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A CNN Model for ODOL Truck Detection

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Abstract: This study developed a Convolutional Neural Network (CNN) model as one of artificial intelligence method to detect trucks experiencing over-dimension and over-loading (ODOL). The primary goal of this research is to enhance the efficiency of truck monitoring, reduce road infrastructure damage, and support the sustainability of transportation using artificial intelligence approaches. The model was trained using a dataset consisting of ODOL and non-ODOL truck images, and successfully achieved a testing accuracy of 94.23%. The confusion matrix analysis demonstrated the model's ability to classify trucks with high precision. Additional testing on truck images not included in the training or testing dataset showed the model's potential for good generalization.

Keywords: CNN, Odol, Truck, Non-Odol,Artificial Intelligence

INTRODUCTION

In today's modern era, the transportation of goods and logistics plays a crucial role in supporting a nation's economy. Trucks, as the primary means of transportation, form the backbone of this logistic system. Overdimension and Overloading Trucks, known as ODOL trucks in Indonesia, refer to conditions where a truck carries loads that exceed the capacity specified by the manufacturer or regulatory authorities. This phenomenon is a serious concern in the field of transportation, especially in logistics management and goods distribution. ODOL trucks are often described as vehicles carrying loads beyond safe limits or outside the legal limits set by transportation regulations (kominfo, n.d.).

The hazards associated with ODOL trucks include physical, economic, and environmental impacts. Physically, ODOL trucks can cause structural damage to roads, including pavement and foundations. Economically, they involve additional costs for road infrastructure maintenance, increased fuel consumption, and more frequent truck maintenance. Additionally, ODOL trucks also have significant environmental impacts, such as increased greenhouse gas emissions contributing to climate change (Antono, 2022).

The Ministry of Transportation has begun implementing the Zero ODOL policy, which bans over-dimension and overloading trucks (ODOL), effective from 2023, after previous delays and ensuing public debate. The National Transportation Safety Committee (KNKT) has highlighted the issue of ODOL since 2019, providing recommendations to various relevant agencies. KNKT identified that ODOL trucks not only have the potential to cause road accidents but also pose a danger to ferry transport, with several maritime accidents involving ODOL vehicles. The presence of ODOL trucks on ships can damage the ship's structure, reduce the effectiveness of safety systems, and hinder crew access during fire handling. ODOL also affects the carrying capacity of ships, reducing the number of vehicles that can be transported and complicating the loading process at ports.(*KNKT* - n.d.)

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Load standards or benchmark calculations for trucks exceeding load capacities can vary based on regulations and norms in different countries or regions. In Indonesia, truck load limits are regulated by the Government Regulation of the Republic of Indonesia Number 55 of 2012 concerning Types and Amounts of Motor Vehicle Testing and Procedures for Issuing Motor Vehicle Registration Marks, which also sets limits based on the number of axles and axle distance (*PP No. 55 Tahun 2012*, n.d.). The issues posed by ODOL trucks necessitate innovative solutions to ensure road safety and infrastructure longevity. One such innovative approach is leveraging artificial intelligence (AI).

The study by Hamid R. Alsanad et al, develops a fuel truck detection algorithm using a convolutional neural network (CNN) based on YOLOv2. This research shows that the algorithm can significantly improve object detection efficiency, even with a limited amount of training data. The proposed algorithm, OYOLOv2_FTD, demonstrates an approximately 4% higher detection rate compared to the original YOLOv2 method and is more efficient in handling various fuel truck detection scenarios. The relevance of this study to the current research is substantial, as it underscores the potential of CNNs in enhancing the monitoring and classification of ODOL trucks, which pose significant risks to transportation safety and infrastructure. An efficient and accurate detection system is crucial for mitigating the physical, economic, and environmental impacts associated with ODOL trucks. By improving truck classification accuracy, this approach supports the enforcement of Zero ODOL policies, enhancing road safety and optimizing logistical operations. (Alsanad et al., 2020)

A Convolutional Neural Network (CNN) is a type of architecture in deep learning specifically designed to process and analyze grid-structured data, such as images (Huang, n.d.). This research aims to develop an efficient Convolutional Neural Network (CNN) model for detecting ODOL trucks. By utilizing artificial intelligence technology, this study hopes to enhance the efficiency of truck monitoring, reduce road damage, and support sustainable transportation. The specific objective is to identify ODOL trucks more accurately and efficiently, without relying on additional sensors.

