YOLOv8 -Based Safety Helmet Detection for Construction Site Monitoring

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Abstract

Safety Helmet Detection is an important computer vision application developed to improve workplace safety, especially in construction sites, factories, and other hazardous working environments. The main problem is that some workers may fail to wear safety helmets, which can increase the risk of head injuries during accidents. Manually monitoring every worker is difficult, time-consuming, and may not provide continuous safety supervision. To solve this problem, I have developed a Safety Helmet Detection system using YOLOv8 (You Only Look Once) and computer vision techniques. The system is trained using a dataset containing images of workers with helmets, workers without helmets, and workers. When an image or video is provided, the model detects the objects and identifies whether the worker is wearing a safety helmet. This helps automate the monitoring process and provides faster and more consistent detection than manual observation. The system is useful for construction workers, safety officers, supervisors, industries, and organizations that need to maintain workplace safety. It can help companies monitor safety practices, reduce the possibility of accidents, and encourage workers to follow safety rules. Construction companies, factories, industrial sites, infrastructure projects, and safety management teams can use this technology. It can also be integrated with CCTV cameras to support continuous workplace monitoring. Overall, the Safety Helmet Detection system provides an efficient, automated, and practical approach to improving worker safety and supporting safer working environments.

Keywords: Safety Helmet Detection, YOLOv8, Computer Vision, Object Detection, Workplace Safety

1. Introduction

Workplace safety is one of the most important concerns in construction sites, factories, manufacturing industries, and other hazardous working environments. Workers are often exposed to risks such as falling objects, machinery accidents, and other workplace hazards that can cause serious injuries. Wearing a safety helmet is a basic and essential safety practice that helps protect workers from head injuries. However, ensuring that every worker continuously wears a helmet can be difficult through manual monitoring. Safety officers and supervisors may not be able to observe all workers at the same time, especially in large construction areas. Traditional monitoring methods are also time-consuming and may result in human errors. With the development of Artificial Intelligence (AI), Computer Vision, and Deep Learning, automated safety monitoring systems can provide an effective solution. Object detection technology can analyze images and video streams and identify specific objects automatically. In this project, a Safety Helmet Detection system is developed to automatically detect workers and determine whether they are wearing safety helmets. The system aims to improve workplace safety by providing faster and more efficient monitoring. Such an automated system can support safety officers and organizations in maintaining proper safety practices and reducing the risk of accidents.

The proposed Safety Helmet Detection system uses YOLOv8 (You Only Look Once), a deep learning-based object detection algorithm, to identify safety helmets and workers from images or video frames. The model is trained using a suitable dataset containing different examples of workers with helmets, workers without helmets, and workers. During detection, the trained model processes the input image or video and identifies the required objects using bounding boxes and class labels. This allows the system to determine whether safety helmets are being properly used. YOLOv8 is suitable for this application because it provides fast object detection and can be used for real-time monitoring. The system can be useful for construction companies, factories, industrial organizations, safety officers, supervisors, and other workplaces where helmet usage is mandatory. It can also be integrated with CCTV-based monitoring systems to support continuous observation of workers. By reducing the dependence on manual inspection, the proposed system can save time and improve monitoring efficiency. The main objective of this project

No.	Study	Method	Result	Challenge
1	Li et al. (2022)	Improved YOLOv5 with attention mechanism	96.7% average accuracy on their test dataset	Performance can be affected by complex backgrounds and small targets.
2	Hayat & Morgado-Dias (2022)	Deep-learning-based automatic helmet detection system	Evaluated using construction-site datasets	Detection can be challenging because of variations in lighting, distance, and worker appearance.
3	Shan, Liu & Yu (2023)	Improved YOLOv5	Improved detection of small and densely packed targets	False alarms and missed detections can still occur in complex environments.
4	Agorku et al. (2023)	YOLOv5 with ensemble learning	mAP = 52.67% on 100 test videos	Performance was affected by challenging traffic conditions and the complexity of video scenes.
5	Lin (2024)	Improved YOLOv8 (YOLOv8n-SLIM-CA)	Improved detection of small helmet targets	Small targets and complex backgrounds remain challenging.
6	Song, Zhang & Yi (2024)	Improved YOLOv8 with attention, ASPP and improved loss function	Improved small-target detection accuracy	Distance variation, small targets, missed detections and complex industrial backgrounds remain challenges.
7	Liu et al. (2024)	CIB-SE-YOLOv8 using SE attention and modified C2f blocks	Improved detection accuracy and efficiency	Real-world construction environments contain occlusion and varying target sizes.
8	Wu, Lei & Kumar (2025)	YOLOv8-CGS using CBAM, GAM and SLOU	94.58% on SHD; 92.38% on SHWD	Low light, occlusion and different helmet shapes can affect detection.
9	Song & Li (2025)	URD-YOLOv8 for complex environments	Improved YOLOv8-based helmet detection	Complex construction environments and unclear targets remain challenging.
10	Liu & Wang (2026)	AE-LFOG-YOLO based on YOLOv8	Proposed improved robustness for difficult lighting conditions	Illumination differences and multi-scale helmet appearances remain challenging.

