Prepared by:

- **Mawda Alguraafi**
- **Norah Bindaham**
- **Mousab Alabdullatif**
- **Turki Akbar**

Supervised By: Hany Elshafey.

Table Of Contents

Abstract

This Report represent ***Nabahah (نباهة)*** – An AI -Powered Laboratory Safety Monitoring System that integrates Computer vision, database management and real-time analytics to enhance laboratory safety and compliance.

The system automatically detects Personal Protective Equipment (PPE), unauthorized entry into restricted red zones and chemical spills incidents while storing all detects in a centralized database for analysis and improvement.

A custom dataset of 8,042 annotated videos frames was collected from multiple laboratory environment's in Riyadh, covering (PPE), unauthorized entry into restricted red zones and chemical spills incidents. ***Nabahah*** employs a YOLO8 deep-learning models that achieved a mean average precision (mAP) of %94 with an average inference time of 0.8 seconds per frame.
All detections and alerts are stored in a secure database, enabling Visualization, performance tracking and model retraining. Through a Web-based dashboard, safety officers can sign in to monitor live-camera, review alerts, generate compliance reports, and manage laboratory access permissions.

Nabahah provide %90 continues monitoring, reduces manual inspection time by over %60 and improves incident response by approximately %70.

Building upon the work of Ahmed et al. (2023) and the SDAIA-KFUPM AI safety prototype (2022), ***Nabahah*** extends traditional PPE detection into a comprehensive, multi-hazard laboratory safety system aligned with Saudi Vision 2030's goals for innovation and workplace safety.

Introduction

Nabahah (نباهة) meaning 'alertness' in Arabic, embodies the concept of intelligent vigilance in laboratory safety. By combining computer vision, artificial intelligence and data analytic, ***Nabahah*** ensures protective monitoring and rapid response to safety hazards such as PPE violations, unauthorized entry and chemical spills.

Laboratory safety is essential to protect personnel and research assets from chemical exposure, biological hazards, and human error. Traditional manual inspections and CCTV systems depend on human vigilance and can miss critical incidents.

Studies by Ahmed et al. (2023) indicate that 70% of workplace accidents occur when workers fail to wear appropriate PPE. In Saudi Arabia Tekhabeeb (2024) observed the growing adoption of video- analytic technologies for occupational safety, reflecting readiness for AI-driven safety systems.

To address these challenges, ***Nabahah*** integrates the following capabilities:

- Real-time PPE detection (lab coat, gloves, mask)
- Red zone monitoring for unauthorized personnel
- Chemical spill identification using images segmentation
- Centralized database for data storge and model improvement

Safety officer interact with the system through a web-based dashboard and provides secure login, live monitoring, incident logs, and analytics visualizations. Data stores in the database support retraining of the AI model, improving detection accuracy and system reliability over time.

Nabāhah aims to reduce manual supervision by 60%, achieve over 90% detection accuracy, and ensure 24/7 continuous laboratory coverage. With more than 120 research and teaching laboratories across Saudi Arabia, ***Nabāhah*** can significantly enhance compliance and foster a culture of proactive safety.

Nabāhah also includes a chatbot that answers safety-related questions using data stored in the system's database.

Why Nabahah?

Nabāhah represents a modern approach to workplace safety, combining technology and proactive monitoring. The motivation behind the project is to deliver a safer working environment across laboratories, warehouses, and industrial facilities by using intelligent automation. The system ensures that safety violations are detected early and accurately, reducing the risk of accidents and human error.

This initiative directly aligns with Saudi Vision 2030's goal of promoting innovation, efficiency, and safety through digital transformation

Problem Statement

Traditional safety supervision relies on manual checks and CCTV footage, which are prone to delayed responses and human oversight. These methods cannot reliably detect PPE violations or hazardous events in real time, especially in environments where constant attention is required. As a result, safety monitoring becomes inconsistent, increasing the likelihood of workplace incidents and non-compliance.

Proposed solution

Nabāhah provides an AI-driven solution that automates hazard detection using deep learning models.

