Helmet Detection with Number Plate Extraction System Using AI And OCR

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Abstract - Road traffic accidents involving two-wheelers remain one of the leading causes of fatalities and serious injuries, particularly in developing countries. A major contributing factor to these accidents is the non-compliance with helmet usage laws. Although traffic regulations mandate helmet use, manual enforcement mechanisms suffer from limitations such as human error, restricted coverage, and high operational costs. To address these challenges, this thesis presents a fully automated Helmet Detection and Fine Generation System using YOLO (You Only Look Once) for object detection and Optical Character Recognition (OCR) for vehicle identification.

The proposed system integrates deep learning–based computer vision, text recognition, database management, and automated notification mechanisms into a unified pipeline. The system captures video input from traffic surveillance cameras, detects two-wheeler riders, determines helmet compliance, extracts vehicle number plates using YOLO-based plate detection combined with PaddleOCR, and automatically generates fines for violators. Fine details are securely stored in an SQLite database, and automated email notifications are sent to registered vehicle owners.The system is designed for real-time or near-real-time operation, ensuring scalability, efficiency, and reliability. By reducing dependency on human intervention, the proposed solution enhances enforcement accuracy, promotes road safety, and aligns with smart city initiatives. This thesis details the system architecture, methodology, implementation, and technical specifications, demonstrating the effectiveness of combining YOLO and OCR for intelligent traffic law enforcement.

Key Words: Helmet Detection, Two-Wheeler Safety, Traffic Law Enforcement, YOLO, Object Detection, Optical Character Recognition (OCR), PaddleOCR, Number Plate Recognition, Automated Fine Generation, Intelligent Transportation System, Computer Vision, Deep Learning, Smart City, Road Safety, Surveillance Systems, Real-Time Detection, SQLite Database, Automated Notification System

1. INTRODUCTION

Road safety is a critical societal issue that directly impacts public health and economic stability. Two-wheelers, such as motorcycles and scooters, are widely used due to their affordability and convenience. However, riders of two-wheelers are particularly vulnerable during accidents, with head injuries being the leading cause of death. Helmets significantly reduce the risk of fatal head injuries, yet non-compliance with helmet laws remains widespread.

Traditional helmet enforcement relies on traffic police personnel stationed at intersections or conducting random checks. This approach is limited by manpower constraints, inconsistent enforcement, and the inability to monitor all locations simultaneously. Moreover, manual enforcement is prone to subjective judgment and corruption, which reduces public trust in traffic systems.

Recent advancements in Artificial Intelligence, Deep Learning, and Computer Vision have enabled automated visual understanding of real-world environments. Object detection models such as YOLO have demonstrated exceptional performance in identifying objects in complex scenes at high speed. Similarly, OCR technologies have matured to accurately recognize text from images under varying lighting and orientation conditions.

This project leverages these advancements to develop an intelligent helmet detection system that not only identifies helmet violations but also automatically extracts vehicle number plates and generates fines. The integration of detection, recognition, data storage, and notification creates an end-to-end automated enforcement system. The goal of this thesis is to design, implement, and analyze such a system, highlighting its practicality and effectiveness in real-world traffic monitoring scenarios.

2. LITERATURE SURVEY

Helmet non-compliance among two-wheeler riders is a major contributor to road accident fatalities, particularly in developing countries. Traditional enforcement methods rely on manual monitoring, which is limited by human error, restricted coverage, and high operational costs. To overcome these limitations, researchers have increasingly explored computer vision–based automated helmet detection systems.

Early helmet detection approaches used conventional image processing techniques such as color segmentation and edge detection; however, these methods performed poorly under real-world conditions involving occlusion, illumination variation, and complex backgrounds. The introduction of deep learning, especially convolutional neural networks (CNNs), significantly improved detection accuracy by enabling automatic feature extraction. Among modern object detection frameworks, YOLO (You Only Look Once) has gained popularity due to its high inference speed and suitability for real-time traffic surveillance.

Several studies have applied YOLO-based models to detect helmeted and non-helmeted riders directly from surveillance footage. For vehicle identification, Automatic Number Plate Recognition (ANPR) systems using deep learning–based plate detection combined with Optical Character Recognition (OCR) have shown promising results. Recent research indicates that PaddleOCR offers improved accuracy for Indian vehicle number plates compared to traditional OCR methods.