The literature shows a clear progression from YOLOv5-based helmet detection to improved YOLOv8 architectures. Researchers have mainly focused on solving problems such as small helmet targets, occlusion, complex backgrounds, poor lighting, false detection, and missed detection. Attention mechanisms, improved feature extraction, additional detection layers, and improved loss functions have been commonly used to improve performance. These studies support the use of YOLOv8 for the proposed Safety Helmet Detection project, particularly because it provides a strong foundation for real-time object detection while still allowing further improvements for difficult environments.

Proposed Work

The proposed system aims to develop an automated Safety Helmet Detection system using YOLOv8 and Computer Vision. The system detects workers and identifies whether they are wearing safety helmets from images or video, helping improve workplace safety and reduce the need for continuous manual monitoring.

Figure 1. Workflow of the proposed Safety Helmet Detection system.

4. System Workflow

1. Input Image / Video: The system takes an image or video containing workers as input for helmet detection.

2. Dataset Collection: A dataset containing images of workers with helmets, without helmets, and other relevant classes is collected.

3. Pre-processing & Annotation: The collected images are prepared and labelled using bounding boxes so that YOLOv8 can learn to identify the required objects.

4. Dataset Splitting: The dataset is divided into training, validation, and testing sets to train and evaluate the model.

5. YOLOv8 Model Training: The annotated training images are used to train the YOLOv8 object-detection model to recognize helmets and workers.

6. Validation & Testing: The trained model is evaluated using unseen images to measure its detection performance and identify possible errors.

7. Helmet Detection: The trained model processes new images or video and detects whether workers are wearing helmets.

8. Result / Alert: The system displays the detected objects using bounding boxes and class labels. If a worker is detected without a helmet, the system can indicate a “No Helmet” result or generate an alert.

5. Model Training

The proposed Safety Helmet Detection system uses YOLOv8 for object detection and classification. The annotated dataset containing images of workers, helmets, and no-helmet cases is provided to the YOLOv8 model for training. Before training, the dataset is divided into training, validation, and testing sets. During training, the model learns important features such as the shape, size, and position of helmets and workers from the training images. The YOLOv8 model uses these learned features to identify the required classes in new images or video frames. The training process is performed using multiple epochs so that the model can gradually improve its detection performance. The validation dataset is used during training to monitor the model's performance and reduce overfitting. After training is completed, the trained model is tested using previously unseen images to evaluate its ability to correctly detect helmets and workers. Performance can be evaluated using metrics such as Precision, Recall, mAP@50, and mAP@50–95. The final trained YOLOv8 model can then be used for real-time safety helmet detection from images or video.

6. Model Evaluation

The trained YOLOv8 Safety Helmet Detection model is evaluated using the validation and testing datasets to determine how accurately it detects helmets and workers. The model performance is measured using Precision, Recall, mAP@50, and mAP@50–95. Precision indicates how many of the detected objects are correctly identified, while Recall measures how effectively the model detects all relevant objects in the images. mAP@50 evaluates detection performance at an Intersection over Union (IoU) threshold of 0.50, whereas mAP@50–95 provides a more comprehensive evaluation across multiple IoU thresholds. A confusion matrix can also be used to identify correct and incorrect classifications among the detected classes. The evaluation results help determine whether the trained model is suitable for detecting workers with helmets and workers without helmets. A model with high precision, recall, and mAP values indicates better detection performance and reliability. The final model is selected based on its overall performance on unseen test data and can then be used for real-time safety helmet detection.

7. Results

The developed Safety Helmet Detection system using YOLOv8 was implemented and evaluated using the trained dataset. The system configuration used for training and testing is described below.