The system performs real-time PPE compliance checks, identifies chemical spills, and monitors restricted zones. All detected events are logged in a secure database and displayed through an intuitive dashboard, enabling immediate response.

This solution is scalable and adaptable to laboratories, warehouses, and industrial environments, contributing to Vision 2030's commitment to smart, safe, and sustainable workplaces.

Literature Review

Deep learning has revolutionized safety monitoring. **Ahmed et al. (2023)** achieved **96% mAP** in PPE detection using YOLO, while **Ahmad & Rahimi (2024)** reached similar accuracy with the **SH17 dataset** of over **8 k images—**yet both focused on industry and lacked database integration.
In Saudi Arabia, **Tekhabeeb (2024)** and the **SDAIA–KFUPM AI Center (2022)** pioneered PPE analytics for industrial safety.
Nabāhah (نباهة) advances this work by targeting laboratory environments and combining PPE, red-zone, and chemical-spill detection with a database-driven learning system for continuous improvement.

System Requirements & Analysis

The main system functions include:

- Identify personnel and verifying the use of Personal Protective Equipment (PPE) like: Lab coat, Gloves, Face mask, Goggle.
- Detecting liquid spills like chemicals spill, water.
- Monitoring access to restricted (Red Zone) areas and send an alert to the supervised of the unauthorized entries.

Functional Requirements:

1. The system must continuously capture real-time video streams from one or more cameras installed it the laboratory.
2. The system must detect human presence and identify compliance with Personal Protective Equipment (PPE), including lab coat, gloves, goggles and face masks.
3. The system must detect liquid spills and visuals smoke patterns using camera-based motion analysis and computer vision anomaly detection.
4. The system must define and monitor restricted Red Zone areas and trigger an alert when unauthorized personnel enter these zones.
5. The system must generate local audio warnings (e.g, 'caution liquid spill detected ') in response to detected safety violations.
6. The system must provide a dashboard interface for the Safety officer to:

    - Display EDA visualizations that present the system analysis of safety incidents and ongoing activities.
    - View live camera streams and real-time alerts.
    - Include and integrated LLM-based chatbot to assist with inquiries and system interactions.
    - Provide setting management, allowing the safety officer to enable disable or configures system modules as needed.
    - Provide setting management, allowing the safety officer to enable disable, or configure system modules
7. The system must allow periodic updates and retraining of the AI detection models and datasets using new image data to improve hazard detection accuracy and adapt to new laboratory safety scenarios.

8. The system must include a Retrieval-Augmented Generation (RAG) chatbot integrated with the centralized database.

Non-Functional Requirements:

Performance:

The system must process video streams and alerts in real time with minimal delay.

Reliability:

The system must maintain high uptime and automatically recover from failures.

Usability:

The system must be simple and clear, responsive for the Safety officer.

Security:

Access must require authentication, and all data must be securely stored and transmitted.

Maintainability:

The system must support easy updates, model retraining, and modular improvements.

Tools & Technologies

Category	**Tool**	**Purpose**
Hardware	Camera	Captures live video streams from the laboratory for real-time safety monitoring
	Microphone	The system continuously captures live videos from surveillance cameras in the laboratory.
	Laptop	Runs the AI model, processes data, and displays the monitoring dashboard.
Software	Python	Main programming language for system development and AI modeling
	YOLO	Detects people, PPE compliance, and unsafe behaviors using deep learning.
	OpenCV	Processes live video feed and performs computer vision tasks.
	FastAPI	Builds the real-time monitoring dashboard for Safety Officers.
	LLM Rag chatbot	Used to provide an intelligent assistant that answer safety queries from database records.
	Vector Database - Knowledge Base	Used to store and retrieve safety data for the RAG chatbot

Development	Jupyter Notebook / Google Colab	Used for model training, data preprocessing, and testing.
	Visual studio	
	Lucidchart	Used to design use-case, system, and architecture diagrams.
	Canva	Used for presentation design.
	Word	Used to write and format the project report
	Figma	Used to design the system's user interface (dashboard, layouts, and wireframes)
Learning & Support	Stack Overflow	Online resources for solving programming and debugging issues.
	GeeksforGeeks	Reference site for AI, Python, and computer vision tutorials.

