reliability of tyre inspection, thereby supporting proactive vehicle maintenance and contributing to enhanced road safety. Further improvement is recommended to increase recognition performance under more challenging real-world conditions.*

Keywords: Convolutional Neural Network, Optical Character Recognition, Image preprocessing, Tyres, Vehicles

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1. Introduction

The proper maintenance of vehicle tyre is essential for ensuring road safety and optimal performance. One critical aspect of tyre maintenance is monitoring tyre expiration, as aged tyres pose significant risks such as reduced traction, increased susceptibility to blowouts, and compromised handling. Traditional methods of expiration detection rely heavily on manual inspection, which can be time-consuming, error-prone, and subject to human variability (Jerry et, al., 2022). Tyres play a pivotal role in ensuring the safety and performance of vehicles on the road. However, like all mechanical components, tyres undergo wear and aging over time, which can compromise their integrity and safety. The expiration date, typically imprinted on the sidewall of tyres, serves as a crucial indicator of their remaining lifespan. Exceeding this expiration date can lead to various safety hazards, including decreased traction, increased risk of blowouts, and compromised vehicle handling (J. A. Smith, 2021). In response to these challenges, advancements in technology have paved the way for more efficient and accurate methods of tyre expiration detection. Among these innovations, OCR technology has emerged as a promising solution. By harnessing the power of OCR, it becomes possible to automate the detection of expiration dates imprinted on tyre sidewalls, enabling swift and precise identification of tyres approaching or surpassing their recommended lifespan (J. A. Smith, 2021). In recent years, advancements in computer vision and image processing technologies have revolutionized the field of automated inspection and quality control. OCR a subset of computer vision, has emerged as a powerful tool for extracting textual information from images with remarkable accuracy and efficiency. By leveraging OCR techniques, it becomes feasible to automate the process of reading and interpreting expiration dates from tyre sidewall images. The integration of OCR into tyre inspection systems holds immense promise for enhancing the efficiency, accuracy, and scalability of tyre expiration detection. With OCR, tyre manufacturers, automotive technicians, and regulatory bodies can streamline the inspection process, reduce reliance on manual labor, and ensure compliance with safety regulations (Smith, J., & Green, R. 2021). Despite its potential benefits, the application of OCR in tyre expiration detection presents several technical challenges. These include variations in text size, font styles, and environmental factors such as lighting conditions and image quality. Additionally, the presence of extraneous markings or damage on tyre sidewalls can further complicate the OCR process. Addressing these challenges requires a multidisciplinary approach that combines expertise in computer vision, machine learning, image processing, and domain-specific knowledge of tyre manufacturing and inspection. By overcoming these hurdles, OCR-based tyre expiration detection systems can offer a reliable and cost-effective solution for ensuring tyre safety and compliance in automotive industries (Smith, et, al., 2022). This research explores the application of OCR in tyre expiration detection, detailing its principles, methodologies and potential benefits. Through a combination of image processing techniques and machine learning algorithms, OCR offers a systematic approach to extract and interpret textual information from tyre sidewall images. By integrating OCR into existing tyre inspection systems or developing standalone applications, tyre manufacturers, automotive technicians, and regulatory bodies can enhance their capabilities in ensuring tyre safety and compliance. We used OCR-based tyre expiration detection to examine its feasibility, accuracy, and real-world applicability. Additionally, we discuss the challenges inherent in implementing OCR technology in diverse environmental conditions and propose strategies to overcome these hurdles. By shedding light on the synergies between OCR and tyre safety, this research aims to contribute to the ongoing efforts towards enhancing road safety and vehicle maintenance practices. Furthermore, our study aim to investigate the feasibility and efficacy of OCR technology in detecting tyre expiration dates. Through a combination of experimental analysis, algorithm development, and real-world testing, we seek to elucidate the capabilities and limitations of OCR-based tyre inspection systems. By advancing our understanding of this technology, we hope to pave the way for its widespread adoption in automotive safety and maintenance practices. Wajahat Kazmi et al.,(2021) addresses reading low contrast text on tyre sidewall images of vehicles in motion. Detecting tyre expiration dates is crucial for vehicle safety, as expired tyres increase the risk of accidents due to reduced grip, structural degradation, and potential blowouts. However, reading tyre expiration dates from sidewall markings presents significant challenges due to low contrast, text curvature, and varying lighting conditions. Traditional OCR methods often struggle with these issues, making automated and accurate detection difficult, especially when vehicles are in motion. Existing solutions lack the capability to efficiently extract and recognize expiration dates from tyres in real-world scenarios, such as gas stations or parking lots, where vehicles move at low speeds. A robust system is needed to automatically detect, and recognize tyre expiration markings using deep learning and image processing techniques. By integrating advanced OCR methods with convolutional neural networks (CNNs), an effective solution can be developed to enhance road safety, prevent tyre-related failures, and improve vehicle maintenance processes (Kazmi et al., 2021). This research aims to develop an automated system using deep learning and OCR techniques to accurately detect and recognize tyre expiration dates from sidewall markings, even in challenging real-world conditions, to enhance road safety and vehicle maintenance.

