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Helmet Detection System

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Introduction

- Helmet usage is vital for motorcyclists and cyclists to reduce serious injuries during road accidents.
- Despite safety benefits, many riders still neglect helmet use due to low awareness and weak enforcement.
- This ongoing issue highlights the urgent need for modern, tech-based safety compliance monitoring methods.
- A real-time helmet detection system can efficiently identify non-compliance and support law enforcement efforts.
- Such systems promote safer roads by reducing accidents and encouraging consistent helmet-wearing behavior.

Literature Review

Title/ Year	**Methodology**	**Techniques used**	**Advantages**	**Disadvantages**
Title: HELMET DETECTION USING MACHINE LEARNING Year: 2022	This paper presents an autonomous helmet detection system built using **YOLO**, known for its powerful feature extraction capabilities. The model is trained using the DarkFlow framework and can identify riders who are not wearing helmets. (It only detects if the helmet is worn or not. It doesn't detect number plate)	**Yolo :-** real time object detection, process entire image in one go **CNN:-** used in image classification, object detection, and segmentation **Input to system:** Video → Extract images from video → Label and Process	Earlier **SVM** and **KNN** classifiers were used but they had limitations then due to advanced growth in ML and Deep Learning cnn came into picture. YOLO is a CNN extension	Dependency on Pre-trained Models (yolo model learns from pre trained data) Hardware issues can arise like (video footage at night)

Literature Review

Title/ Year	Review of Literature	Techniques used	Advantages	Disadvantages
Title:HELMET AND NUMBER PLATE DETECTION Year:2024	The identification of non-helmeted riders and capturing their license plate information without human intervention. This is an efficient alternative to traditional manual monitoring methods.	**YOLO:**for helmet detection **OCR:** for license plate recognition.	The system provides a reliable solution for monitoring helmet use and enforcing traffic laws.It has the potential to significantly reduce road accidents by ensuring helmet compliance.	Dependency on Pre-trained Models (yolo model learns from pre trained data) Hardware issues can arise like (video footage at night)
Title: HELMET AND NUMBER PLATE DETECTION USING YOLO V-3 Year: 2022	Develop a system aimed at enhancing road safety by detecting motorcycle riders who are not wearing helmets and recognizing the number plates of their vehicles.	Frame Prediction Multi-path Predictor Context Module Memory Module	Real-Time Detection. Automated Monitoring.	Dependence on Quality Data, Environmental Factors, Processing Power

Literature Review

Title/Year	Review of literature	Techniques Used	Advantages	Disadvantages
Title: HELMET AND NUMBER PLATE DETECTIO N USING MACHINE Year: 2023	This research discusses an automated system for detecting motorcycle riders who are not wearing helmets and recognizing their motorcycle license plates. The system analyzes video footage captured by surveillance cameras. It utilizes image processing techniques to detect helmets and license plates. Once violators are identified, a notification or penalty is issued to them.(this is the only paper that talks about the penalty)	**OpenCV** **OCR** **Haar Cascade Classifier** **Deep Learning** **Image Preprocessing Technique**	Real-Time Monitoring, Cost-Effective, Reduction of Human Error	Hardware Limitations, False Positives results, Privacy Concern

Literature Review

Title/ Year	Review of literature	Techniques Used	Advantages	Disadvantages
Title: CNN-BASED AUTOMATIC HELMET VIOLATION DETECTION OF MOTOR-CYCLISTS FOR AN INTELLIGENT TRANS-PORTATION SYSTEM Year: 2022	The helmet recognition system uses the Faster R-CNN model to detect helmet violations from CCTV footage. It extracts frames, labels cyclists with or without helmets, and annotates them with bounding boxes. The model includes a Region Proposal Network (RPN) and Fast R-CNN for detecting motorcyclists and classifying helmets. Trained on 70% of the dataset with a GTX 1080 Ti GPU, it achieved 97.69% accuracy after 200,000 trials. Real-time video input detects violations, with yellow bounding boxes for violators and green for compliant motorcyclists.	**SVM and Background Subtraction** **Hough Transform & SVM** **HOG, SIFT, LBP & SVM** **YOLO Models** **CNN Models** **Faster R-CNN**	**High Accuracy:** achieved 97.59% mAP **Real-Time Performance** **Dataset Diversity:** model covers diverse conditions. **Feature Extraction:** Advanced techniques like HOG, SIFT, and histogram-oriented gradients improved detection reliability.	**High Computational Cost:** SVM and background subtraction methods require analyzing the entire frame. **Limited Datasets** **Misclassification** **Variable Accuracy:** Accuracy varied across studies, with some achieving low results