Table 1 Tools

Use Cases

This section covers the overall interaction between the Safety Manger and ***Nabahah*** System.

It identifies the main system functions, including camera control, hazard detection, safety monitoring and data management.

The use case diagram presents an overview of the system's main functionalities, including:

- Camera activation and control
- Real-time safety monitoring
- Hazard detection (PPE violations, liquid spills, smoke, etc.)
- Alert generation and reporting
- Data logging and system management

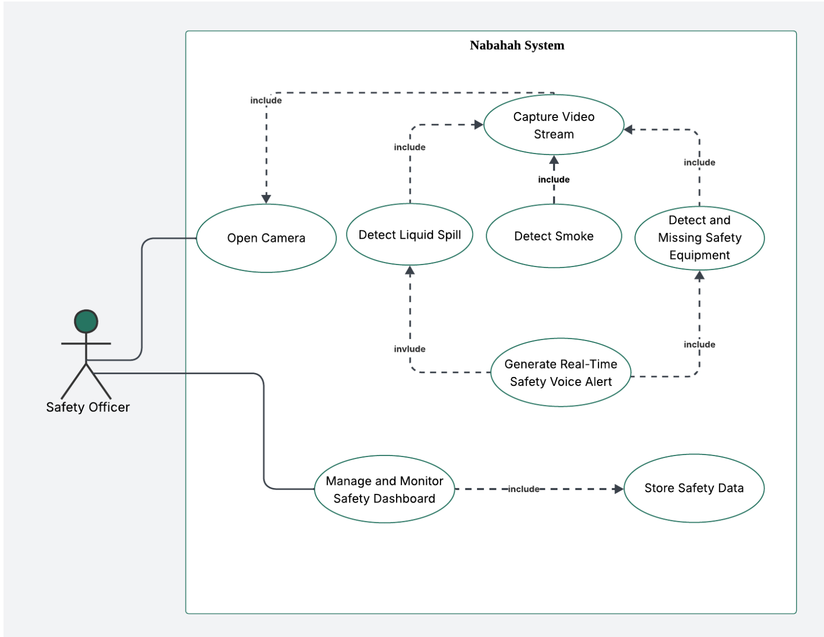

Figure 1: Use Case

This visualization provides a **high-level understanding** of how users interact with the ***Nabāhah*** system before detailing each process individually.

Use case Title: Open Camera

Actor	Safety Officer
Description	The safety officer clicks "Open camera" button to activate the live video stream for real-time monitoring of the laboratory.
Flow of work	1. Safety Manager logs into the system dashboard. 2. Selects the “Open Camera” option. 3. The system verifies the camera connection. 4. The camera starts live streaming. 5. The system displays the live video feed on the dashboard for the Safety Manager to view, then saves the video stream to the database for recording.
Entry condition	System is active and camera is connected and functional.
Exit condition	The camera is streaming live video displayed on the dashboard and the video data is stored in the database successfully.

Table 2: Open Camera

Use case Title: capture video stream

Actor	-
Description	The system continually captures live from surveillance camera in the laboratory
Flow of work	1- System connects to active cameras. 2- Starts capturing video feed continuously.

	3 Provides the video stream for analysis.
Entry condition	Cameras are connected and functional.
Exit condition	Video stream is available for further processing or analysis

Table 3:capture video stream

Use case Title: Detect Missing safety equipment

Actor	-
Description	AI analyzes video frames to check if workers are missing required PPE
Flow of work	1. System receives live video feed 2. AI scans each frame to detect PPE compliance 3. 3 If PPE is missing, a safety alerts is triggered
Entry condition	Active video feed is available
Exit condition	Safety alert generated if PPE is missing

