Real-Time PPE Detection System

Hackathon Team 2

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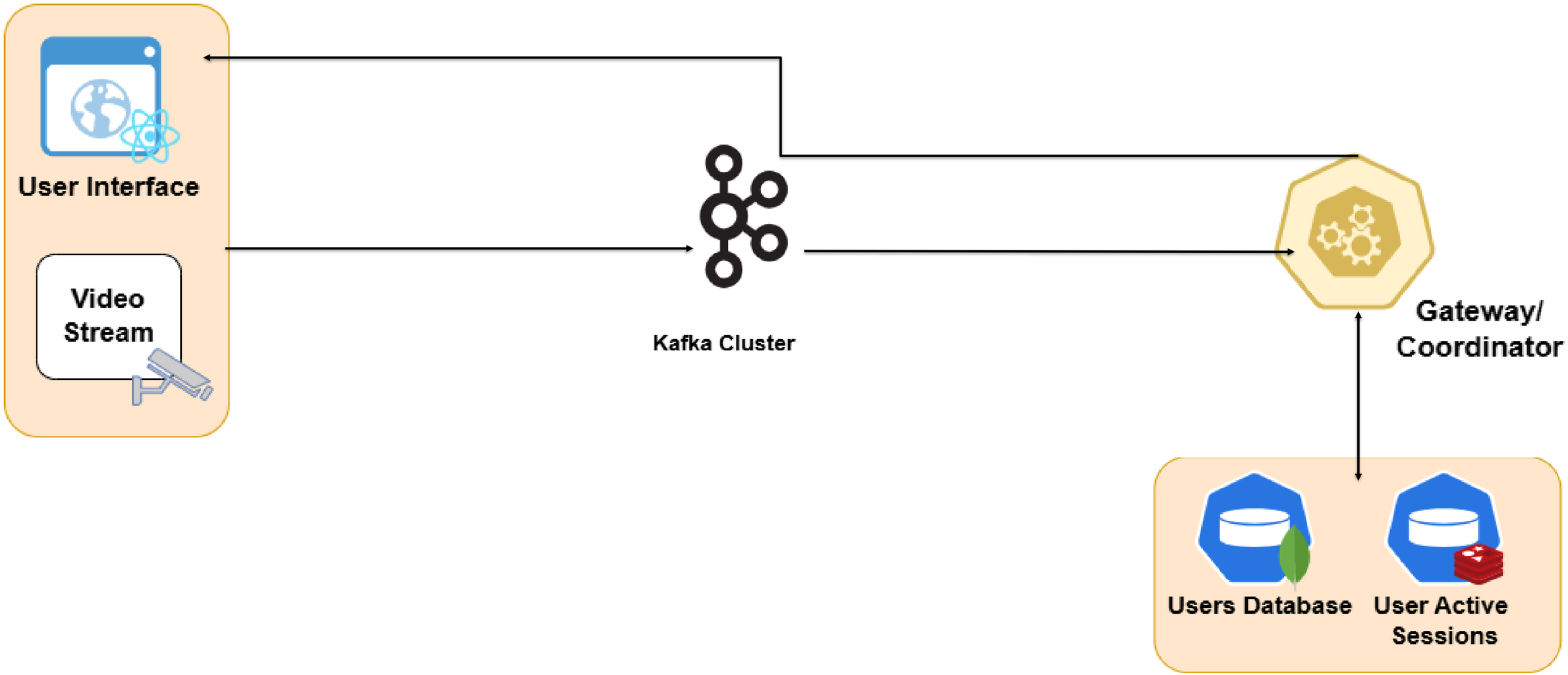
Problem statement

- **PPE non-compliance** leads to accidents, financial losses, and legal penalties.
- **Manual PPE checks** are slow, error-prone, and hard to scale in large industries
- **Existing AI solutions** often lack scalability, efficiency, and real-time alerts.

Solution

“Our computer vision-based PPE detection solution follows a robust architecture that ensures real-time, scalable, and efficient monitoring, ensuring safety compliance with instant alerts and low-latency processing.”

ARCHITECTURE



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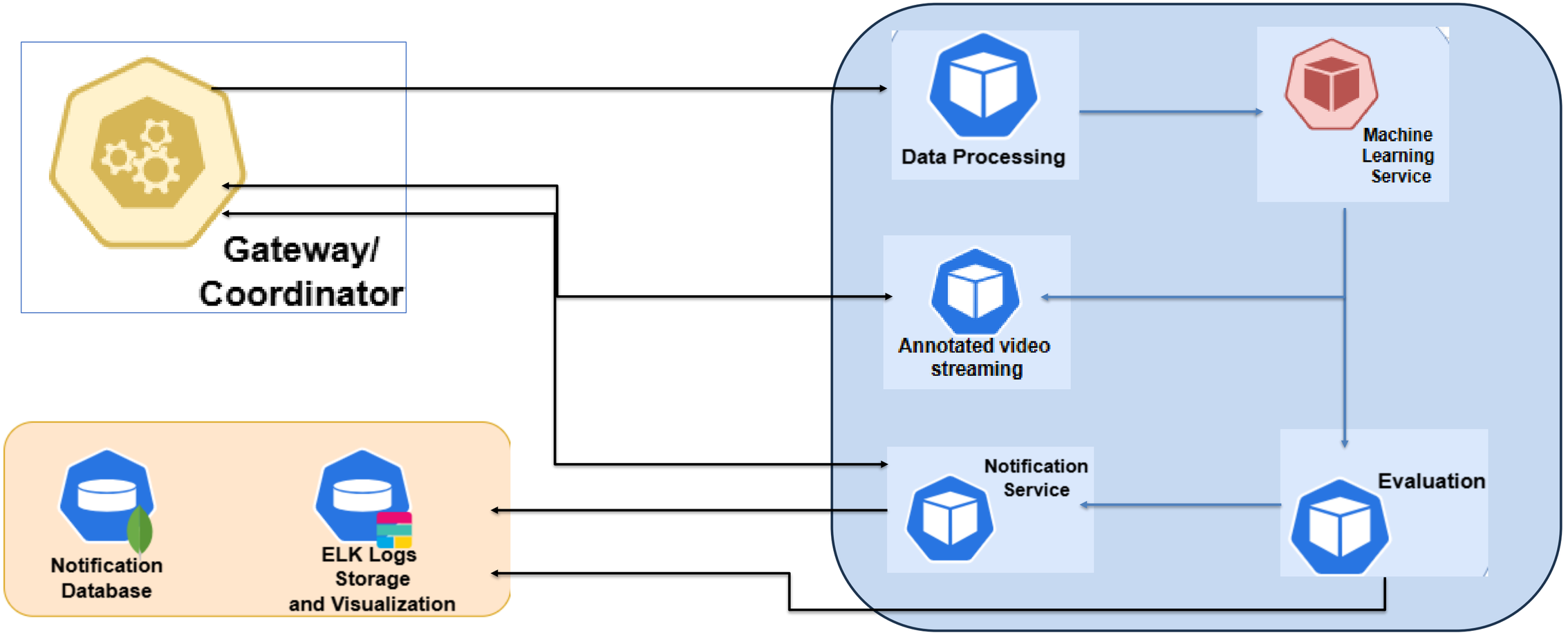

