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Monitoring Safety and Compliance in Industrial Sector Using Computer Vision and Deep Learning

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Abstract

The well being of a worker in the industrial sector is important and can be a life threatening, if fully not equipped with PPE (Personal Protective Equipment). PPE grants the workers the safety from different life threatening situations like goggles protect from strong flash lighting generated by certain industrial equipment, helmet protect the head when heavy objects fall on the worker. However, many workers fail to properly equip their Personal Protective Equipment, leading to numerous problems and accidents This project main motive is to detect the PPE which is worn by the workers in the industrial sector using CV and Deep Learning to minimize the risk and safeguarding the worker protection. The framework monitors the environment and identifies the objects like helmet, goggles, vest, boots etc and informs the supervisor using the YOLOv8 algorithm which implements faster detection and improved accuracy when detecting smaller objects.

Keywords: Deep learning, Computer Vision, YOLOv8, PPE, Industrial sectors

INTRODUCTION

Industrial sectors are the places where a huge cluster of workers work every day and many heavy machines, objects are used and many hazardous materials are handled. It is important for the workers to wear/use the Personal Protective Equipment (PPE) all the time, therefore they can overcome from hazardous situations and injuries. Manually watching over the worker might fail to notice the users who are not using the PPE with one who are wearing.

The project "Monitoring safety and compliance in Industrial Sector using Deep Learning and Computer Vision" aims to provide a robust solution by continuously monitoring the worker all the time and identifying different PPE items being used by workers. If any PPE item is missing, the system alerts the supervisor. This system uses the latest techniques available in Deep Learning and Computer Vision, specifically utilizing YOLOv8 (You Only Look Once Version 8) algorithm to identify and detect the Personal Protective Equipment (PPE) helping to assure all the users use their Personal Protective Equipment (PPE).

Industrial safety is a critical issue that impacts not only the health and well-being of workers but also the overall productivity and operational efficiency of an organization. Injuries and accidents in industrial settings can lead to significant downtime, legal liabilities, and financial losses. Therefore, implementing a reliable system for monitoring PPE

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compliance is not just a matter of safety but also an economic necessity.

LITERATURE REVIEW

The safety of workers in the industrial sector is important and to ensure it may studies have been conducted. This project mainly focuses on the PPE (Personal Protection Equipment) Kit equipped by the workers in the industrial sectors.

The paper [1] discusses about a custom dataset consists of 3500 images, using a labeling software to categorize helmet, vest and boots. The project [1] uses the Google colab, Google Drive and YOLOv3 which is a CNN for real-time object identification. YOLOv3 is highlighted for its super speed compared to other object detection models or its previous versions.

The paper [2] described the Deep Learning models autonomously learn useful features by its own from the training data. The techniques in CV for Constructional Intelligence – Image Classification for Classification, Object Detection for identifying objects in motion, Object Tracking for tracking one or more objects in motion, Segmentation for dividing image into a group of pixels which can be labelled, Instance Segmentation to categorize multiple overlapping objects. These techniques are essential for creating systems that can accurately detect and classify PPE in dynamic industrial environments.

The paper [3] mainly focus on the detection and identification of different helmet colours like blue, red, yellow and no helmet and Support Vector Machine for human classification, further illustrating the importance of tailored machine learning approaches in industrial safety applications. The ability to distinguish between different types of helmets can be crucial for identifying different roles or departments within an industrial setting.

EXISTING SYSTEM

Current systems rely heavily on manual checks to ensure PPE compliance in industrial sectors. Different industries adopt varied manual inspection methods, which are prone to human error. Workers may neglect the risks involved by not wearing or using their PPE, leading to injuries. This method is neither efficient nor accurate compared to automated detection methods using advanced technologies like Computer Vision [4].

Manual inspection systems are typically inconsistent, conducted sporadically, or only before workers start their shifts, leaving significant gaps where non-compliance can occur unnoticed. This project addresses these shortcomings by providing a continuous, automated monitoring system that reduces the likelihood of human error and ensures consistent PPE compliance. The system can instantly alert supervisors to any issues, allowing for immediate corrective actions. This real-time capability is crucial in preventing accidents and ensuring a safe working environment [5].