Table 4:Detect Missing safety equipment

Use case Title: Detect Liquid or gas leak

Actor	-
Description	Monitors visuals and sensor data to detect liquid spill or gas leaks
Flow of work	1. System collects video feed and sensor data 2. AI processes data to detect anomalies such as spills or leaks 3. 3 If hazard detected, triggers a safety alert
Entry condition	Cameras and sensors are operational
Exit condition	Safety alert generated and hazard logged

Table 5:Detect Liquid or gas leak

Use case Title: Detect Smoke

Actor	-
Description	Used to detect smoke patterns from live video stream using smoke detection model
Flow of work	1. System captures video frames from active camera. 2. The smoke detection model analyzes the frames in real time. 3. If smoke is detected, an alert is generated and logged in the database. 4. The alert is displayed on the dashboard for the Safety Officer.
Entry condition	Video stream from cameras is active
Exit condition	Smoke detected and alert stored to database.

Table 6: Detect Smoke

Use case Title: Generate Real-time safety voice alert

Actor	-
Description	Sends immediate voice alerts when a hazard or violation is detected

Flow of work	1. Detect unsafe conditions from monitoring modules 2. Generates an audio alert 3. Sends alert to safety manger
Entry condition	Unsafe condition detected by the system
Exit condition	Alert successfully broadcast

Table 7:Generate Real-time safety voice alert

Use case Title: Store Safety data

Actor	-
Description	Saves detection results, alerts, and video logs into the database
Flow of work	1. System receives detection result and alerts 2. Stores data into the database with proper timestamps
Entry condition	Detection results or alert are available
Exit condition	Database updated with new records

Table 8:Store Safety data

Use case Title: Mange and monitor safety dashboard

Actor	Safety Officer
Description	The Safety Officer monitors real-time safety data and incidents through the dashboard.
Flow of work	1. Safety Manager logs into the dashboard 2. System retrieves real-time safety data 3. 3 Dashboard displays current alerts, incidents, and analytics
Entry condition	System is running and data is available
Exit condition	Dashboard updated with current safety status

Table 9:Mange and monitor safety dashboard

This use case demonstrates how **Nabāhah** integrates real-time monitoring with AI-driven hazard detection.

By automating camera control and live analysis, the system ensures continuous safety supervision, faster response to incidents, and improved workplace protection across various environments.

System Design

The proposed *Nabahah* is designed to enhance laboratory safety through the integration of artificial intelligence (AI) and real-time monitoring.

The architecture follows a three-layer design, consisting of:

- **Data Acquisition Layer** – Captures video streams from connected cameras in real time.
- **AI Detection Layer** – Processes video frames using YOLOv8-based models to identify potential safety hazards.
- **Monitoring & Alert Layer** – Displays detections on an interactive dashboard and triggers instant alerts for supervisors.