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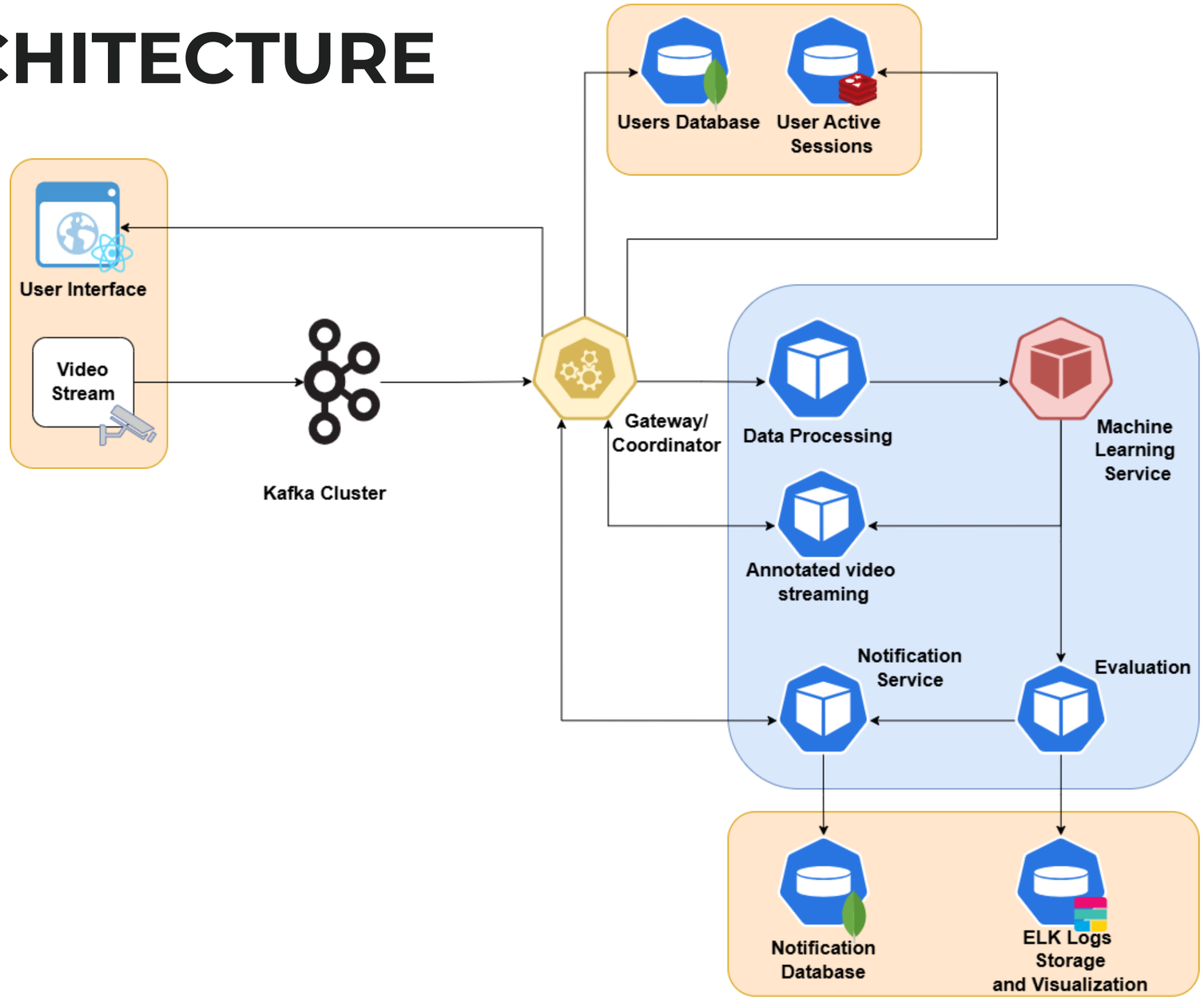
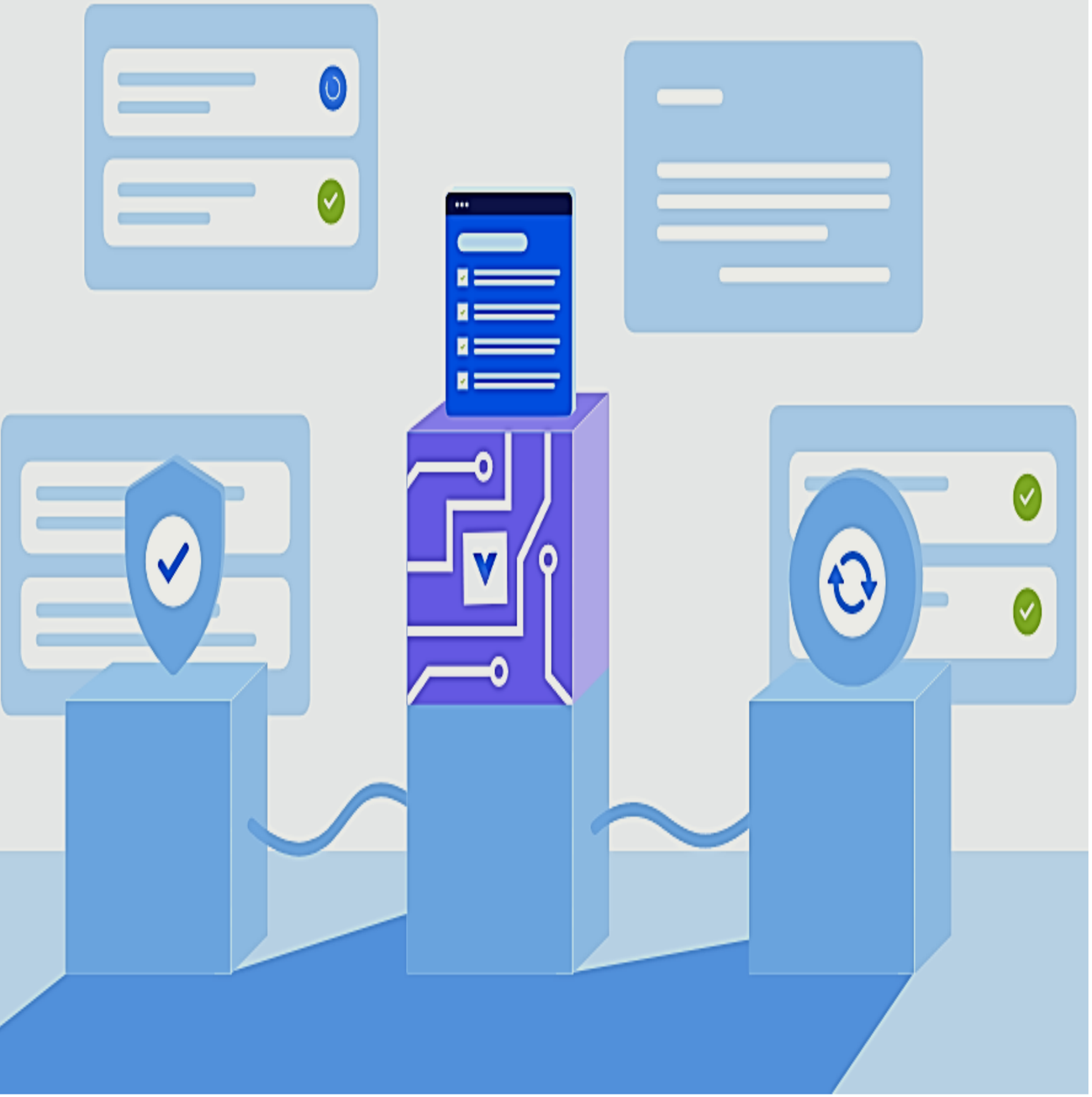


