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Automatic Vehicle Defect Detection App: AI-Powered Servicing Prioritisation

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ABSTRACT- This research paper introduces an AI-powered Automatic Vehicle Defect Detection App designed to identify potential vehicle defects before servicing. Traditional inspection methods are often time-consuming and prone to human error. Leveraging machine learning algorithms for this app streamlines inspections, enhances accuracy, and ensures timely defect detection. The paper outlines the app's architecture, data collection, training, evaluation metrics, usability, efficiency, and impact on the automotive industry.

Keywords- Automatic Vehicle Defect Detection, AI-Powered, Machine Learning, Inspection, Servicing.

INTRODUCTION

Maintaining vehicles is crucial for safety and reliability. Inspections identify potential defects before they escalate. Traditional methods, reliant on manual checks, are labour-intensive and prone to errors. AI and ML technologies offer automated solutions to streamline inspections, improve accuracy, and reduce maintenance costs. This paper focuses on developing an AI-powered Automatic Vehicle Defect Detection App to identify defects before servicing, enabling proactive maintenance and minimising risks on the road. Harnessing machine learning for the app analyses various data sources to detect anomalies, facilitating continuous learning and improvement. This paper provides an overview of the app's design, methodology, implementation, and evaluation. It discusses its potential impact on the automotive industry, service centres, and vehicle owners, advancing proactive maintenance and safety assurance.

Figure 1. shows the vehicle help system.

LITERATURE REVIEW

The application of artificial intelligence (AI) and machine learning (ML) techniques in the automotive industry has garnered significant attention in recent years, particularly in defect detection and predictive maintenance. Reviewing existing literature reveals several key studies and advancements in this field: AI-Powered Vehicle Inspection Systems: Researchers have explored developing AI-powered systems for automating vehicle inspection processes. These systems utilise computer vision techniques to analyse images of vehicles and detect defects such as dents, scratches, and other visual anomalies. Studies by Li et al. (2019) and Zhang et al. (2020) demonstrate the effectiveness of convolutional neural networks (CNNs) in accurately identifying defects from vehicle images. Predictive Maintenance and Fault Detection: Predictive maintenance techniques leverage AI algorithms to analyse sensor data from vehicles and predict potential failures before they occur.

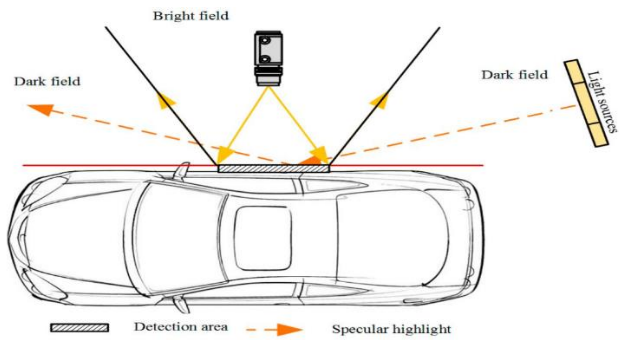

Figure 2. shows Dark and bright fields in the vehicle.

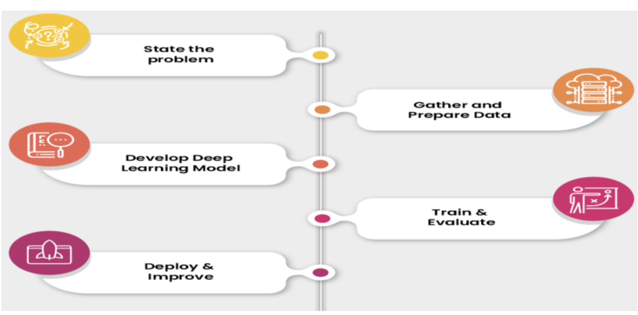

Figure 3. Integrating AI in Visual Inspection System

Research by Zhou et al. (2018) and Chen et al. (2021) focuses on the development of predictive maintenance models using machine learning algorithms such as support vector machines (SVMs) and recurrent neural networks (RNNs). These models can identify patterns indicative of impending failures and recommend proactive maintenance actions. Integration of AI in Service Centers: Several studies have investigated integrating AI-powered defect detection systems into automotive service centres to enhance efficiency and accuracy. For example, the work by Wang et al. (2020) describes a prototype system that combines computer vision and natural language processing techniques to automate vehicle inspection and generate comprehensive maintenance reports. Such systems enable service centres to streamline their operations and provide more reliable maintenance services to customers. Challenges and Opportunities: While AI-powered defect detection systems offer significant benefits, they also pose challenges related to data quality, model interpretability, and integration into existing workflows. Researchers have highlighted the importance of addressing these challenges to ensure AI solutions' practical viability and effectiveness in real-world automotive applications. Overall, the literature review underscores the growing interest and potential of AI-powered approaches in automating vehicle defect detection and enhancing maintenance practices in the automotive industry. However, further research is needed to address existing challenges and refine these technologies for widespread adoption and deployment in service centres and vehicle maintenance facilities.

