Dual Detection of Licence Plates and Helmets Using an Optimized Yolo and Neural Networks

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Abstract - Computer vision technologies are advancing quickly and are being used more often to improve safety monitoring and surveillance in industrial and transportation settings. Traditional monitoring methods rely heavily on manual supervision. This approach can be inefficient, time-consuming, and prone to errors. Deep learning-based object detection algorithms, like YOLO, have greatly improved the ability to detect and classify objects in real time. Among the existing object detection models, YOLOv8 is widely used for helmet detection and related safety applications because of its speed and accuracy. However, earlier models often face practical challenges. These include reduced accuracy in complex environments, difficulties in detecting small objects, and limits when processing multiple objects at once. This project proposes a new computer vision framework that uses the YOLOv10 architecture for the dual detection of safety helmets and vehicle license plates in real time. The proposed system improves accuracy by using data augmentation techniques, coordinate attention mechanisms, and layers for detecting small targets. These elements help handle complex backgrounds and partially hidden objects more effectively. Additionally, the system is trained on annotated datasets that include various helmet types and vehicle plates under different lighting and environmental conditions to enhance robustness. Experimental results show improved accuracy in object detection, faster inference speed, and reliable performance in real-time situations. The findings suggest that the YOLOv10-based framework offers an efficient and scalable solution for improving safety compliance in workplaces and for automated vehicle monitoring in modern surveillance systems.

Key Words**:** Safety Helmet Detection, License Plate Recognition, YOLOv10, Computer Vision, Deep Learning, Real-Time Object Detection.

1. INTRODUCTION

Workplace safety and effective vehicle monitoring have become critical concerns in modern industrial and construction environments. Industrial workers are often exposed to hazardous conditions, particularly in construction zones and high-risk workplaces where accidents can occur due to the absence of proper safety equipment such as helmets. Safety helmets play a crucial role in protecting workers from head injuries caused by falling objects, slips, or high-altitude falls. Ensuring that workers consistently wear safety helmets is essential for maintaining occupational safety standards. However, traditional monitoring methods rely heavily on manual supervision, which can be inefficient, time-consuming, and prone to human error. Similarly, vehicle monitoring systems that rely on manual observation or basic recording mechanisms often fail to provide accurate and real-time information about vehicle movements and license plate identification. These limitations highlight the need for intelligent automated monitoring systems capable of improving safety compliance and surveillance efficiency.

This project introduces a state-of-the-art computer vision system to address these issues. It uses the newest YOLOv10 object detection model to spot both safety helmets and vehicle license plates. YOLOv10 improves on earlier versions in how well it detects objects how fast it works, and how it uses computer power. The system applies advanced ways to pull out features, pay attention to important parts, and optimize detection layers. This helps it find small or hidden objects like safety helmets better. Also, it learns from labeled datasets with many types of helmets and license plates taken in different settings. By combining helmet detection and license plate reading in one system, it offers a good way to watch things in real-time. This helps make sure people follow safety rules at work and supports smart surveillance tools.

2. Body of Paper

2.1 Literature Survey

Wu and his team (2023) developed an improved method for detecting safety helmets using the YOLOv8 system. Their mission was to enhance worker safety in hazardous environments like construction sites and mines. The research team, consisting of X. Wu, D. Hong, Z. Huang, and J. Chanussot, introduced the CC-YOLOv8 model to address the shortcomings of older techniques, which often lacked accuracy and required significant computational resources. They incorporated the C2fcc module to enhance the backbone network's ability to identify features, allowing the model to detect safety helmets even in challenging conditions. Additionally, they employed the EMA attention mechanism to help the model concentrate on the most relevant parts of the image, improving its object detection accuracy. During testing, their innovative approach performed exceptionally well across various scenarios, achieving a mean Average Precision (mAP0.5) of 92.6%, which is a 0.5% improvement over the original YOLOv8 model. This research provides a fast and reliable method for detecting safety helmets in real-world situations.

2.2 Proposed Methodology

The system we're proposing is designed to create a smart, real-time monitoring framework that focuses on Safety Helmet Detection and License Plate Recognition, all powered by the cutting-edge YOLOv10 object detection architecture. By combining computer vision with deep learning techniques, this system can automatically check if workers are wearing their safety helmets and recognize vehicle license plates from surveillance images or video feeds. The whole process involves several key stages, including data collection, preprocessing, object detection, feature extraction, and generating results.

A. YOLOv10-Based Object Detection

The proposed system uses the **YOLOv10 object detection model** to achieve accurate and fast real-time detection. YOLOv10 provides improved feature extraction and efficient object detection compared to earlier YOLO versions, enabling reliable identification of **safety helmets and vehicle license plates** in complex environments.