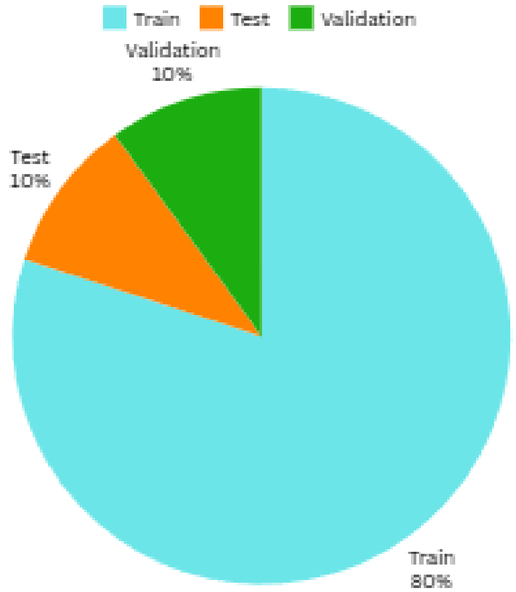


Rationale

- Scalability
- Load balancing
- YOLOv8 is optimized for real-time inference
- Kafka ensures real-time, scalable, and fault-tolerant video stream processing.

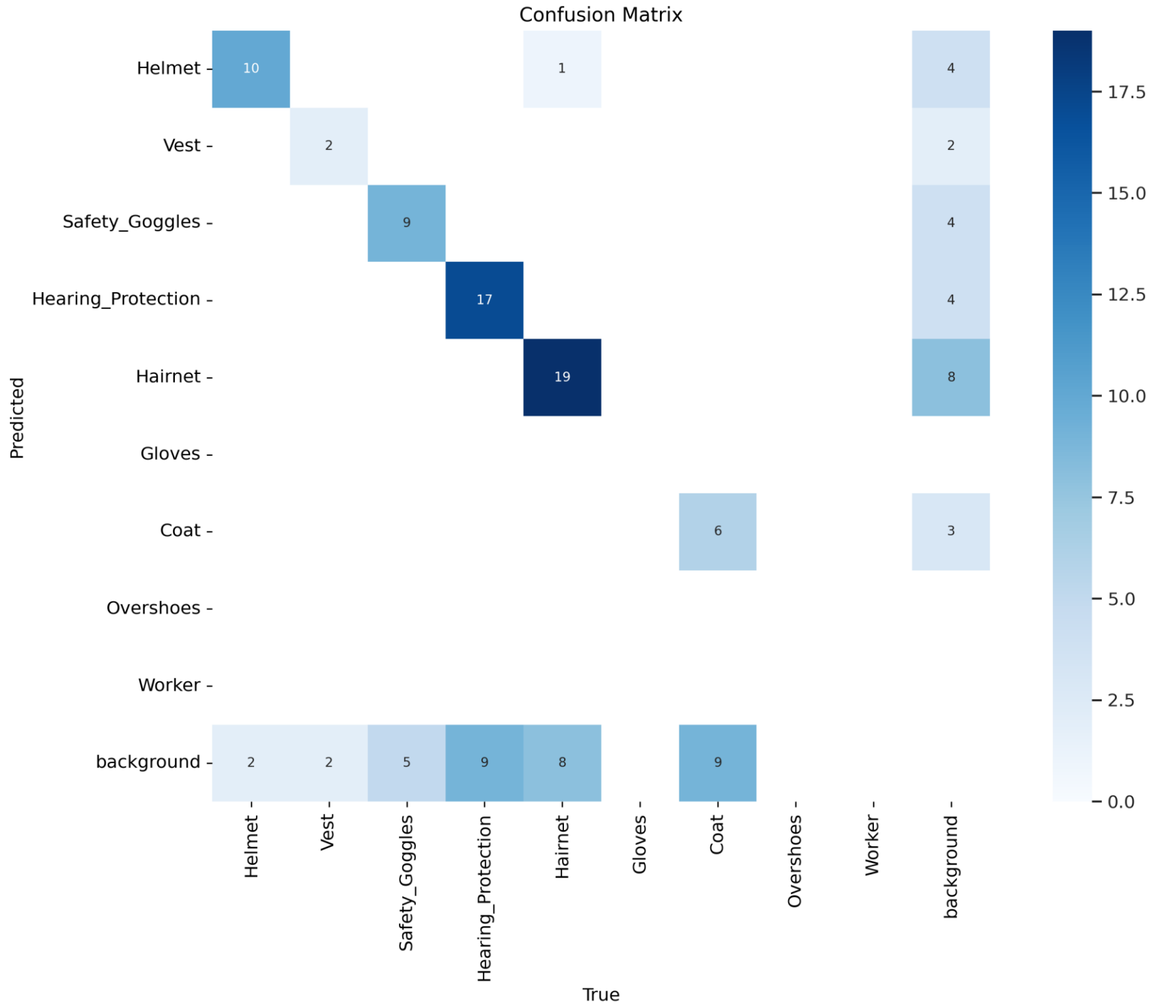
Dataset

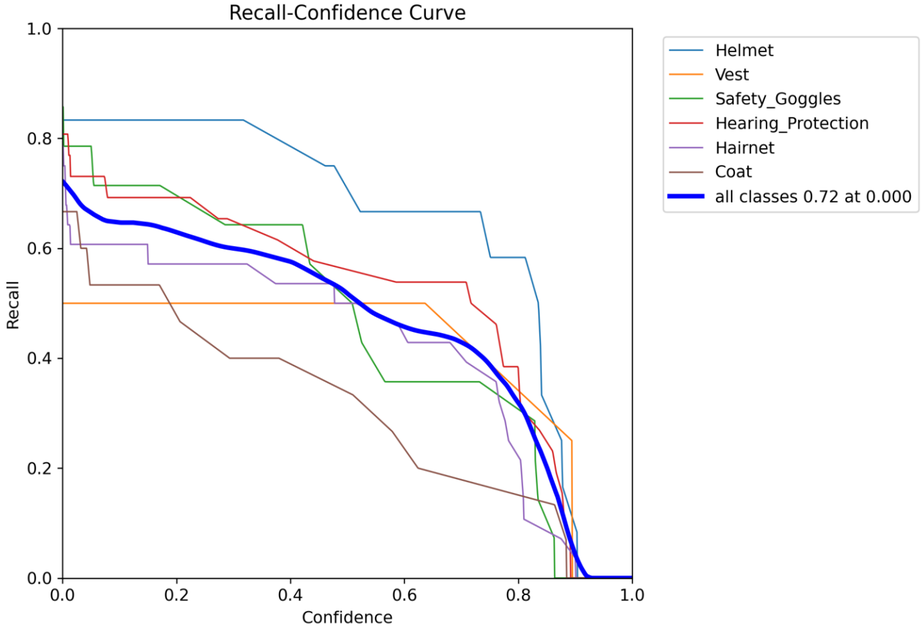
- 536 images of PPEs and workers with/without PPEs
- Duplicated were removed --> 445 images
- All images were resized to 640x640 (for YOLO training)
- Images were manually annotated using LabelImg
- 80/10/10 : train/validation/val
- Classes
  - "Helmet",
  - "Vest",
  - "Safety_Goggles",
  - "Hearing_Protection",
  - "Hairnet",
  - "Gloves",
  - "Coat",
  - "Overshoes",
  - "Worker"