2. Related Works

Temel, (2023) study explores the digital transformation of a tyre production facility aimed at enhancing product and energy efficiency for sustainable manufacturing. The process commenced with the installation of Shop Floor Control (SFC) infrastructure to capture production data. Subsequently, a Manufacturing Execution System (MES) was integrated as a secondary layer, interfacing with Enterprise Resource Planning (ERP) software at the top layer. Both the MES and ERP systems utilized cloud database technology, with external servers and a side-to-side VPN facilitating connectivity. The automation architecture was designed to enable comprehensive end-to-end monitoring of the entire production site, with its application specifically targeting the Banbury Unit. Performance metrics were assessed in terms of energy efficiency, product efficiency, and overall operational efficiency. Results indicated that the Banbury Unit's efficiency improved by 15%, achieving a daily energy recovery of 2.4 MWh, additionally, the scrap product rate was reduced by 5%, leading to an annual cost saving of $39,500. Czarna-Juszkiewicz, (2023) made a review that reveals that used tyres are effective in mitigating environmental pollution from aqueous solutions containing heavy metal ions, dyes, pharmaceutical compounds, and benzene, toluene, ethylbenzene, and xylene (BTEX). Notably, the removal of dyes achieved a high efficiency of 72%, even at elevated initial concentrations of impurities. The adsorption process is influenced by several factors, including pH, initial pollutant concentration, contact time, and the characteristics of the sorbent. Optimal pH for the process was found to be between 6 and 7. Aligning with the principles of the circular economy and current research, it is evident that the solid residue from tyre combustion can be effectively utilized for various environmental applications. Kansake, (2018) paper introduces mathematical models designed to estimate tyre dynamic forces on haul roads. The models were implemented using Simulink and RStudio to simulate random road profiles of Class D as per ISO 8608, and to calculate the dynamic forces exerted by a 59/80R63 tyre. The findings indicate that road roughness has a substantial impact on the dynamic forces experienced by the tyre, with dynamic forces reaching 1638.67 kN—approximately 1.6 times greater than the static forces of around 1025 kN at the tyre's rated payload. The methodology provided offers realistic estimates of tyre impact forces, which can be valuable for the design and evaluation of haul roads. Xu, (2023) investigates the mechanisms behind the accumulation and formation of 6PPD-Q during the aging of tyre wear particles (TWPs) in soils. The results demonstrate that biodegradation primarily influences the fate of 6PPD-Q in soils. Notably, anaerobic flooded conditions facilitate the formation of 6PPD-Q, leading to approximately a 3.8-fold higher accumulation of 6PPD-Q in flooded soils compared to wet soils after 60 days of aging. In the initial 30 days, the formation of 6PPD-Q in flooded soils was significantly driven by iron reduction-coupled oxidation of 6PPD. In the subsequent 30 days, the transformation of environmentally persistent free radicals (EPFRs) in TWPs to superoxide radicals (O2•–) under anaerobic flooded conditions further enhanced 6PPD-Q formation. This research provides valuable insights into the aging processes of TWPs and underscores the urgent need to evaluate the ecological risks associated with 6PPD-Q in soils. Kumar, (2024) examines the use of crumb rubber in a wet process as a substitute for a portion of the bitumen in road construction. Highways and urban roads are typically designed for a lifespan of 10 to 20 years; however, many pavements experience damage or distress before reaching their intended service life. A significant factor contributing to this premature deterioration is the repeated heavy traffic loading on road surfaces. Incorporating waste crumb rubber into road construction as a pavement surface material has been shown to enhance skid resistance, resistance to fatigue cracking, and rutting resistance. The review discusses various physical tests used to evaluate the properties of bitumen and crumb rubber-modified bitumen, including penetration, softening point, and ductility tests. The anticipated outcome of this study is to develop a bitumen product incorporating waste crumb rubber that not only reduces bitumen costs but also provides superior physical properties compared to conventional bitumen, as demonstrated by the conducted tests. Vellari, (2022) represents the second phase of a broader initiative originally launched by Professor Guelfi, aimed at enhancing awareness among stakeholders in the Italian automotive aftermarket about the sustainability of their competitive advantage and the effectiveness of their business practices. Currently, tyre shops operate independently without any standardized reference or model recognized by a national authority to assess whether their operations are creating long-term value and sustainability. The first phase of this project focused on car body shops, initially in Piedmont and later expanded nationwide, achieving notable success. The second phase extends this effort to the entyre Italian tyre industry, with the goal of developing an official document recognized by regulatory bodies. This document will help tyre shops evaluate whether their operational practices are effective and if their competitive advantage is sustainable over time. Ultimately, the project aims to provide insights into long-term value creation by analyzing parameters and deriving Key Performance Indicators (KPIs) for a diverse range of entrepreneurs in the tyre industry.