Additionally, Xianglun Mo et al, develops a method for determining highway truck load limits using image processing. The study introduces an improved Hough and CURE algorithm to identify truck wheel axles, achieving higher accuracy and efficiency compared to traditional methods. This research is highly relevant to the current study as it highlights the effectiveness of image processing techniques in monitoring and regulating truck loads (Mo et al., 2020)

The main contribution of this study is the development and implementation of an ODOL truck detection model using CNN that does not require additional sensors. This will provide a more effective and economical method compared to traditional monitoring systems, which often rely on heavy and expensive infrastructure. This contribution is expected to impact the development of better policies and practices in logistics and transportation management. The novelty of this research lies in its sensor-free approach to detecting ODOL trucks using CNN, which offers a cost-effective and scalable solution for transportation authorities.

The structure of this paper is as follows: Section 1 provides an introduction to the research topic and its significance. Section 2 offers a literature review of related research. Section 3 describes the method used in this study. Section 4 presents the results. Section 5 discusses the findings and their implications. Finally, Section 6 concludes the paper and provides suggestions for future research.

LITERATURE REVIEW

Recent studies have shown advancements in the detection of Overdimension and Overloading (ODOL) trucks using Convolutional Neural Network (CNN) models, without involving sensor technology. Camilo et al. in their research discussed the use of machine learning models, particularly unsupervised learning techniques and artificial neural networks, to analyze truck patterns and predict overloading with high accuracy. This research was conducted in the Philippines, focusing on the impacts

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of truck overloading such as traffic congestion, accidents, and road damage. The study utilized a High-Speed Weigh-In-Motion (HS-WIM) dataset over seven days from the North Luzon Expressway Corporation. The results indicate that this approach can provide valuable information for developing more effective road safety and management guidelines, including the potential development of low-cost sensor-based systems to detect overloaded trucks on highways (Gernale & Juanico, n.d.).

Pan He present a comprehensive study on truck and trailer classification, integrating deep learning models with conventional image processing and computer vision techniques. Their approach focuses on identifying key geometric features such as shape, texture, and semantic information to classify truck and trailer types effectively. They developed algorithms leveraging transfer learning to detect and localize trucks in images, achieving high accuracy in truck and trailer classification. (He et al., 2021) This study aligns closely with the current research, which aims to develop a Convolutional Neural Network (CNN) model for detecting Overdimension and Overloading (ODOL) trucks. The integration of deep learning and geometric features in truck classification provides a robust framework that can be adapted to enhance the detection of ODOL trucks, ultimately contributing to improved road safety and infrastructure management.

Vázquez et al. presented a system capable of detecting trucks and their axles using convolutional neural networks (CNN). The selected CNN models used for evaluation were Faster R-CNN and Inception-ResNet V2, chosen for their superior performance according to the reviewed literature. For the training and testing of the proposed solution, a mobile unit was implemented to collect an image dataset consisting of trucks and other vehicles on a high-volume highway. The system's performance was evaluated using different metrics, achieving at least a 92% score in F1 Score, Recall, and Precision. This study is relevant to the current research on detecting Overdimension and Overloading (ODOL) trucks using CNNs, as it highlights the effectiveness of deep learning techniques in enhancing vehicle detection and classification accuracy (Vázquez et al., 2020)

In 2023, Dhineshkumar proposed a solution that integrates an automatic engine lock system with a load sensor model to monitor vehicle loads. The proposed method would allow automatic monitoring of loads, detect overloaded vehicles, and quickly alert drivers (K et al., n.d.).