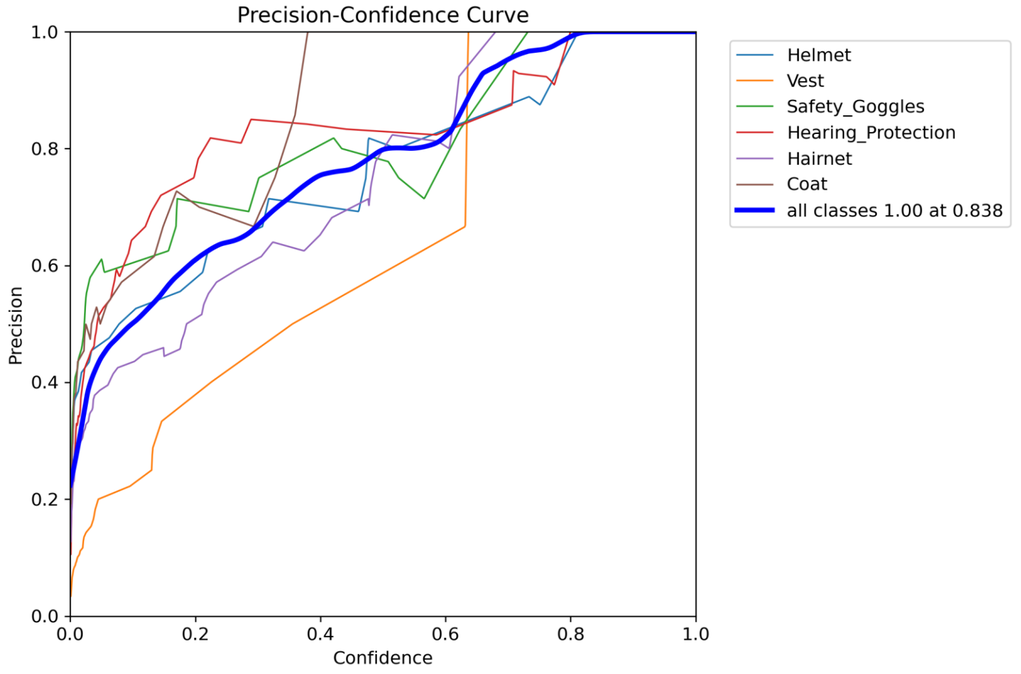


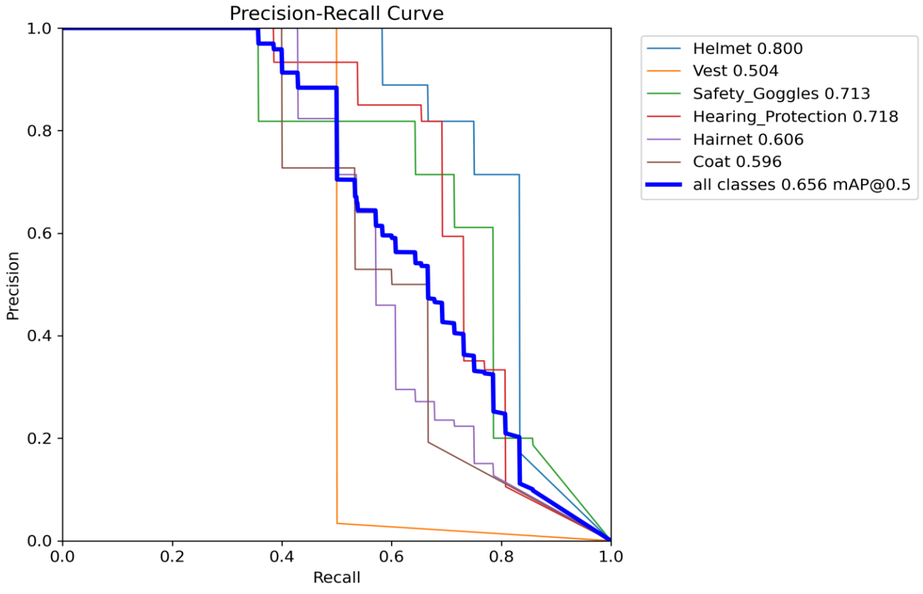
Model Results

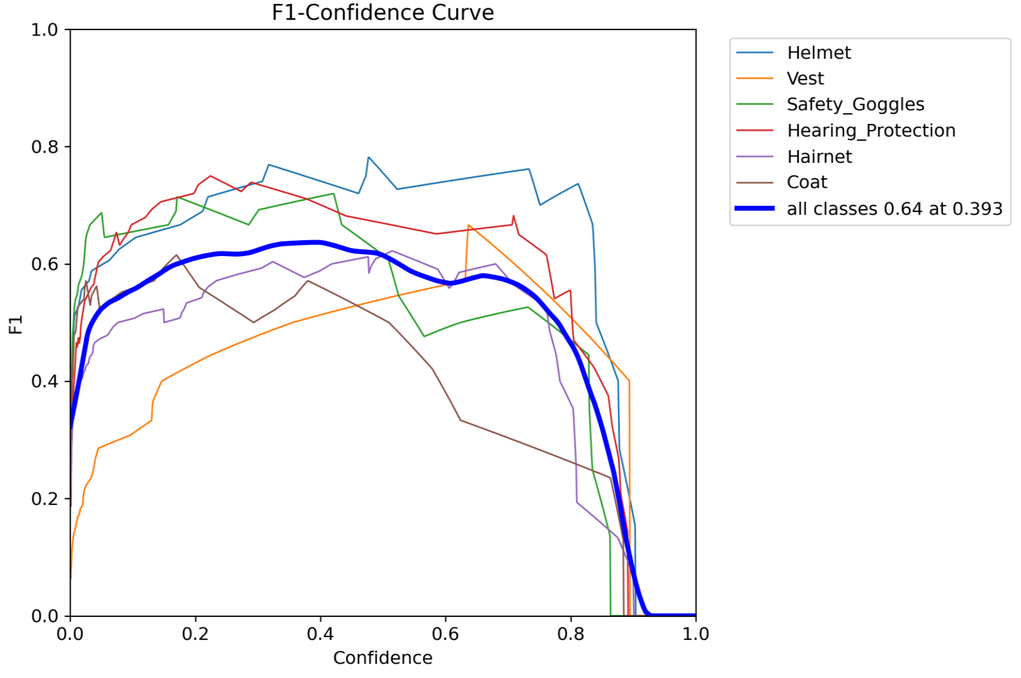
Metric	All Classes	Helmet	Vest	Safety Goggles	Hearing Protection	Hairnet	Coat
Precision (P)	0.738	0.706	0.511	0.791	0.842	0.625	0.955
Recall (R)	0.583	0.801	0.500	0.643	0.617	0.536	0.400
mAP@50	0.656	0.800	0.504	0.713	0.718	0.606	0.596