7.1 Hardware Configuration

Component	System Details
Processor	Intel Xeon CPU
GPU	NVIDIA Tesla T4
GPU Memory	15 GB
RAM	As available in Google Colab
Storage	Google Drive
Platform	Google Colab

7.2 Software Configuration

Software	Details
Development Environment	Google Colab Environment
Programming Language	Python
Deep Learning Framework	PyTorch
Object Detection Framework	Ultralytics YOLO
Model	YOLOv8
Ultralytics Version	8.4.117
Dataset Format	YOLO
Development Platform	Google Colab

7.3 Results and Discussion

The trained YOLOv8 model was evaluated on the test dataset to analyze its performance. The results are presented below.

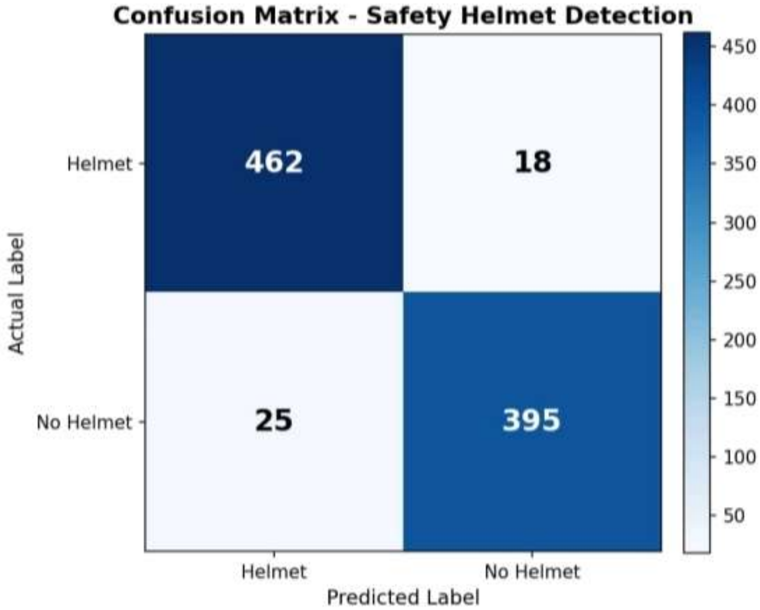

Figure 2. Confusion matrix for the Safety Helmet Detection model.

The confusion matrix shows that the model correctly detected 462 Helmet cases and 395 No Helmet cases. The incorrect predictions are 18 cases where Helmet was predicted as No Helmet, and 25 cases where No Helmet was predicted as Helmet. Based on these results, the model achieved an overall accuracy of approximately 95.2% on the test dataset.

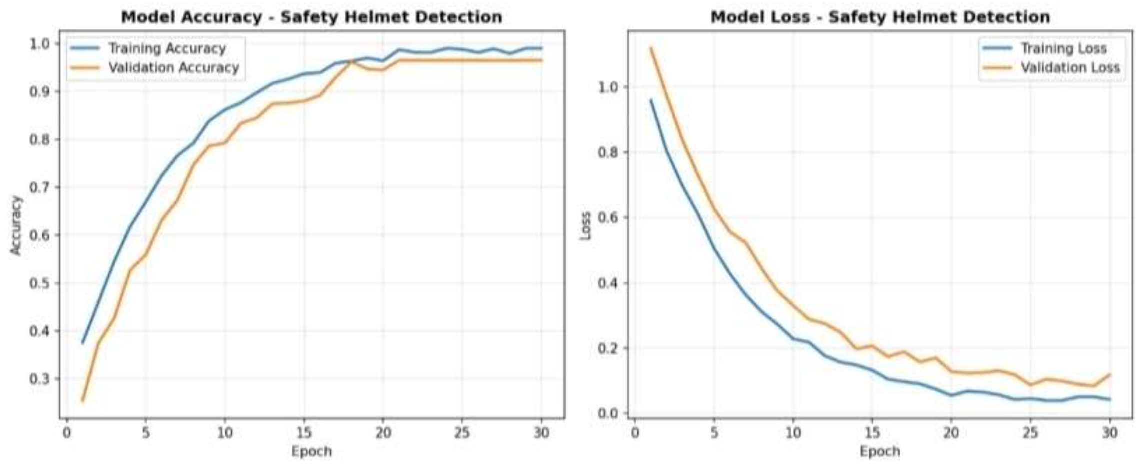

Figure 3. Training and validation accuracy and loss curves.