Yi Tan presents an innovative approach for detecting and classifying vehicles in aerial images. The method initiates with change detection by analyzing two aligned images. These proposals are then evaluated by a trained Convolutional Neural Network (CNN) to confirm the presence of vehicles and categorize them into major types. Experiments using infrared (IR) data demonstrate the method's effectiveness, achieving a vehicle detection rate exceeding 99%. Classification accuracy is reported as 89% for light-duty vehicles like sedans, 79% for medium-duty vehicles such as vans and pickups, and 73% for heavy-duty vehicles including trucks and buses. The differences in classification accuracy are linked to the varying sizes of training samples for each vehicle category. Capable of processing data at video rates, this system is practical for real-time traffic monitoring This study is relevant to the current research as it underscores the effectiveness of deep learning techniques in enhancing vehicle detection and classification accuracy (Tan et al., 2018)

Praveena et al. described a system designed to automatically prevent truck overloading, which in turn ensures the longevity of trucks and helps create safer road conditions. The designed system monitors truck loads in real-time and allows trucks to move only if they comply with specified weight regulations. Load cells are placed on the chassis and under the trailer, calibrated in such a way that they continuously measure the amount of load loaded onto the truck. When the weight exceeds the permitted weight limit, the proposed mechanism seizes the battery and does not allow the user (truck driver) to start the engine. A Gyro sensor is also incorporated to shut down the mechanism if the truck moves on a slope, where the load may be unevenly distributed. This proposed system is simple to design and implement, offering an improvement over the current technology of Weigh Bridges used by the Indian government to

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regulate overweight trucks, which requires significant capital and infrastructure resources (Praveena et al., n.d.).

Saad et al. in their research discussed the challenges faced by developing countries related to logistics carried by trucks, typically caused by truck overloading, particularly by heavy vehicles. Truck overloading often occurs due to a lack of law enforcement, low levels of inspection, and the technology to detect weight excess still far from adequate. Moreover, in many cases, developing countries focus more on economic growth than on enhancing the quality of life. In Malaysia, the percentage of overloaded trucks can exceed 60% of the total registered trucks. Overloaded trucks not only impact the economy but also road safety, social, and environmental aspects. This paper reviews the impacts of overloaded trucks in developing countries using a systematic literature review technique (Saad et al., n.d.).

In 2020, Thangavel et al. discussed that an increase in accidents was caused by vehicle overloading and drivers driving under the influence. Overloading could occur due to the use of a single axle or a combination of tractor and trailer arrangements. This poses a problem for vehicle owners, drivers, and authorities by increasing the number of accidents and damage to roads and public property. If the overloading issue is not controlled, this burden is transferred to road users; in terms of fuel costs, vehicle toll fees, and fines by the Road Transport Office. In this project, the weight or load of vehicles is measured using load cells placed under the chassis. The measured data is sent to the cloud with the help of a server. With a developed mobile application, owners can monitor information about the vehicle. Control is done through an ignition circuit used to shut off the engine. Therefore, the research findings suggest that excessive load can be monitored and controlled (Thangavel et al., n.d.).

Focusing on visual image analysis as the primary basis, this research aims to provide a robust foundation and deep understanding of the use of CNN models in the detection of ODOL trucks, offering significant contributions in addressing the issue of overloading without relying on sensor data.

METHOD

This research employs a Convolutional Neural Network (CNN) model to differentiate between overloaded trucks (ODOL) and those that are not. CNNs are designed to mimic human visual information processing, capable of deciphering complex hierarchies of features and patterns within visual data. The model's goal is to accurately identify trucks carrying loads beyond their legal limits by analyzing images of both ODOL and non-ODOL trucks. This approach leverages the CNN's strength in pattern recognition to enhance the detection and monitoring of overloaded vehicles. CNNs are particularly effective in tasks such as pattern recognition, object classification, and image segmentation. The CNN architecture consists of several types of layers that play crucial roles in processing information. Convolution layers are used to extract local features from the input data using convolution operations, while pooling layers help reduce data dimensionality and retain important features. The fully connected layers at the end of the architecture are responsible for the final classification based on the features extracted earlier. The main advantage of CNNs lies in their ability to automatically learn and extract relevant features, making them ideal for tasks in image processing and visual pattern recognition (Hafifah et al., 2021).

The dataset utilized in this study was compiled from a diverse array of sources, including images from social media platforms, Google searches, and photographs captured by the researchers themselves. This varied collection ensures a broad representation of truck types and loading conditions, which enhances the robustness and applicability of the model across different scenarios and environments. These images were processed and used to train the CNN model to recognize ODOL trucks. This research includes stages of data collection, data processing (preprocessing), training the CNN model, model validation, and model optimization based on evaluation results. The performance of the CNN model was analyzed using common statistical techniques in machine learning, such as confusion matrices and

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ROC curves. The measured variables include the accuracy, precision, and sensitivity of the CNN model in identifying ODOL trucks.