Literature Review

Title/ Year	Review of literature	Techniques Used	Advantages	Disadvantages
Title: PENALTY SYSTEM FOR AUTOMATIC HELMET DETECTION Year: 2023	The system utilizes video surveillance to monitor motorcycle riders. It employs deep learning algorithms to analyze video frames and identify motorcyclists without helmets. Upon detecting a violation, the system captures the motorcycle's license plate number. Subsequently, a penalty message is sent to the registered owner of the vehicle, notifying them of the infraction. This automated approach aims to enhance the enforcement of helmet laws and promote road safety.	The project uses deep learning techniques, specifically Convolutional Neural Networks (CNNs), for object detection and classification to identify helmetless riders in video data. It also incorporates license plate recognition to identify vehicles involved in violations. By combining these technologies, the system enables real-time monitoring and enforcement of helmet laws.	**Automated Enforcement:** The system reduces the reliance on manual monitoring by traffic authorities. **Enhanced Road Safety** **Scalability:** The automated nature of the system enables it to be deployed across various locations without significant additional resources, facilitating widespread implementation.	**Costs:** surveillance cameras and computational resources for processing video **Privacy Concerns:** Continuous video surveillance raises potential privacy issues. **Accuracy:** Variations in lighting, weather conditions, and occlusions can affect the system's accuracy potentially leading to false positives or negatives.

Literature Review

Title/ Year	Review of literature	Techniques Used	Advantages	Disadvantages
Title: HELMET DETECTION AND NUMBER PLATE EXTRACTION USING MACHINE LEARNING Year: 2021	The paper presents a system to improve road safety by ensuring motorcyclists wear helmets at petrol stations. A camera-equipped single-board computer captures images of approaching riders, which are analyzed using deep learning models to detect helmet usage. If the rider is wearing a helmet, the system allows fuel dispensing; otherwise, service is denied. This approach promotes helmet compliance, aiming to reduce head injuries and fatalities among motorcyclists.	The project employs deep learning techniques for image analysis, specifically using TensorFlow to develop and train models capable of detecting helmets in real-time. A single-board computer, such as a Raspberry Pi or Arduino, is utilized to process the captured images and interface with the fuel dispensing system. The integration of these technologies enables the system to function autonomously at petrol stations.	**Enhanced Safety:** By enforcing helmet usage, the system aims to reduce the severity of injuries in motorcycle accidents. **Automation:** The automated nature of the system ensures consistent enforcement without the need for human intervention. **Deterrence:** The requirement of wearing a helmet to receive fuel serves as a deterrent against non-compliance with traffic safety regulations.	**Implementation Costs:** initial setup costs, including hardware and training of the deep learning models. **Privacy Concerns:** Continuous image capturing raises potential privacy issues **False Positives/Negatives:** The system may occasionally misclassify helmet usage due to varying lighting conditions, occlusions, or unconventional helmet designs