Architecture design

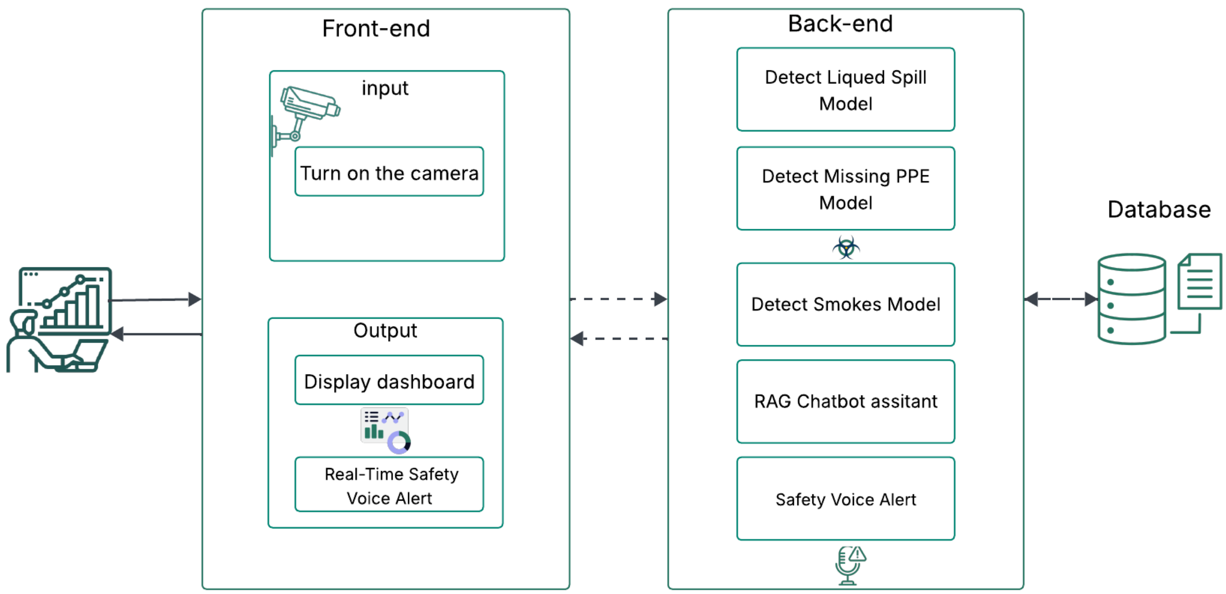

Figure 2: Nabahah Architecture

The system architecture integrates both **front-end** and **back-end** modules:

- **Front-End:**
  - Activates the live camera feed and sends input frames to the AI module.
  - Displays real-time results and alerts through a responsive web dashboard.
  - Provides a **Safety Voice Alert System** for audible notifications.
- **Back-End:**
  - Hosts and runs multiple trained AI models for detecting:
    - Liquid Spills
    - Missing PPE
    - Smoke
  - Integrates **a** RAG-based Chatbot Assistant**.**
  - Manages a secure database for storing incident data, system logs, and user information.

Overall, this architecture ensures seamless real-time operation, supporting efficient hazard detection, immediate alerting, and intelligent data management.

By integrating AI with a scalable web-based platform, ***Nabāhah*** provides a proactive, continuous safety monitoring solution suitable for various environments such as laboratories, factories, and hospitals.

Implementation

The *Nabahah* system was developed To provide real-time, AI- driven safety monitoring across laboratories environment.

Its development followed a structured process that combined dataset preparation, model training, and system integration.

Database and preparation

The project used the "Academic Laboratory Safety Incidents" from Kaggle, which contains detailed recodes of real laboratory incidents such as PPE violations, chemical spills, and unauthorized entries, while image datasets from Roboflow were utilized to train and validate the AI models for visual hazard detection.

These dataset included thousand of annotated images covering safety scenarios such as missing PPE, liquid spill and smoke.

Data preprocessing included resizing images, normalizing lighting conditions, and applying augmentation techniques to improve model performance under various environmental settings.

Model development

The detection model was built using YOLOv8, a state of the art Deep Learning architecture for object detection. We trained the models with Python and PyTorch frameworks.

During training, the models learned identify key safety violations, including:

- Missing or incorrect Personal Protective Equipment (PPE)
- Unauthorized access to restricted (Red Zone) areas
- Liqud spills and potential hazards

The trained model achieved a **Mean Average Precision (mAP)** of **94.5%** and an **average inference time** of **0.8 seconds per frame**, enabling fast and accurate hazard detection in real-time.

System Integration

The trained AI model was integrated into a full-stack monitoring platform using **FastAPI** and **OpenCV**.