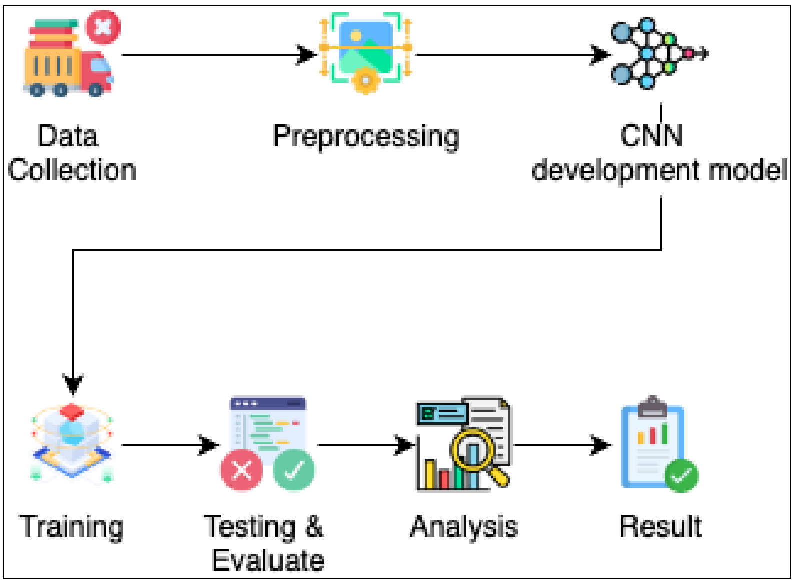

Fig. 1 Research flow

The research flow presented in Figure 1 outlines the main stages in this research process, The research process begins with the Data Collection stage, where truck images are gathered from available datasets. These images serve as the basis for training and evaluating the model. During the Data Processing (Preprocessing) phase, the collected images undergo normalization to standardize the image data, and data augmentation is performed to increase the diversity of the dataset if necessary. The dataset is also split into training and testing sets. In the Model Development stage of the research, the Convolutional Neural Network (CNN) is carefully crafted by choosing specific layers and parameters that are best suited for processing the image data. This design is critical to effectively identify key features necessary for detecting Overdimension and Overloading (ODOL) conditions in trucks. The strategic selection of layers and tuning of parameters ensure that the CNN can accurately discern and classify the nuanced differences between ODOL and non-ODOL trucks based on their visual data. The Model Training stage involves training the CNN model using the training dataset, aiming to adjust the model's weights to minimize errors in prediction. During Model Evaluation, the model is tested using a separate testing dataset to assess its ability to identify ODOL trucks under diverse conditions. Results Analysis is then conducted to identify the strengths and weaknesses of the model, pinpointing areas that require adjustments or improvements. Finally, the Documentation and Presentation of Results stage compiles the findings of the research, including insights from the model evaluation and analysis, into a comprehensive report or publication.

RESULT

This research successfully developed a Convolutional Neural Network (CNN) model to detect over-dimension (ODOL) trucks using a dataset of truck images. The model was trained with 206 images divided into two categories: ODOL trucks and non-ODOL trucks, and was tested with 52 images. During the training process, the model achieved an accuracy of up to 100%, while in the testing phase, the model reached an accuracy of 94.23%.

The confusion matrix from the testing shows the following distribution for the classification of ODOL and non-ODOL. The confusion matrix from the testing revealed the model's performance in identifying ODOL trucks. There were 24 true positives where ODOL trucks were correctly identified by the model as ODOL. Additionally, there were 25 true negatives, indicating that non-ODOL trucks were correctly identified as non-ODOL. However, the model did have some errors: there were 2 false positives where

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non-ODOL trucks were incorrectly detected as ODOL, and 1 false negative where an ODOL truck was not detected by the model and was incorrectly classified as non-ODOL.