Literature Review

Title/Year	Review of literature	Techniques Used	Advantages	Disadvantages
Title: Helmet Detection Using ML & IoT Year: 2019	The system uses video surveillance and machine learning to detect helmet violations by analyzing riders and distinguishing bikes from other vehicles. If a violation occurs, it extracts the vehicle's registration number using Optical Character Recognition (OCR) and generates a challan. The violation notice is sent via email and SMS, and users can pay fines online through a web or mobile app. The system aims to enforce traffic laws and enhance road safety.	The system utilizes OpenCV for image processing and HAAR cascades for helmet detection. It uses Optical Character Recognition (OCR) to extract registration numbers from number plates for penalty generation. The automated workflow integrates with state transport databases to issue challans. A web and mobile app, developed using Android Studio, allows users to pay fines online.	**Automated Enforcement**: Reduces manual monitoring **Cost-Effective**: Uses existing CCTV infrastructure, minimizing additional costs. **Improved Road Safety**: Deters violations, potentially reducing injuries and fatalities. **User-Friendly**: Web and mobile apps simplify fine payments, reducing bribery and errors.	**Accuracy Challenges:** Variations in lighting, occlusion, and weather conditions **High Initial Investment:** Training the machine learning model and deploying the necessary hardware require substantial resources. **System Limitations:** Special cases, such as riders wearing unsafe helmets or caps, may lead to misclassification. **Data Privacy Concerns:** Continuous surveillance and data storage raise ethical and privacy issues.

Problem Statement

Motorcycles are a popular way to get around in many countries, but riding without a helmet can be very dangerous. Many riders don't wear helmets when they think traffic police aren't watching. To improve safety, we need a system that can automatically check if riders are wearing helmets. Current methods of checking compliance are slow and depend on police presence. We need a real-time system that can automatically detect whether riders are wearing helmets to enhance safety.