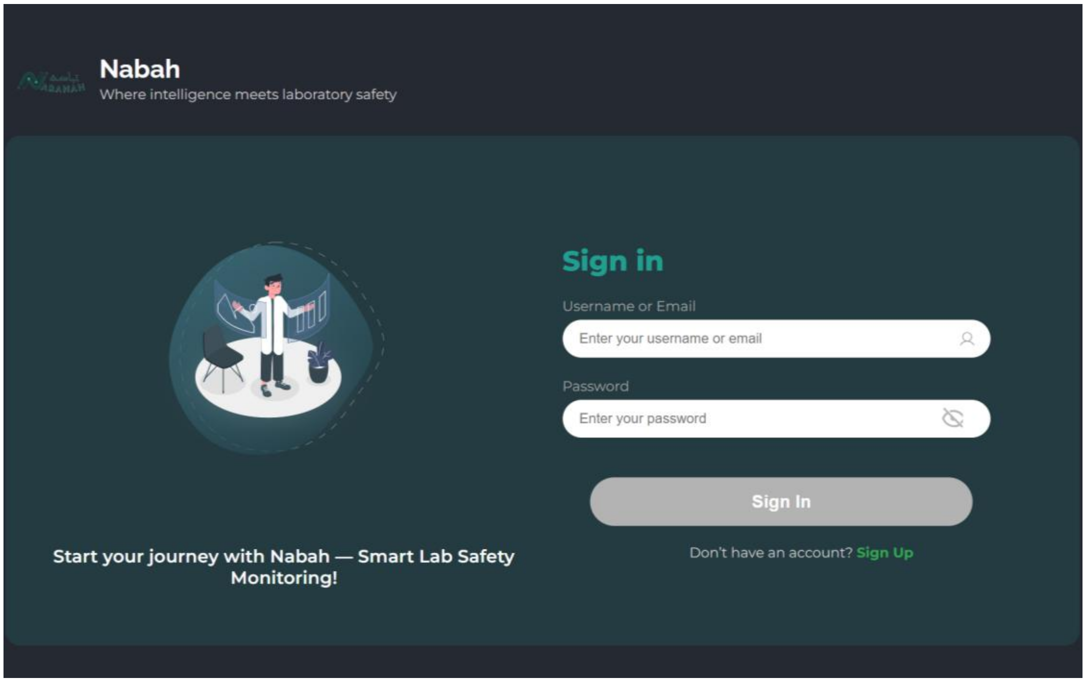

Figure 3: Nabah Sign-In Interface

The user authentication page of the Nabah system that allows secure access to the lab safety analytics platform.

The system connects to live camera feeds for continuous monitoring, detect potential hazards, and sends real-time alerts through a web-based dashboard.