Moreover, manual systems are labor-intensive and require significant human resources, which can be better utilized elsewhere. By automating the PPE compliance monitoring process, organizations can optimize their workforce and allocate personnel to more strategic tasks [6].

PROPOSED SYSTEM

The project focus on detecting the PPE (Personal Protection Equipment) kit consists of different items like helmet, goggles, vest and gloves equipped by the workers at the industrial sectors and to alert the workers or the supervisor about the missing equipment.

This project also covers multiple media for detecting, such as images and videos. It can classify the PPE items in the single frame (image) and video. It is limited to only detecting the equipment used by worker and alerting the supervisor.

YOLOv8 is the algorithm used and trained by the images in the dataset, so that it can detect and classify different objects like helmet, vest, goggles and gloves equipped by the worker. If the worker is detected and not wearing proper PPE kit then an alert is sent to the supervisor. As most recent algorithm, YOLOv8 is fast and also has high accuracy detecting the equipment [7–8]

The system's architecture is designed to be scalable and flexible, allowing for integration with other safety and compliance systems. For example, the data collected by the PPE detection system can be integrated with incident reporting systems, providing a comprehensive view of safety compliance and incidents in real-time.

Furthermore, the system can be expanded to include additional safety checks, such as monitoring workers' adherence to social distancing protocols or detecting hazardous materials. This flexibility ensures that the system can evolve with changing safety requirements and standards (Figure 1).

DATASET

The Dataset to train, valid and test the model contains a sum of 1618 images where 1125 images are to train model which is of 70% of the total. 332 images are used to validate the model which is of 20% and finally 161 images are used to test the model for its accuracy which is of 10% of total dataset. This comprehensive dataset ensures the model can generalize well to new, unseen images, maintaining high accuracy in real-world applications.

The dataset includes diverse scenarios and variations in PPE usage, ensuring robust model performance. Each image is labeled to train the YOLOv8 model effectively, encompassing various angles, lighting conditions, and PPE combinations to simulate real-world conditions accurately.

In addition to standard PPE items, the dataset can be expanded to include more specific equipment used in different industries, such as respiratory protection for chemical plants or flame-resistant clothing for workers in fire-prone areas. This expansion will further enhance the model's applicability and effectiveness across various industrial settings [9].

Data augmentation techniques are also employed to artificially expand the dataset, introducing variations in scale, rotation, and lighting conditions. This approach helps the model learn to recognize PPE items under different circumstances, improving its robustness and reliability (Figure 2).

IMPLEMENTATION

The implementation of system starts with homepage where the administrator can login to start different media of identification such as image identification and live video detection, the administrator can choose either of the options to start the PPE detection.

If image identification is the one chosen, then a camera will be activated to capture the image, with the capture button administrator allow the model to receive the image to detect the PPE. If live detection is selected then the camera will be activated and start identifying the PPE automatically.

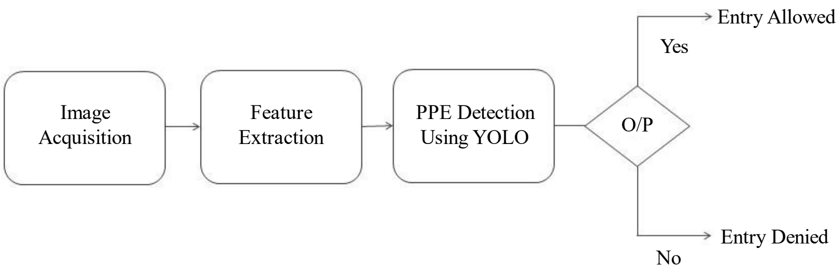

Figure 1. System Design.