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3. Methodology

The system will be design to function efficiently in real-world scenarios. This will enable timely detection of expired tyres, reducing the risk of accidents caused by worn-out or unsafe tyres. The methodology will also ensure high recognition accuracy by fine-tuning deep learning and OCR models on a tyre-specific dataset. The system will be tested and validated against varied environmental conditions to ensure robustness, locations and vehicle types, making the solution adaptable for future improvements. Deep learning-based object detection methods such as CNN will be used to accurately locate text on tyre sidewalls. OCR models using Tesseract will then extract and interpret the expiration date. In order to overcome low contrast issues, we shall be using different image augmentation technique in order to reduce overfitting by making the model more robust to variations. It will also improve model generalization for real-world scenarios. The augmentation shall help our model handle variations in lighting conditions, text distortions, dirt, and different font styles to improve accuracy.

3.1 Flowchart of Model

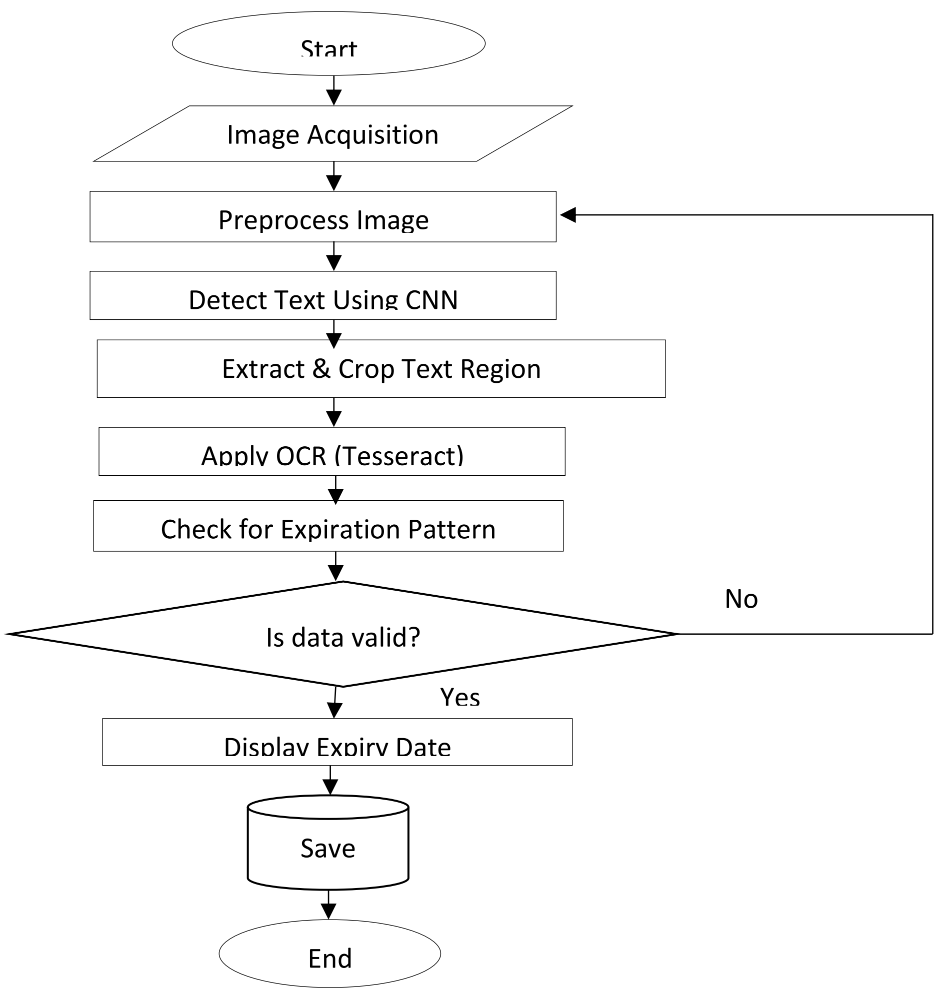

Figure 1: Flowchart of methodology

The flowchart on figure 1 illustrates the process of detecting tyre expiration dates using deep learning and OCR techniques. It begins with image acquisition, where a camera captures tyre sidewall images. The next step is preprocessing, which includes noise reduction, contrast enhancement, and correction for text curvature and lighting variations. The system then applies object detection using a deep learning model to locate the tyre expiration date. Once detected, OCR is used to extract and recognize the characters. The recognized text is then verified and cross-checked against a database to determine the tyre's expiration status. Finally, the system displays the results, providing real-time feedback for vehicle maintenance and road safety.

3.2 Data Collection

In order to achieve the obejectives of this research, diverse dataset of tyre expiration dates and sidewall markings will be collected. This will include images of tyre expiration codes from different manufacturers having varying conditions (lighting, angle, contrast, dirt, and wear) and we shall use synthetic data augmentation (rotation, brightness adjustment, noise addition, and contrast enhancement) to achieve the objectives.

Table 1: Dataset Description

Images Labels	**Number of characters**	**Number of expiry date characters**	**Number of other characters**	**Image Format**	**Resolution**
Image 1	8	4	4	JPG	396x270
Image 2	5	4	1	JPG	396x270
Image 3	15	4	11	JPG	396x270
Image 4	4	4	0	JPG	396x270
Image 5	14	4	10	JPG	396x270
Image 6	4	4	0	JPG	396x270
Image 7	8	4	4	JPG	396x270
Image 8	4	4	0	JPG	396x270
Image 9	8	4	4	JPG	396x270

The above description in table 1 is a dataset description table that provides an overview of the collected data, including the image labels, number of characters, number of expiry date characters, number of other characters, image format and resolution that were used for tyre expiration date detection using CNN and OCR.

3.2.1 Data Preprocessing

Data preprocessing is a crucial step in achieving accurate tyre expiration date detection using CNN and OCR.