The framework includes the following components:

- Lightweight backbone network
- Optimized feature extraction mechanism
- Decoupled detection head

The system captures Images input from surveillance cameras and divides the Images into frames. Each frame is processed by the YOLOv10 model to detect helmets and license plates. The model extracts spatial features using convolutional layers and predicts bounding boxes around detected objects. A bounding box is represented as **(x, y, w, h)** where **x and y** represent the center coordinates and **w and h** represent the width and height of the detected object. Detection accuracy is measured using the **Intersection over Union (IoU)** metric: Higher IoU values indicate better object localization.

$$IoU = \frac{Area(Overlap)}{Area(Union)}$$

B. Helmet and License Plate Identification

After detecting objects, the system identifies whether workers are wearing **safety helmets** and simultaneously recognizes **vehicle license plates**. The model is trained using annotated datasets containing helmet and license plate images under different environmental conditions.

The YOLOv10 model analyzes spatial and visual features to distinguish helmets and license plates from other objects. If a worker without a helmet is detected, the system marks it as a **safety violation**. License plates are also identified for monitoring and security purposes.

Precision

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

Recall

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

Accuracy

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

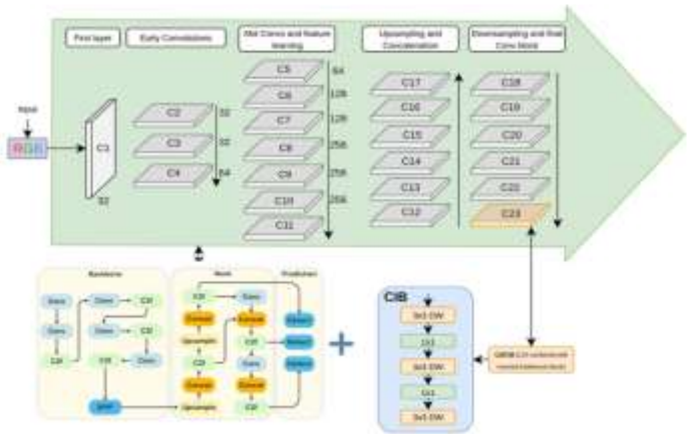
where TP represents True Positives, FP represents False Positives, FN represents False Negatives, and TN represents True Negatives.

C. Real-Time Monitoring and Alert Generation

When a worker without a safety helmet is detected or a vehicle license plate is recognized, the system generates alerts for supervisors or security personnel. The optimized YOLOv10 architecture enables fast and accurate real-time monitoring.

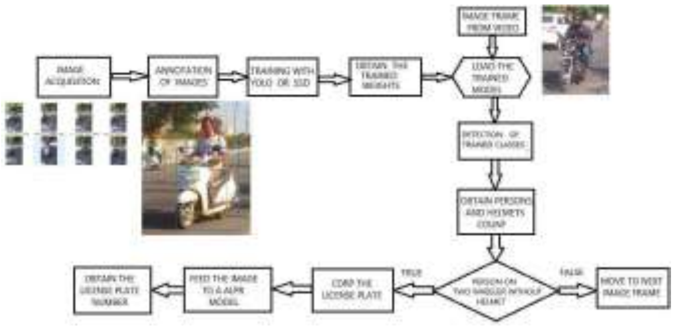
The lightweight model can run on **edge devices and smart surveillance cameras**, allowing continuous monitoring with low computational resources. This system improves **workplace safety compliance and automated surveillance** in industrial environments.

3. System Architecture



The proposed system architecture is based on the **YOLOv10 deep learning framework** for real-time detection of safety helmets and vehicle license plates. The system receives **RGB images or video frames** from surveillance cameras as input. These images first pass through the **backbone network**, which consists of multiple convolution layers and C2f modules that extract important visual features such as edges, shapes, and textures. The architecture also includes the **SPPF (Spatial Pyramid Pooling Fast) layer**, which helps capture multi-scale information and improves detection of small objects. The extracted features are then passed to the **neck network**, where operations such as upsampling and concatenation combine features from different layers to improve detection accuracy in complex scenes. Finally, the **prediction or detection head** processes these fused features to generate bounding boxes, class labels, and confidence scores for detected objects. The architecture also integrates **CIB (Convolutional Inverted Bottleneck) blocks** to enhance feature learning while reducing computational complexity. As a result, the system can efficiently detect **workers wearing helmets and vehicle license plates** in real time, making it suitable for safety monitoring and automated surveillance applications.

3.1 Workflow of the Proposed System



Step 1: Dataset Collection and Preparation

Images or video frames containing **workers with helmets, workers without helmets, and vehicle license plates** are collected from different environments. The dataset is annotated with bounding boxes indicating helmet and license plate regions. The dataset is then divided into **training, validation, and testing sets**, and a configuration file (data.yaml) is created to define dataset paths and class labels.