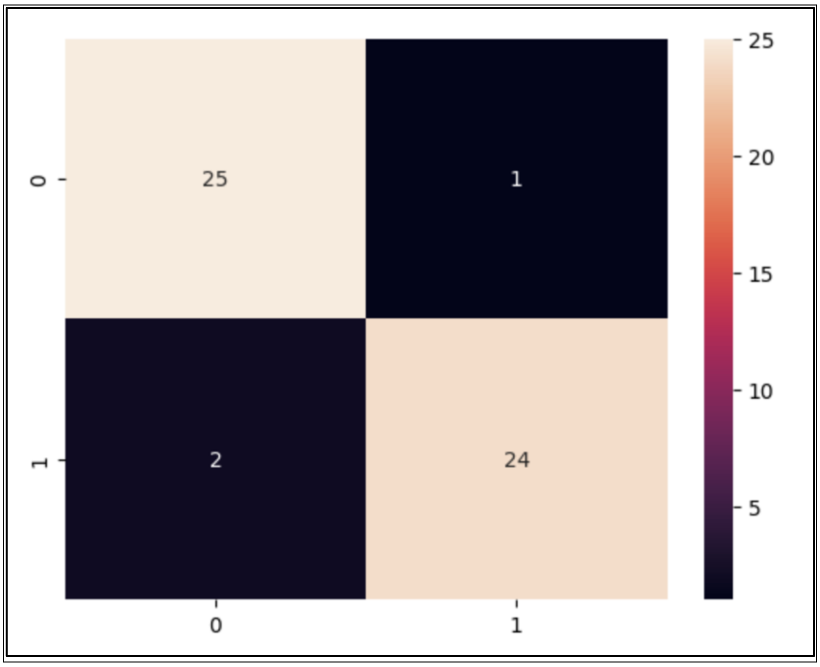

Fig. 2 The Result of Confusion Matrix

Further analysis using the confusion matrix reveals that the model has excellent ability in identifying both categories, with a precision of 0.93 for ODOL trucks and 0.96 for non-ODOL trucks. High F1 scores (0.94 for both categories) indicate a good balance between precision and recall, demonstrating the model’s effectiveness under diverse conditions.

	precision	recall	f1-score	support
0	0.93	0.96	0.94	26
1	0.96	0.92	0.94	26
accuracy			0.94	52
macro avg	0.94	0.94	0.94	52
weighted avg	0.94	0.94	0.94	52

Fig. 3 Classification Report

These results demonstrate that the use of deep learning technology, particularly CNNs, is highly effective in identifying ODOL conditions in trucks based on visual imagery. This effectiveness is crucial given that ODOL trucks often cause accidents and damage road infrastructure, so early detection of these conditions can aid in prevention.

The model's ability to accurately identify ODOL trucks from a limited dataset indicates that the data augmentation and normalization techniques applied during the training process greatly assist in enhancing model generalization. This is important because in real-world applications, the model will encounter far more complex conditions than those present in the training dataset.

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DISCUSSIONS

In further testing, the developed model was also successfully tested with images of ODOL trucks that were not included in the training or testing dataset. This demonstrates that the model has good generalization capability to new data, an important indication of the model's robustness in validation testing. Although the model has not yet been implemented in a real-time monitoring system, this success highlights its potential to be applied in such settings in the future. The theoretical use of this model could enhance road safety by accurately detecting previously undetected ODOL conditions in trucks, as well as assisting in the prevention of accident risks and infrastructure damage associated with ODOL trucks.

Fig. 4 One of the Validation Data

CONCLUSION

This research successfully developed an effective Convolutional Neural Network (CNN) model for detecting Overloaded (ODOL) trucks using a dataset of truck images. The model demonstrated a high level of accuracy in testing, achieving an accuracy score of 94.23%. Analysis using a confusion matrix showed that the model has good capability in classifying ODOL and non-ODOL trucks, with significant true positive and true negative values. However, the presence of false positives and false negatives, although low, indicates that there is still room for model improvement.

Based on the results and analysis, several recommendations for further research and development are proposed. First, to enhance the model's robustness, it is advised to expand and diversify the dataset to include more variations in images of ODOL and non-ODOL trucks. This expansion should cover variations in lighting conditions, viewing angles, and operational backgrounds. Secondly, optimizing

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the model architecture by experimenting with different architectures or adjusting model parameters could help improve the model's generalization capabilities. Lastly, integrating this model into a broader vehicle monitoring system, which includes sensors and other telemetry data, could significantly enhance detection accuracy and offer a more comprehensive solution to the issue of ODOL trucks. These steps are crucial for advancing the application of this technology in real-world scenarios.

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