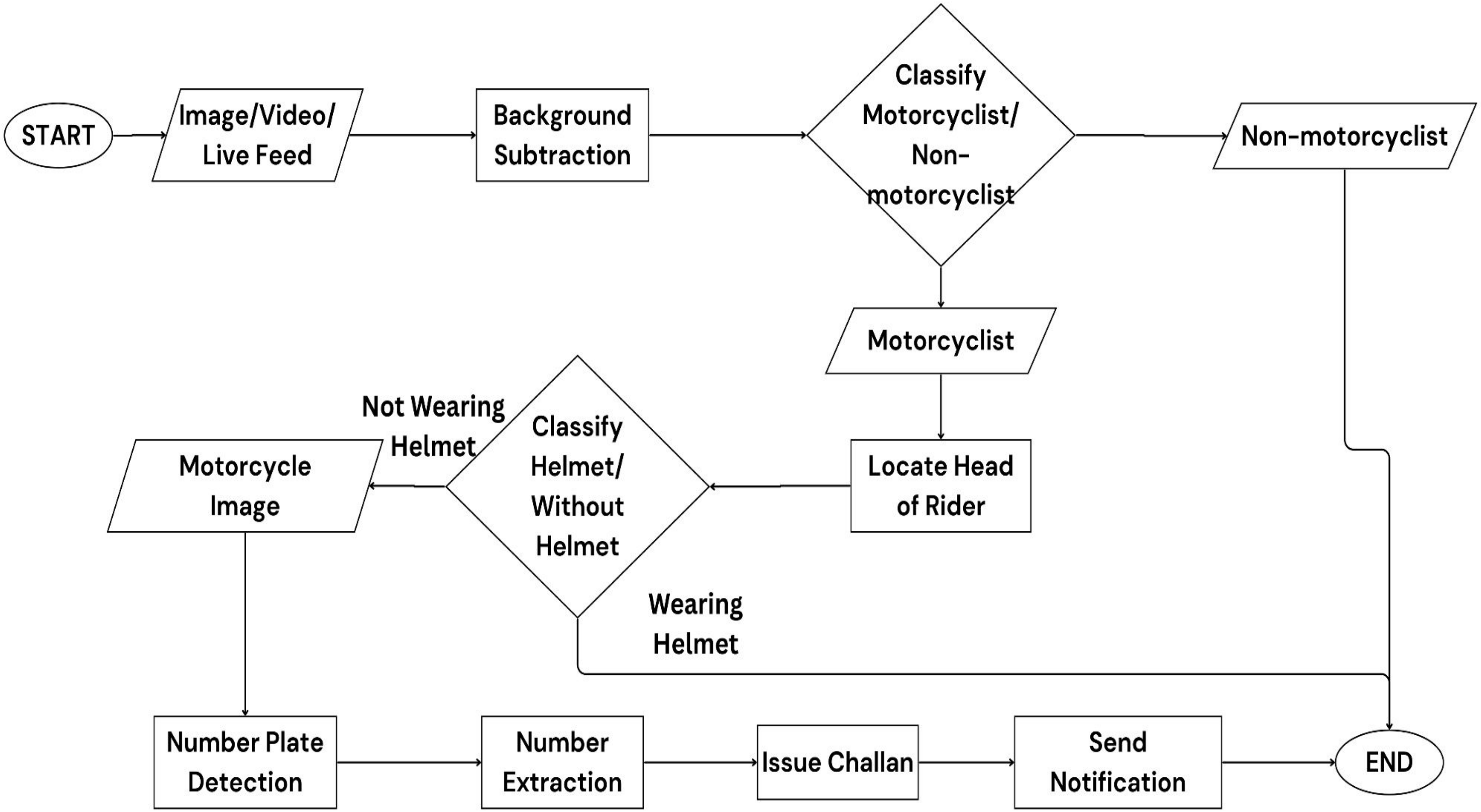
Proposed Solution

- To develop a real-time Helmet Detection System that can automatically detect and classify whether individuals in a monitored area are wearing safety helmets or not.

- We would like to build an autonomous helmet detection system for real-time helmet detection. The system will include cameras placed at key locations, processing video feeds quickly to send instant alerts to traffic authorities if a rider isn't wearing a helmet. Privacy measures will be implemented to protect individual identities.

- The expected outcomes include increased helmet use, leading to safer roads, fewer motorcycle-related injuries and deaths, and improved data to enhance motorcycle safety regulations.

Helmet Detection Block Diagram



Overview of the system

Phase 1: Video Input & Background Subtraction

- Video footage is captured from a camera monitoring roads.
- Background subtraction is applied to remove stationary objects and detect moving vehicles.

Phase 2: Classification of Motorcyclists vs. Non-Motorcyclists

- Using object detection models (YOLO), the system differentiates motorcyclists from other vehicles.
- Non-motorcyclists are discarded from further processing.

Overview of the system

Phase 3: Helmet Detection & Violation Identification

- The head region of the motorcyclist is extracted.
- A helmet classifier model determines whether the rider is wearing a helmet or not.
- If the rider has a helmet, the image is discarded.
- If the rider is not wearing a helmet, a violation is flagged.

Phase 4: Number Plate Detection & Fine Issuance

- Automatic Number Plate Recognition (OCR) detects and extracts the motorcycle's license plate.
- The extracted number plate is recorded into the database for further inquiry and penalty processing.

YOLO(You Only Look Once)

In our project, we use YOLO to quickly detect if a rider is wearing a helmet. YOLO processes the video feed in real time, identifying both helmets and number plates in a single pass. When a helmet violation is detected, YOLO captures the bike's number plate and uploads to the concerned authorities. YOLO's speed and accuracy make it ideal for continuous monitoring, making our system efficient and reliable for enforcing helmet laws.

OCR(Optical Character Recognition)

In our project, OCR is used to read and extract text from number plates. When a rider without a helmet is detected, OCR processes the image to recognize the letters and numbers on the plate. This allows our system to identify the vehicle and issue fines automatically. OCR is essential for translating the image of the number plate into readable text, making our enforcement process both quick and automated.