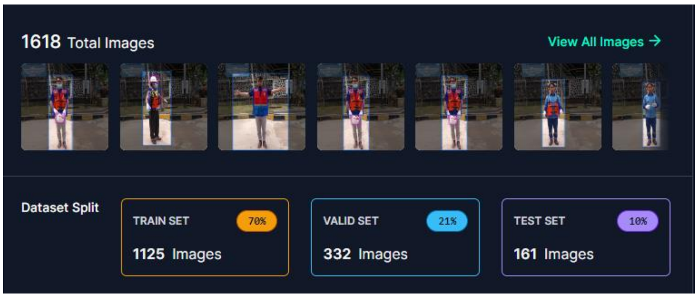

Figure 2. Dataset details.

If any PPE objects where to be not found on the worker or user then an alert message is displayed that the PPE is missing or if the worker is fully equipped with the PPE then the worker will be given access to enter in the industrial sector by an alert message.

YOLOv8

YOLOv8 is a SOTA Deep Learning Model designed to detect real time objects in computer vision applications. It has advanced architecture and cutting edge algorithms to detect objects much faster and accurately than the previous versions.

YOLOv8 architecture has 3 parts Backbone, Neck, and Head. Backbone is the deep learning architecture which acts as an attribute extractor. It is made up of numerous convolution layers. Neck combines the features from the layers of the Backbone. The head predicts the classes and bounding box regions which is final outcome produced by the object detection model.

It has a total 53 convolutional layers (Conv2d), Batch Normalization layers (batchnorm2d), LeakyReLU, MaxPool2d layers (Figure 3).

In addition to its architectural improvements, YOLOv8 also has the various optimization techniques, such as data augmentation, transfer learning, and fine-tuning, to enhance its performance. These techniques enable the model to learn more effectively from limited data and adapt to new scenarios.

Furthermore, YOLOv8's real-time capabilities are crucial for applications in industrial safety, where timely detection and response can prevent accidents and save lives. The model's ability to process and analyze video streams in real-time ensures continuous monitoring and immediate alerts for any PPE non-compliance.

The model has achieved the F1 score of 93% and below image shows the F1-Confidence Curve graph of the model (Figure 4).

The model has the following features: Helmet, Vest, Gloves, Goggles, Boots.

OpenCV

OpenCV (Open Source Computer Vision) is open source multiplatform library for CV, ML and image processing. OpenCV has an large number of algorithms to identify, detect and classify objects.

As a multiplatform library, OpenCV is used on any Operating System. It was written in C++ and its primary interfaces also in C++. It facilitates various languages like Python, Java and MatLab.

OpenCV's extensive library of image processing functions allows for preprocessing steps such as resizing, normalization, and augmentation, which are crucial for preparing the dataset for training. Its real-time processing capabilities are essential for the live detection mode of the proposed system, ensuring fast and efficient analysis of video streams.