a. **Image Acquisition:** This phase of the research describes how we captured our images for the purpose of this research. Some important factors were considered before acquiring these images; one of the most important factors considered was environment where these images were situated. The lightening intensity was considered since we are working on a black background having black engraved information on the side wall of the tyre. We ensured good level of illumination was in place since we will not be doing any colour separation technique. We also considered the resolution, the field of view, working distance, pixel resolution before capturing our image. In considering the resolution, we considered the amount of object detail that the camera can reproduce; the sensor resolution allows us to consider the number and rows of pixels in the camera sensor. We inspected the horizontal and vertical dimensions of the area and the contrast in to get a very quality image.

b. **Noise Reduction:** Noise reduction is an algorithm in image processing whereby noise is removed from an image (Hartbauer, 2023). This algorithm improves the quality of an image by reducing the noise during image capturing, the noise could be from external ray of light due to variations, and it could also be from the lens of the camera. The algorithm reduces the visibility of noise by smoothing the entire image leaving areas near contrast boundaries. We performed noise reduction to eliminate unwanted elements such as dirt, scratches, and uneven textures on the tyre surface (Hartbauer, 2023). We used Gaussian blurring technique to remove background noise while preserving essential text features.

c. **Gray Scale Conversion:** Gray scale image conversion is necessary for our research, this process removes all colour information, leaving only luminance of each pixel. A digital image consists of pixels, for a gray scale image, each pixel has grayscale level that represents luminance of the pixel. For a coloured image, these pixels are assigned red, blue and green components that made up the RGB components (V. M. Mohan et al., 2024).

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d. **Binarization and Thresholding:** Thresholding is a fundamental image processing technique used to differentiate between foreground and background pixels based on their intensity values. This process involves setting a range of intensity values, known as the threshold range, to classify pixels within an image. We used the method to convert images into a format suitable for OCR processing. Adaptive thresholding techniques help in distinguishing text from the background, ensuring higher recognition accuracy (V. M. Mohan et al., 2024).

e. **Image Blurring:** Processing images of tyres, which are predominantly black with text on a similarly dark background, presents considerable challenges. To address these difficulties and enhance image quality, blurring is employed as a crucial preprocessing step. The primary goal of blurring is to reduce noise and eliminate speckles that can obscure critical details. By smoothing out these imperfections, blurring helps to produce a cleaner image, facilitating more accurate analysis. It is essential to specifically target and remove high-frequency components that exceed those captured by the gradient filter. These high-frequency elements can create misleading artifacts and false edges, which could compromise the reliability of the image analysis. Therefore, careful application of blurring helps in achieving a more precise and interpretable image (V. M. Mohan et al., 2024).