While existing works demonstrate effective helmet and plate detection, most systems stop at violation identification and lack automated fine generation, database management, and notification mechanisms. The proposed system addresses these gaps by integrating helmet detection, number plate recognition, fine generation, and automated alerts into a unified real-time enforcement framework.

3. METHODOLOGY

The methodology of the proposed system follows a modular, pipeline-based architecture to ensure robustness, scalability, and ease of maintenance. Each module is responsible for a specific task and communicates with other modules through well-defined interfaces. The overall methodology can be divided into six major stages.

3.1. Video Acquisition and Frame Sampling

The first stage involves acquiring video input from traffic surveillance cameras or uploaded video files. The video is read frame by frame using OpenCV. To optimize computational efficiency, the system dynamically reduces the frame processing rate by skipping frames based on the original frames per second (FPS) and a configurable target FPS. This ensures that the system maintains near-real-time performance while minimizing redundant computations.

3.2. Rider Detection Using YOLO

In the second stage, the system applies a YOLO-based object detection model trained on multiple classes, including riders, helmeted riders, non-helmeted riders, and number plates. YOLO processes each selected frame in a single forward pass, producing bounding boxes, class labels, and confidence scores. Only detections classified as riders are considered for further analysis.

3.3. Helmet Compliance Analysis

For each detected rider, the system crops the rider region and performs a secondary detection pass using the same YOLO model. This localized detection focuses on identifying helmet-related classes within the rider region. Logical rules are applied to determine helmet compliance. If a rider is detected with a helmet, the system marks the rider as compliant. If the rider is detected without a helmet, the system flags the instance as a violation. Ambiguous cases, where both helmet and non-helmet classes are detected, are ignored to reduce false positives.

3.4. Number Plate Detection and OCR

Once a helmet violation is confirmed, the system proceeds to identify the vehicle number plate. A dedicated YOLO model trained specifically for number plate detection is applied to the violation frame or rider crop. The detected number plate region is extracted and passed to the OCR module.

PaddleOCR is used to recognize alphanumeric characters from the number plate image. The OCR output undergoes extensive post-processing, including text cleaning, character correction, spatial ordering, and validation against Indian vehicle number plate formats. Only plates that satisfy predefined regex patterns and state code constraints are accepted as valid.

3.5. Fine Management and Database Storage

After successfully identifying a valid number plate, the system checks whether the vehicle is registered in the vehicle database. Duplicate fines for the same vehicle on the same day are prevented using timestamp-based checks. Valid fines are stored in an SQLite database, including plate number, fine amount, timestamp, proof image, and payment status.

3.6. Automated Notification and User Interface

In the final stage, the system sends automated email notifications to registered vehicle owners using Gmail SMTP services. The email includes violation details and proof images. A Streamlit-based web interface provides an intuitive dashboard for uploading videos, running detection, viewing stored fines, and visualizing proof images. This interface ensures transparency and ease of use for administrators.

4. CONCLUSION

In this research, we have explored the application of machine learning and optimization techniques, including Random Forest algorithm, Multilayer Perceptron (MLP), and Genetic Algorithm, in determining the decision-driving strategy of autonomous vehicles. Through an extensive examination of existing literature and research studies, several important insights have emerged. Firstly, Random Forest algorithm demonstrates promising capabilities in handling complex decision-making tasks within autonomous driving systems. Its ability to handle high-dimensional data and nonlinear relationships makes it suitable for tasks such as object detection, path planning, and behavior prediction. However, the interpretability of Random Forest models and the need for careful parameter tuning remain important considerations. Secondly, MLP offers a powerful framework for modeling intricate decision-driving strategies by leveraging its ability to learn complex mappings from input features to output decision With advances in deep learning architectures and training techniques. Lastly, Genetic Algorithm provides a robust optimization framework for refining decision

strategies and parameter tuning in autonomous driving systems. Integration of Random Forest algorithm, MLP, and Genetic Algorithm holds significant promise for enhancing the decision-driving capabilities of autonomous vehicles. By harnessing the strengths of each approach and addressing their respective limitations, researchers and practitioners can pave the way for safer, more efficient, and more intelligent autonomous driving systems. Future research directions may focus on hybrid approaches, reinforcement learning techniques, and real-world validation to further advance the state-of-the-art in autonomous vehicle decision-making.

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