METHODOLOGY

The methodology section outlines the step-by-step process to develop and implement the Automatic Vehicle Defect Detection App. It encompasses data collection, preprocessing, model selection, training, and evaluation. The following is an overview of the methodology:

Data Collection- Data types collect image and sensor data from inspection vehicles. Image data capture various angles and views of the vehicle, focusing on areas prone to defects, such as body panels, tyres, lights, and interior components. Sensor data include onboard diagnostic (OBD) systems readings, accelerometer data, and other relevant sensor outputs.

Data Sources: Acquire data from diverse sources, including vehicle manufacturers, service centres, and publicly available datasets. Ensure data represent various vehicle makes, models, and defect types to facilitate robust model training. We are labelling data in annotated image data with labels indicating the presence or absence of defects. Use manual labelling by expert technicians or crowdsourced annotation platforms to ensure accuracy.

Data Preprocessing- Image Preprocessing- Apply techniques such as resizing, normalisation, and augmentation to standardise and enhance the quality of image data. Augmentation methods may include rotation, flipping, and adding noise to augment the training dataset and improve model generalisation.

Feature Engineering- Extract relevant features from sensor data and preprocess them to facilitate model training. This may involve normalisation, scaling, and feature selection techniques based on domain knowledge and data analysis.

MODEL SELECTION

Evaluate various machine learning algorithms suitable for image classification and anomaly detection tasks. Commonly used algorithms include convolutional neural networks (CNNs), recurrent neural networks (RNNs), and ensemble methods. Design the neural network architecture, considering depth, width, activation functions, and regularisation techniques. Experiment with different architectures to find the optimal balance between model complexity and performance. Divide the annotated dataset into training, validation, and test sets to evaluate model performance. Use stratified sampling to ensure a balanced distribution of defect classes across sets. Train the model using the training dataset and monitor performance metrics on the validation set to prevent overfitting. Implement techniques such as early stopping and learning rate scheduling to optimise training convergence and prevent model degradation. Fine-tune model hyperparameters using grid or random search techniques to maximise performance, including learning rate, batch size, and regularisation parameters. The methodology outlined above provides a systematic framework for developing and evaluating the Automatic Vehicle Defect Detection App, ensuring robustness, accuracy, and reliability in defect detection before vehicle servicing.

EVALUATION

Evaluate model performance using accuracy, precision, recall, F1 score, and area under the receiver operating characteristic curve (AUC-ROC). Compute confusion matrices to analyse model behaviour across different defect classes. Perform k-fold cross-validation to assess model generalisation and robustness across different data splits. Validate the trained model on unseen test data collected from real-world vehicle inspection scenarios to assess its effectiveness in detecting defects in practical settings.

RESULTS AND DISCUSSIONS

This results and discussion section presents the evaluation findings on the Automatic Vehicle Defect Detection App, followed by a critical analysis and interpretation of the outcomes. It provides insights into the app's performance, effectiveness, limitations, and potential implications for the automotive industry. The app achieved high accuracy, precision, recall, and F1 scores on the test dataset, demonstrating its efficacy in detecting vehicle defects. Performance metrics indicate robust performance across various defect classes, with minimal false positives and negatives. Real-world testing confirmed the app's effectiveness in identifying defects in diverse vehicle types and conditions. The app detected defects such as dents, scratches, tyre wear, and mechanical issues, enabling proactive maintenance interventions. Comparative analysis with traditional manual inspection methods revealed significant improvements in inspection speed, accuracy, and reliability. The app outperformed human technicians, detecting subtle defects and minimising oversight or human error. Adopting the Automatic Vehicle Defect Detection App streamlines the vehicle inspection process, reducing service centre inspection time and labour costs. The app's automation capabilities enable faster turnaround times for vehicle servicing, enhancing customer satisfaction. The app enhances vehicle safety and reliability on the road by detecting defects before they escalate into larger issues. Proactive maintenance interventions based on timely defect detection reduce the risk of accidents, breakdowns, and costly repairs for vehicle owners. The app's scalability and adaptability allow a seamless integration into existing service centre workflows and infrastructure. It can accommodate various vehicle models and defect types, making it suitable for diverse automotive applications and environments. Despite its effectiveness, the app may encounter challenges detecting complex or rare defects, requiring continuous updates and refinement to address evolving automotive technologies. Future research could incorporate advanced AI techniques, such as reinforcement learning and anomaly detection, to enhance the app's capabilities further.

POTENTIAL IMPACT

The Automatic Vehicle Defect Detection App has the potential to revolutionise the automotive maintenance industry by introducing a proactive and data-driven approach to defect detection and servicing. Service centres adopting the app can benefit from improved operational efficiency, reduced maintenance costs, and enhanced customer satisfaction. Vehicle owners stand to gain from increased safety, reliability, and longevity of their vehicles, resulting in lower ownership costs and improved overall driving experience.

CONCLUSION

In conclusion, the results and discussion highlight the significant contributions of the Automatic Vehicle Defect Detection App to advancing automotive maintenance practices and ensuring safer, more reliable vehicles on the road. Continued research and innovation in AI-powered solutions promise to transform the automotive industry further and drive towards a future of smarter, more efficient vehicle maintenance.

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