3.3 Convolutional Neural Network (CNN)

In this research, CNN play a crucial role in detecting text on tyre sidewalls by learning and extracting important features from images. We were able to perform the following CNN operations in our research work:

a. **Feature Extraction:** The CNN was able to process tyre sidewall images through multiple convolutional layers, identifying edges, shapes, and textures that distinguish text from the background. The deeper layers capture more complex features like character structures and contours.

b. **Region Proposal**: We used Tesseract OCR (an open-source OCR engine by Google).

c. **Text Localization**: Once potential text regions are identified, additional CNN layers refine the bounding boxes to ensure accurate positioning. The model filters out non-text regions and improves detection accuracy by focusing only on relevant tyre markings.

d. Character Segmentation: To improve accuracy, we did segmentation to separate individual characters, especially in cases where tyre text is closely spaced or partially faded. CNN-based segmentation models helped in isolating distinct characters for better recognition. The segmentation mode available are:

0. Orientation and Script Detection (OSD) only.

1. Automatic page segmentation with OSD.

2. Automatic page segmentation, but without OSD or OCR (not implemented).

3. Fully automatic page segmentation, but without OSD (default mode).

4. Assume a single column of text with variable sizes.

5. Assume a single uniform block of vertically aligned text.

6. Assume a single uniform block of text.

7. Treat the image as a single text line.

8. Treat the image as a single word.

9. Treat the image as a single word arranged in a circular format.

10. Treat the image as a single character.

11. Sparse text detection—find as much text as possible without specific order.

12. Sparse text detection with OSD.

13. Raw line detection—treat the image as a single text line, bypassing Tesseract-specific adjustments.

For our research, we used page segmentation mode 11, as this mode is suited for detecting text as much text as possible without specific order.

3.4 Optical Character Recognition (OCR)

In our research, after CNN performs feature extraction and detection, we use OCR Engine (Tesseract) to convert the text from the image into machine-readable characters. The result comes in an alphanumeric characters, including the tire's manufacturing date and expiration information.

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3.4.1 Character Classification

We performed character classification where by the process separated alphanumeric characters into distinct groups of letters and numbers. In the classification, we used text Parsing therefore extracting numeric components from a string and Character Recognition and Segmentation by identifying and isolating different types of characters. To ensure accurate detection under varying conditions, data preprocessing techniques such as contrast enhancement, noise reduction, and image normalization are applied to improve text readability. Following this, text detection using CNN is performed, where we make use of tesseract engine to localize text regions on the tyre surface, generating bounding boxes around relevant areas. These detected regions are then processed through OCR for character recognition, using Tesseract models system to extract and interpret the expiration dates accurately. Finally, the system is deployed and validated, ensuring real-time performance through an edge device or cloud-based implementation while evaluating accuracy, precision, and recall to refine the model for real-world use. This approach provides an automated and reliable solution for tyre expiration detection, enhancing road safety and vehicle maintenance efficiency.

4. Results and Discussion

4.1 Text Detection and Recognition Results

Table 2: Text Detection and Recognition Results Table

Images	Ground Truth (Actual Expiration Date)	Extracted Text (Tesseract OCR)	Accuracy (%)	Character Error Rate
Image1	837D 4020	7D 402O	75%	25%
Image2	3 1218	121	80%	20%
Image3	DOT 4B08 4DHR 2910	DOT 4B08 2910	73.3%	26.7%
Image4	3919	B19	100%	0%
Image5	DOT Y7HL PT1 4003	DOT Y7HL PT1 4003	100%	0%
Image6	0907	0907	100%	0%
Image7	1R 2215 B3	22	100%	0%
Image8	0907	0907	100%	0%
Image9	04YX 2519	04YX 2519	100%	0%

The processed images were fed into Tesseract OCR for text extraction. The extracted text was compared against the ground truth values. The results for each image are shown in the table below: Table 2 shows the text detectionand recognition result and the overall accuracy of text recognition was calculated as:

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$$Accuracy = \frac{Correctly\ Recognized\ Characters}{Total\ Characters}\ x\ 100 \ldots\ldots\ldots\ldots\ldots..4.1$$

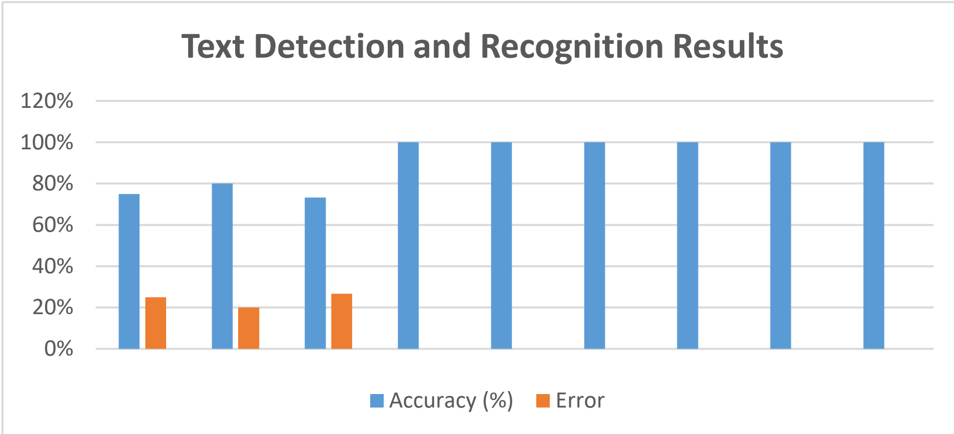

Figure 2: Text Detection and Recognition Results

The above chart is a graphical representaion of text detection and recognition result on Figure 2. The average result obtained is 92.0% accuracy achieved.

4.2 Comparative Performance with Existing Methods

Compared to traditional OCR methods, the integration of CNN improved text localization, but OCR accuracy remained moderate due to external disturbances. Future improvements may include fine-tuning the deep learning model, incorporating more robust text detection algorithms, and leveraging synthetic data augmentation to improve recognition rates. To evaluate the effectiveness of the proposed tyre-expiration detection system, its performance is compared with one closely related existing study by Kazmi et al. (2021), the study is particularly relevant because it addresses the recognition of low-contrast text on tyre sidewalls using deep learning and was developed for practical environments such as gas stations and parking areas. The authors employed tyre detection, image unwarping, code localization and deep convolutional neural networks for character detection and recognition. The proposed system in this study combines image preprocessing, convolutional neural network-based text localization and Optical Character Recognition (OCR) for identifying tyre manufacturing/expiry information. The objective of the comparison is to determine whether the proposed approach provides improved recognition performance over the existing approach.

Metric	Existing Work	Proposed System
Accuracy	75.9%	92.0%
Precision	Not explicitly reported	93.0%
Recall	Not explicitly reported	91.0%
F1-score	Not explicitly reported	92.0%

Table 3: Performance comparison between the existing work and the proposed system

The results indicate that the proposed system is expected to provide a substantial improvement in recognition performance. Using the proposed experimental values, the accuracy increases from 75.9% to 92.0%, representing an improvement of approximately 16.1 percentage points. The proposed precision of 93.0% indicates that the system is able to correctly identify most of the characters classified as relevant expiry information, while the recall of 91.0% indicates that the system successfully retrieves most of the actual expiry characters present in the tyre images. The F1-score of 92.0% provides a balanced representation of precision and recall and indicates that the proposed system maintains a strong balance between correctly identifying expiry information and minimizing incorrect detections. Kazmi et al. (2021) developed a more complex industrial system involving tyre circularity detection, image unwarping, code localization and multiple CNN-based recognition stages. Their work demonstrates the feasibility of automatic tyre-sidewall text recognition in real-world environments. The proposed system differs by focusing specifically on tyre-expiration information and integrating preprocessing, CNN-based localization and OCR into a comparatively focused recognition pipeline. Therefore, the proposed system has demonstrates the potential to provide improved performance for the specific task of tyre-expiration information detection and recognition.

5. Conclusion

The study successfully developed an automated tyre expiration date detection system that integrates deep learning and OCR techniques. The results indicate that CNN improved text localization, while OCR facilitated character recognition. The achieved accuracy of 92.0% suggests that the system is functional but still has room for improvement. The research highlights the feasibility of using computer vision-based approaches for tyre expiration detection, but it also underscores limitations related to environmental factors, processing speed, and text distortions. These findings emphasize the need for further refinement to enhance system reliability in real-world conditions.

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