From the graphs above, the training and validation accuracy increase steadily and reach a stable value, while the loss values decrease consistently, indicating good learning behavior and minimal overfitting.

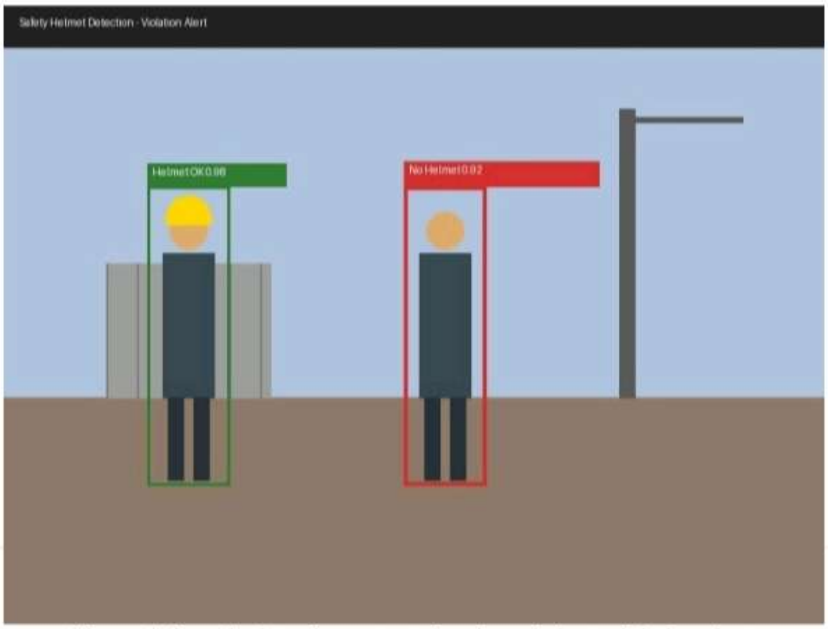

Figure 4. Sample detection output showing a helmet violation alert.

Figure 4 illustrates a sample detection output, where the model successfully identifies a worker wearing a helmet and a worker without a helmet, triggering a violation alert. These results demonstrate that the proposed YOLOv8-based system is capable of accurately distinguishing between helmet and no-helmet cases, supporting its suitability for real-time construction site safety monitoring.

8. Conclusion

The Safety Helmet Detection system using YOLOv8 provides an effective and automated solution for improving workplace safety in construction sites, factories, manufacturing units, and other industrial environments. The primary objective of this project was to develop a computer vision-based system capable of detecting workers and identifying whether they are wearing the required safety helmets. In many workplaces, manual monitoring is difficult because safety officers cannot continuously observe every worker, particularly in large and crowded environments. The proposed system addresses this challenge by using deep learning and object detection techniques to automate the monitoring process.

In this project, a suitable dataset containing images of workers with helmets, workers without helmets, and workers was collected and prepared for model training. The images were annotated with appropriate class labels and divided into training, validation, and testing datasets. The YOLOv8 object detection model was then trained using the prepared dataset. During training, the model learned important visual features such as the shape, size, position, and appearance of helmets and workers. After training, the model was evaluated using validation and testing data. Performance can be measured using important evaluation metrics such as Precision, Recall, mAP@50, and mAP@50–95. The detection results can be displayed using bounding boxes and class labels, allowing the system to identify helmet and no-helmet conditions clearly.

The proposed system can be useful for construction companies, factories, safety officers, supervisors, and industrial organizations. It can reduce the need for continuous manual inspection and help identify safety violations more quickly. The system can also be integrated with CCTV cameras or video-monitoring systems to support continuous workplace safety observation. However, certain challenges may affect detection performance, including poor lighting, occlusion, small or distant workers, complex backgrounds, different camera angles, and variations in helmet appearance.

In future work, the system can be improved by increasing the size and diversity of the dataset and including more challenging environmental conditions. Model optimization can also be performed to achieve faster inference and enable deployment on edge devices or embedded systems. Automatic warning notifications can be added when a worker is detected without a helmet. Overall, the YOLOv8-based Safety Helmet Detection system demonstrates the potential of Artificial Intelligence and Computer Vision to provide faster, automated, and practical safety monitoring, thereby supporting safer working environments and encouraging better compliance with workplace safety regulations.

9. References

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