Step 2: Data Preprocessing

The collected images are resized, normalized, and formatted according to the requirements of the **YOLOv10 model**. Data augmentation techniques such as **flipping, scaling, rotation, and mosaic augmentation** are applied to improve model generalization and help the system detect small or distant helmets.

Step 3: Model Training using YOLOv10

The prepared dataset is used to train the **YOLOv10 object detection model**. The backbone extracts important visual features, the neck combines multi-scale features, and the detection head predicts **bounding boxes and class probabilities** for helmets and license plates.

Step 4: Model Weight Generation

During training, the model saves weight files such as **best.pt** (best performing model) and **last.pt** (final trained model), which are used for evaluation and deployment.

Step 5: Helmet and License Plate Detection

In the detection stage, the trained model processes new images or real-time video frames. The system analyzes the input and detects **safety helmets and vehicle license plates** in the scene.

Step 6: Output Visualization and Alert Generation

The detection results are displayed with **bounding boxes, labels, and confidence scores** around the detected objects. If a worker without a helmet is identified, the system generates an alert to notify supervisors or safety personnel.

Step 7: Performance Evaluation

The system performance is evaluated using metrics such as **Precision, Recall, F1-score, and mean Average Precision (mAP)** to measure the accuracy and efficiency of helmet detection and license plate recognition.

4. Result and Discussion

Table 1:Performance Results of the Proposed YOLOv10 Helmet and License Plate Detection Model

Metric	Value
Precision	0.95
Recall	0.93
F1-Score	0.89
mAP@0.5	0.92
mAP@0.5:0.95	0.85

Description:
Table I shows the evaluation results of the proposed **YOLOv10-based dual detection system for safety helmets and vehicle license plates**. The model achieves high precision and recall values, indicating that it can accurately detect helmets and license plates while reducing false detections. The **F1-score** represents the balance between precision and recall, reflecting the model's reliability in identifying workers wearing helmets and vehicles entering the monitored area. The **mAP@0.5 and mAP@0.5:0.95 values** demonstrate the overall object detection performance of the system across different Intersection over Union (IoU) thresholds. These results indicate that the proposed model performs efficiently in real-time surveillance environments

Table 2: Comparison of Different Object Detection Models for Helmet Detection and License Plate Recognition

Method	Backbone	Dataset	mAP@0.5
Faster R-CNN	ResNet-101	Helmet Dataset	0.84
SSD	ResNet-50	Helmet Dataset	0.86
YOLOv7	CSPDarknet	Helmet Dataset	0.88
YOLOv8	CSPDarknet	Helmet Dataset	0.90
Proposed YOLOv10	CSPNet	Helmet Dataset	**0.92**

Description:
Table II presents a comparison between the proposed **YOLOv10 model** and other object detection algorithms used for helmet detection and license plate recognition. The results indicate that the proposed model achieves a higher **mean Average Precision (mAP)** compared with traditional detection models such as Faster R-CNN, SSD, YOLOv7, and YOLOv8. The improvement in performance demonstrates that the **YOLOv10 architecture provides better detection accuracy and faster inference**, making it more suitable for real-time safety monitoring and intelligent surveillance systems..

5. CONCLUSIONS

In this research work, a smart surveillance system for **dual detection of safety helmets and vehicle license plates** based on the **YOLOv10 model** has been proposed and implemented. The system uses deep learning–based computer vision techniques to analyze video frames and detect whether workers are wearing safety helmets while simultaneously recognizing vehicle license plates in real time. By utilizing the advanced capabilities of the YOLOv10 architecture, the model can accurately detect multiple objects even in complex industrial environments with varying lighting conditions and occlusions.

The experimental analysis shows that the proposed system provides **high detection accuracy and fast processing speed**, making it suitable for real-time workplace safety monitoring and automated surveillance. This work highlights the importance of **AI-based safety monitoring systems** in improving industrial safety standards and enhancing vehicle monitoring through intelligent and automated detection mechanisms.

FUTURE SCOPE

In the future, the proposed system can be improved by integrating **advanced deep learning techniques and larger datasets** to further enhance detection accuracy. The system can also be extended to detect additional **personal protective equipment (PPE)** such as safety vests, gloves, and goggles to provide a more comprehensive safety monitoring solution. Furthermore, integrating **optical character recognition (OCR)** can improve license plate reading accuracy across different regions. The system may also be connected with **IoT-based alert systems and cloud platforms** to enable real-time notifications and centralized monitoring. These enhancements can expand the application of the system in **smart surveillance, intelligent transportation systems, and industrial safety management.**

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