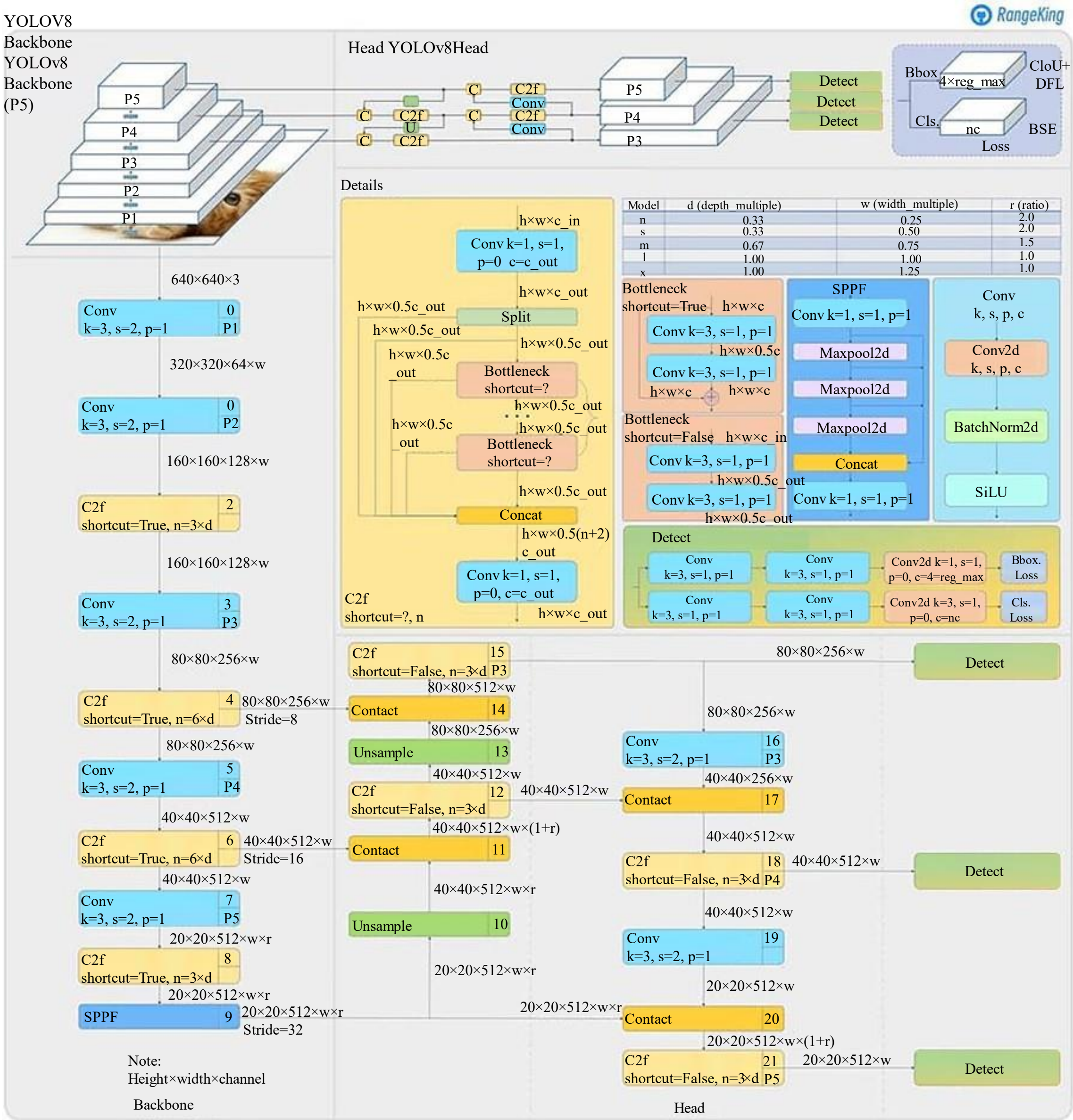

Figure 3. YOLOv8 Architecture.

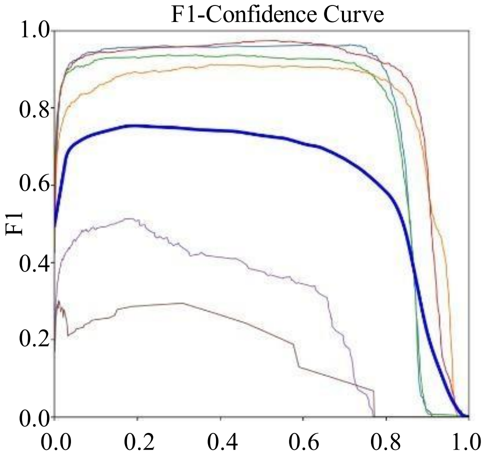

Figure 4. F1-Confidence Curve.

Moreover, OpenCV's integration with deep learning frameworks, such as TensorFlow and PyTorch, enables seamless implementation of advanced machine learning models, including YOLOv8 (Figures 5–8).

Figure 5. PPE detected alert.

Figure 6. PPE detected.