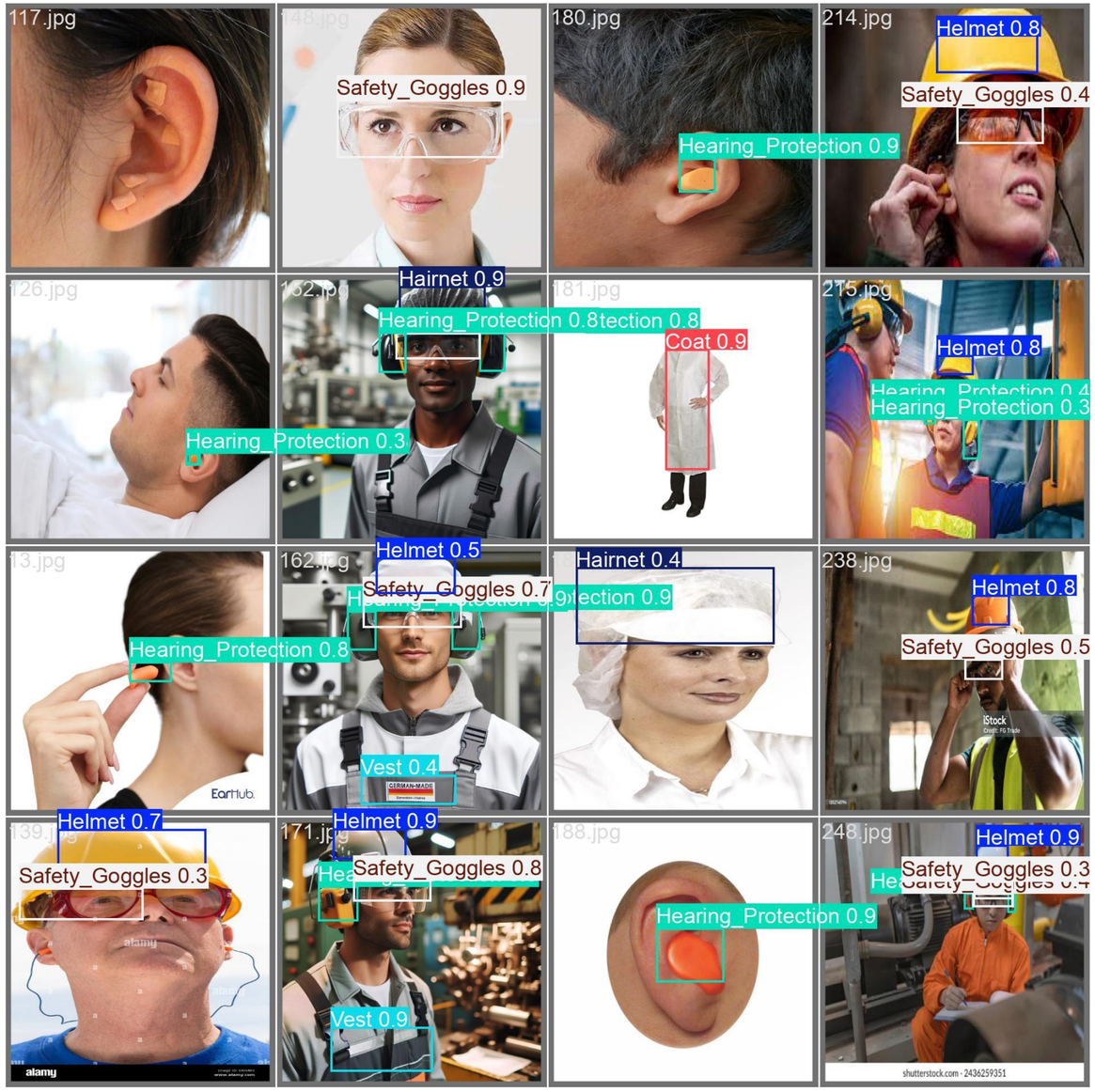



Recall-Confidence Curve
Recall
Confidence
Helmet
Vest
Safety_Goggles
Hearing_Protection
Hairnet
Coat
all classes 0.72 at 0.000


Precision-Confidence Curve
Precision
Confidence
Helmet
Vest
Safety_Goggles
Hearing_Protection
Hairnet
Coat
all classes 1.00 at 0.838


Precision-Recall Curve
Precision
Recall
Helmet 0.800
Vest 0.504
Safety_Goggles 0.713
Hearing_Protection 0.718
Hairnet 0.606
Coat 0.596
all classes 0.656 mAP@0.5


F1-Confidence Curve
F1
Confidence
Helmet
Vest
Safety_Goggles
Hearing_Protection
Hairnet
Coat
all classes 0.64 at 0.393

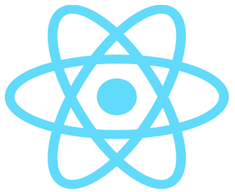

117.jpg
Safety_Goggles 0.9
180.jpg
Hearing_Protection 0.9
214.jpg
Helmet 0.8
Safety_Goggles 0.4
126.jpg
Hearing_Protection 0.3
Hairnet 0.9
Hearing_Protection 0.8
Coat 0.9
Helmet 0.8
Hearing_Protection 0.3
13.jpg
Hearing_Protection 0.8
Helmet 0.5
Safety_Goggles 0.7
Vest 0.4
Hairnet 0.4
238.jpg
Helmet 0.8
Safety_Goggles 0.5
139.jpg
Helmet 0.7
Safety_Goggles 0.3
171.jpg
Helmet 0.9
Safety_Goggles 0.8
Vest 0.9
Hearing_Protection 0.9
248.jpg
Helmet 0.9
Safety_Goggles 0.3


418.jpg
Hairnet 0.7
465.jpg
Hairnet 0.3
Helmet 0.35
Hearing_Protection 0.7
Hairnet 0.3
Coat 0.3
Coat 0.9
Hearing_Protection 0.4
Helmet 0.9
Safety_Goggles 0.8
Vest 0.6
Vest 0.6
Helmet 0.3
Hearing_Protection 0.7
Hairnet 0.8
Safety_Goggles 0.6
Hairnet 0.5

Technology Stack

Frontend

- Provides a concise and clear way for the user to enter the system, read notifications, check in real time the detection process & also get notified when there are anomalies detected.
- Build using ReactJS and Material UI



Backend

- Built using Flask and is based on a microservice architecture to offer consistent and easier improvement in scalability and load balancing.
- It is also fed with information by a Kafka cluster from which the entry point of the app is subscribed to.