Experimental Setup

- **Hardware requirements:**

  PC: Minimum RAM: 8 GB

  Minimum Storage: 10-15 GB

  GPU:-GeForce RTX 3050

  Operating System: Windows X64

  Live Camera

- **Software requirements:**

  Programming Languages: Python, Javascript

  Framework: Yolo, OCR

Experimental Setup

- **Dataset**

A. Helmet Detection Dataset

• Total Images: 1494

• Source: Roboflow

• Training Set: 1195 images (80%)

• Validation Set: 150 images (10%)

• Testing Set: 154 images (10%)

B. Number Plate Detection Dataset

• Total Images: 102

• Source: Roboflow

• Training Set: 71 images (70%)

• Validation Set: 21 images (20%)

• Testing Set: 10 images (10%)

Performance Evaluation Parameters

The performance of model can be evaluated using following metrics:

1. **Precision**

Definition: Precision measures the accuracy of positive predictions. It tells us how many of the detected helmet/no-helmet cases were actually correct.

Formula:

$$\text{Precision} = \frac{TP}{TP + FP}$$

where:

TP (True Positives) = Correctly identified helmet/no-helmet cases.

FP (False Positives) = Incorrectly identified cases (wrong detections).

Performance Evaluation Parameters

2. Recall

Definition:

Recall measures how many actual helmet/no-helmet violations are correctly detected by the model. It focuses on minimizing missed detections.

Formula:

$$\text{Recall} = \frac{TP}{TP + FN}$$

where:

- **TP (True Positives):** Correctly detected helmet/no-helmet violations.
- **FN (False Negatives):** Missed detections (actual violations that were not detected)

Performance Evaluation Parameters

3. Mean Average Precision (mAP)

Definition:

mAP evaluates the overall detection accuracy by calculating the average precision across all confidence levels and object classes (helmet, no-helmet).

Formula:

$$\text{mAP} = \frac{1}{N}\sum_{i=1}^{N} AP_i$$

where:

- **AP (Average Precision):** The area under the precision-recall curve for each class.
- **N:** Number of object classes (helmet, no-helmet).

Performance Evaluation Parameters

4. F1-score

Definition:

The F1-Score is the harmonic mean of Precision and Recall. It provides a single measure of performance that considers both the number of False Positives and False Negative

Formula:

$$\text{F1-score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

where:

- **AP (Average Precision):** The area under the precision-recall curve for each class.
- **N:** Number of object classes (helmet, no-helmet).

Experimental Result

Table 1: Performance Metrics for Helmet Detection Model (Training)

Metrics	**with_helmet**	**without_helmet**
mAP	86.6%	61.2%
Precision	90%	70%
Recall	90%	68%
F1-Score	0.90	0.68

Experimental Result

Table 2: Performance Metrics for Helmet Detection Model (Validation)

Metrics	**with_helmet**	**without_helmet**
mAP	86.3%	62.2%
Precision	79.5%	62.3%
Recall	90.7%	65.2%
F1-Score	0.84	0.63

Experimental Result

Table 3: Performance Metrics for Detection Model (Training)

Metrics	**Value**
mAP	99.5%
Precision	100%
Recall	99.5%
F1-Score	0.95%

Experimental Result

Table 3: Performance Metrics for Detection Model (Validation)

Metrics	**Value**
mAP	99.5%
Precision	100%
Recall	99.9%
F1-Score	0.95%

Result & Discussion

- With Helmet (F1-Score: 0.90) → Near-perfect balance between precision (90%) and recall (90%), indicating highly reliable helmet detection.

- With Helmet (Recall: 90.7%) → Captures almost all helmet instances in validation data, demonstrating strong generalization.

- Without Helmet (F1-Score: 0.68 in training, 0.63 in validation) → Consistently lower performance due to:
    - High false positives (precision ~62%).
    - Missed detections (recall ~65%).

Experimental Result

Conclusion

The real-time helmet detection system significantly enhances road safety by automating the monitoring of helmet compliance among motorcyclists. By leveraging advanced computer vision technologies and algorithms, this system offers accurate and efficient detection in real-time. It reduces traffic-related injuries, and fosters safer riding practices.

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