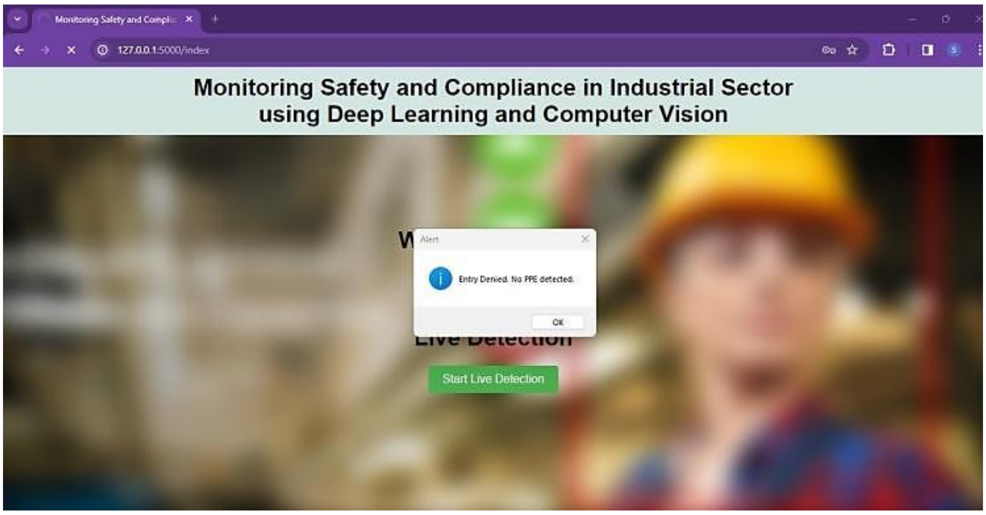

Figure 7. PPE not detected alert.

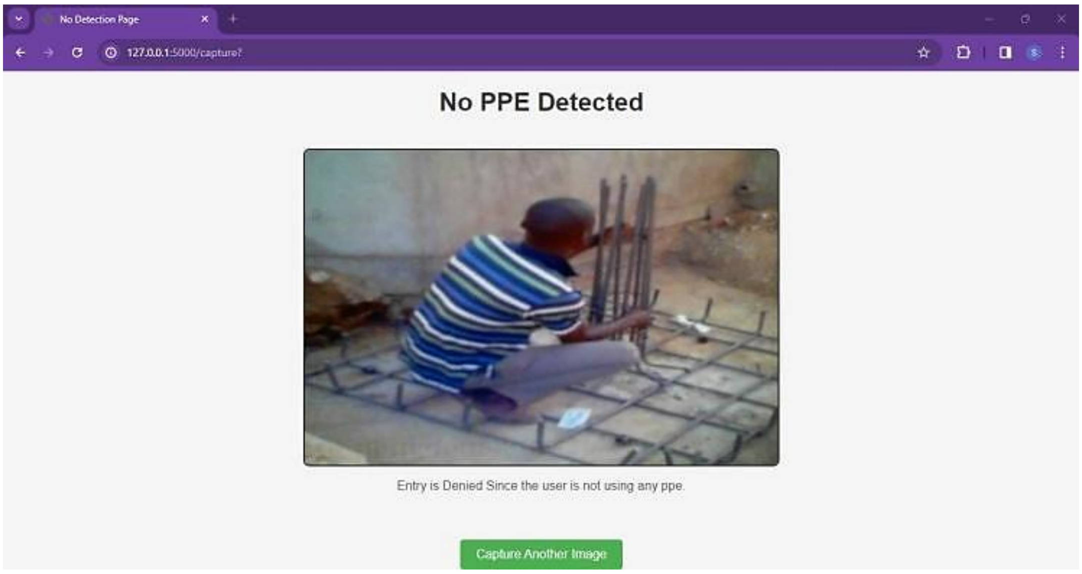

Figure 8. No PPE detected.

CONCLUSION

The paper objective is to reduce the risks and hazardous situations happen at the industrial sector by monitoring the workers equipment (PPE). Manually watching over the worker might fail to notice the users who were not using the PPE.

The system combines the Computer Vision techniques and Deep Learning model to identify and detect the PPE and helps alerting the Supervisor, if any PPE is missing. With the fastness and high accuracy of YOLOv8 we can detect whether the user/worker is using PPE or not.

The system's implementation in industrial settings can lead to a substantial reduction in workplace accidents, ensuring a safer environment for all workers. Future work could involve integrating additional safety features, such as monitoring worker behavior or detecting environmental hazards, further enhancing the system's capabilities and impact.


Figure 9. Input (1).

Figure 10. Output (1).


Figure 11. Input (2).

Figure 12. Output (2).

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