Technology Stack

Machine Learning

- YOLOv8 was used for PPE detection
- Trained on a custom dataset with nine classes.
- Evaluation was conducted using precision, recall, mAP scores to ensure reliable detection.

Storage

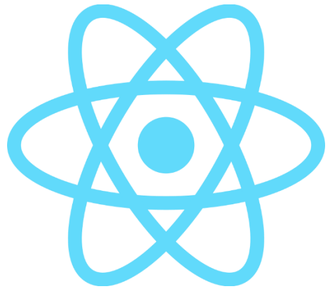
- Different levels of storage are considered.
- A Redis cache for storing user sessions used to open sockets for notifications, MongoDB
- Databases for Users, Cameras and Notification, and an Elastic Search instance for inserting validation logs and connecting to Kibana for visualizations.

TOOLS

LabelImg

Microservices

APACHE kafka®



User Interface Overview

Dashboard

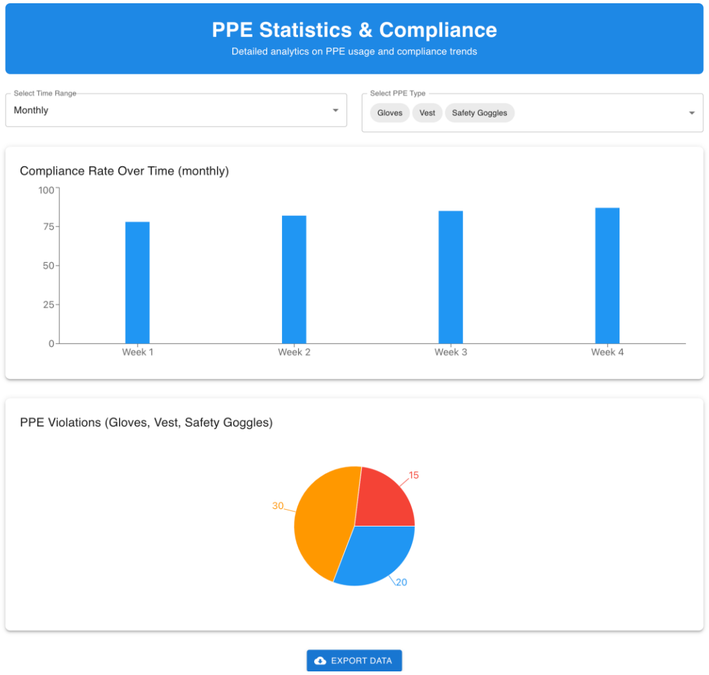
- Total Detections: Displays the number of detected PPE usages.
- Compliance Rate: Indicates the percentage of users adhering to PPE guidelines.
- PPE Alerts: Users can select specific alerts to view details about compliance issues.

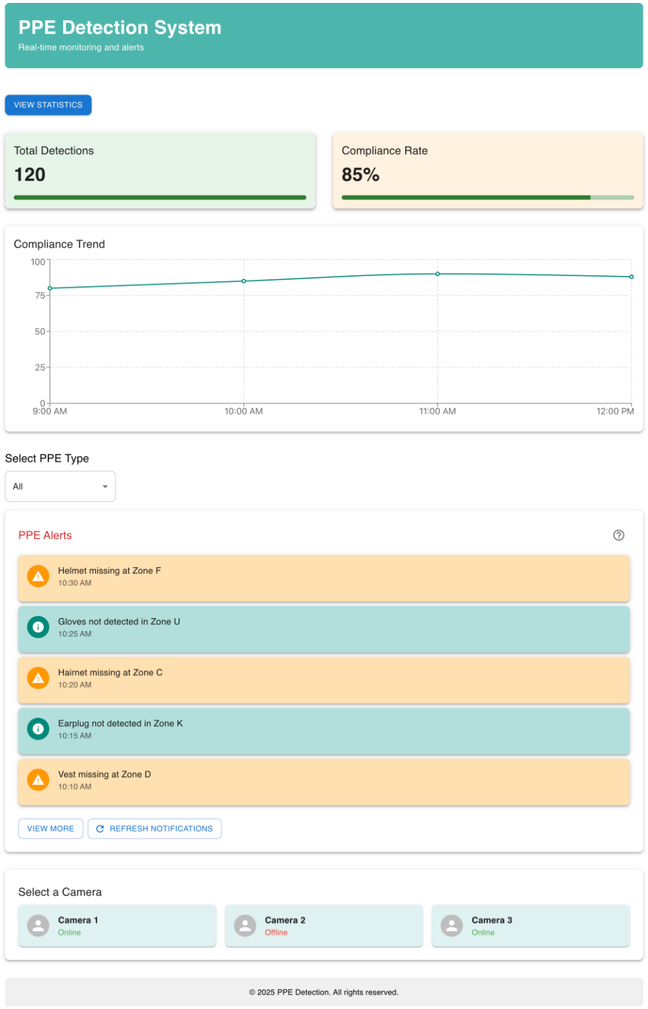
Camera View

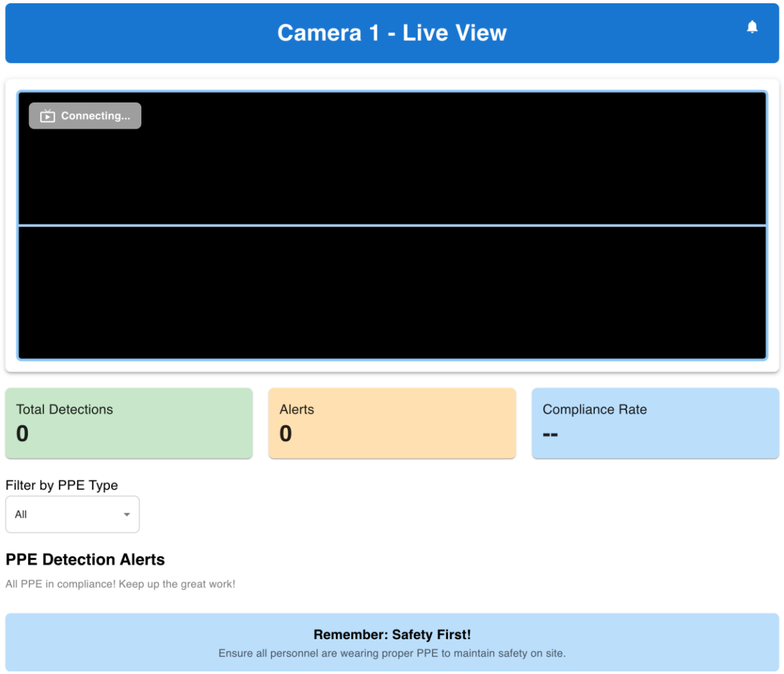
- Live Stream: Show the current camera feed for specific cameras.
- Notification Alerts: Users receive real-time notifications specific to the selected camera.
- Key Metrics Displayed: Total Detections, Alerts, Compliance Rate

Statistics

- Weekly, Monthly, Yearly Statistics: Visualize data trends over time.
- PPE Type Breakdown: Show compliance rates and alerts categorized by PPE type
- Download the data as a CSV







User Interface Design

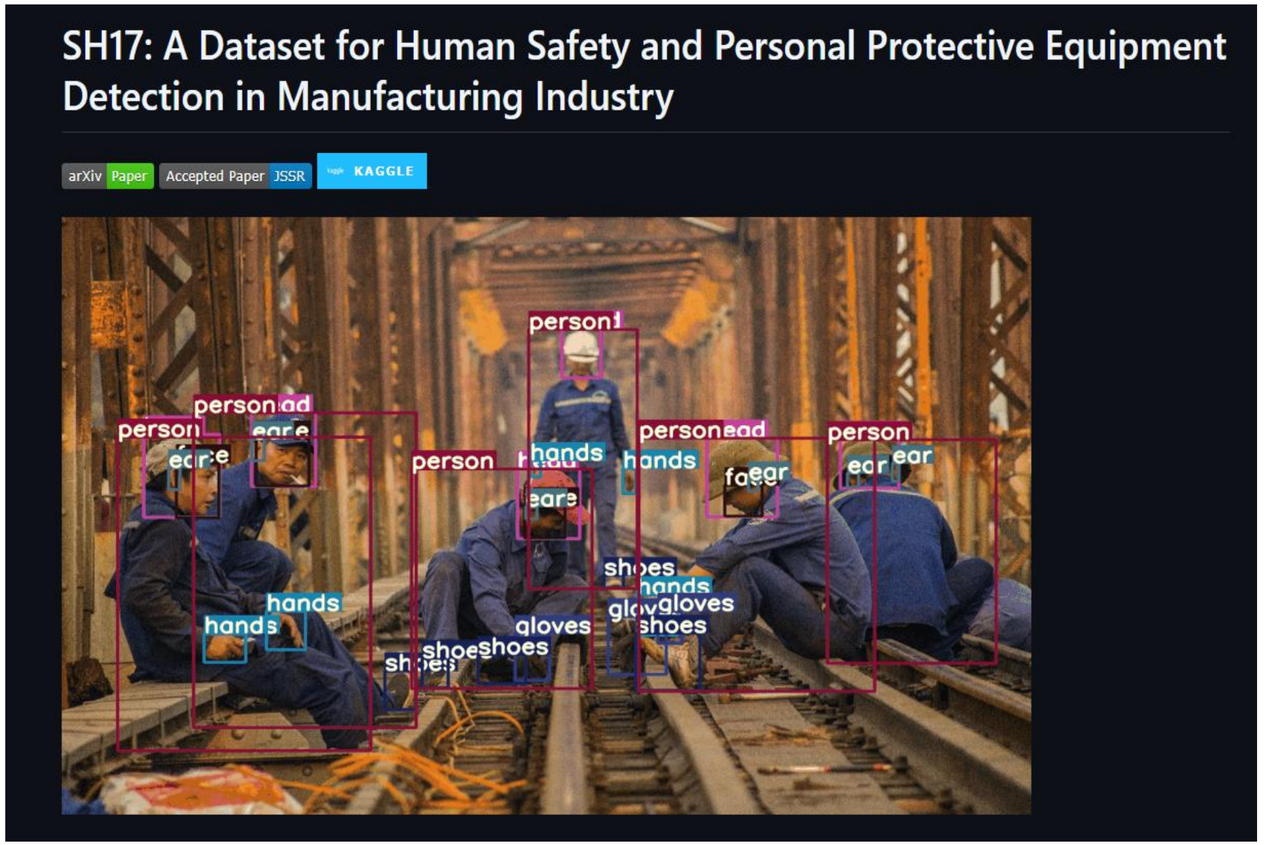
Impact

The solution strives to:

- Efficiently detecting existing personal protecting equipment
- Reporting correctly the missing equipment and notifying the user in real time
- **Offering analytics** for understanding better staff behavior in time.
- Allowing the user to monitor the video stream with the detected equipment.

Future work

- Experimenting with different AI models. (**R-CNN, SSD**)
- Expanding the dataset for better accuracy
- Integrating with edge devices for real-time processing
- Experimenting with cloud or server by orchestrating through Kubernetes and implementing load Balancing



Bigger Picture

Ensure work safety with PPE compliance and protecting lives

THANK YOU

EDISS
MASTER'S PROGRAMME

Aptar