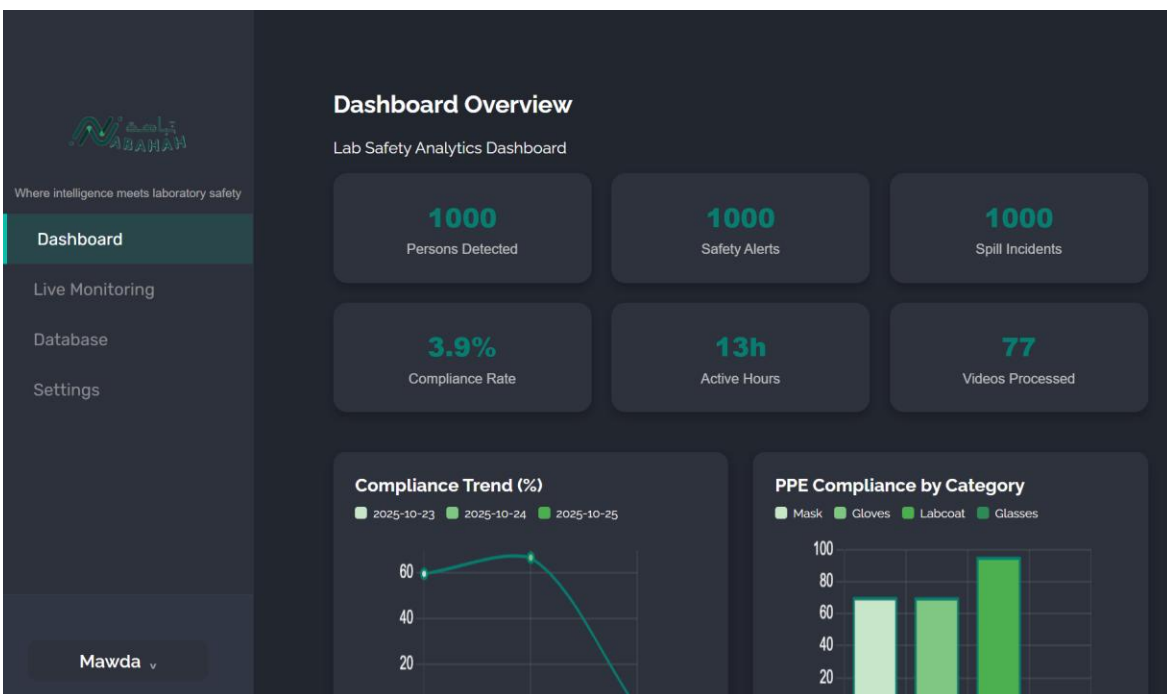

Figure 4:Dashboard Overview

This dashboard presents statistics such as persons detected, safety alert. Liquid incidents and compliance rate for real-time monitoring of lab safety performance.

The dashboard allows safety officers to:

- View live camera streams
- Monitor incident alerts
- Access historical logs and analysis
- Interact with an integrated LLM based RAG chatbot

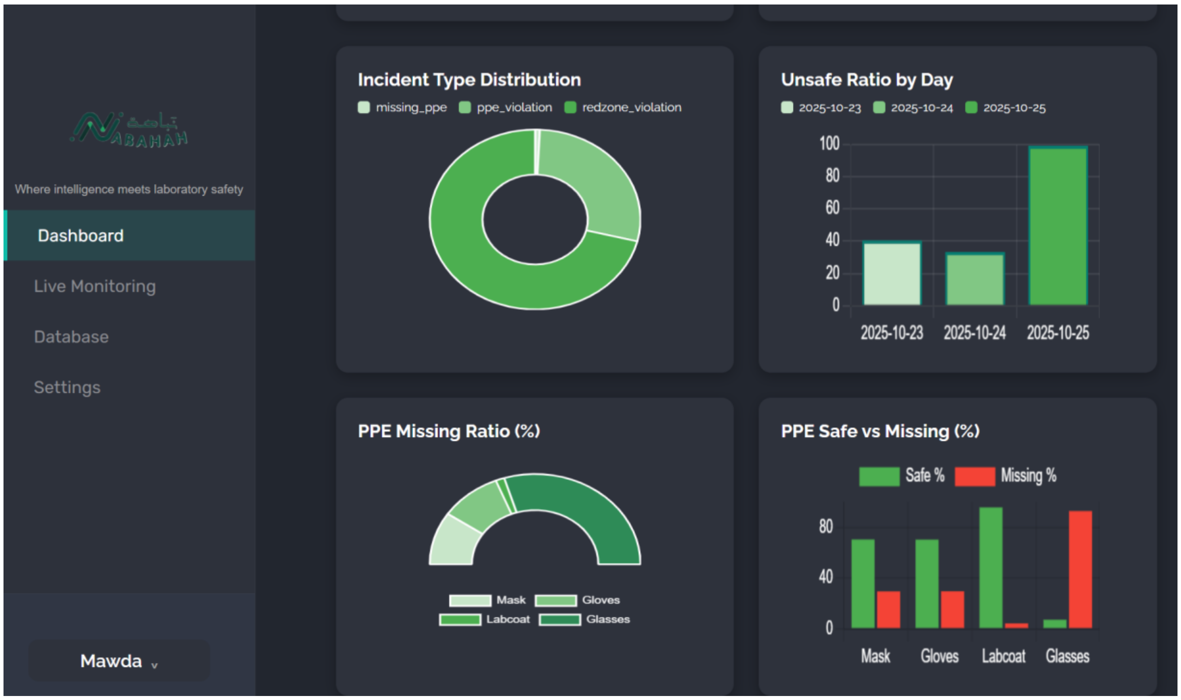

Figure 5: Dashboard Analytic

It present a Visualizations of incident distribution, unsafe ratio and PPE compliance for improved safety awareness.

All detections are stored in a secure vector database, allowing model retraining and trend analysis for continuous system improvement.

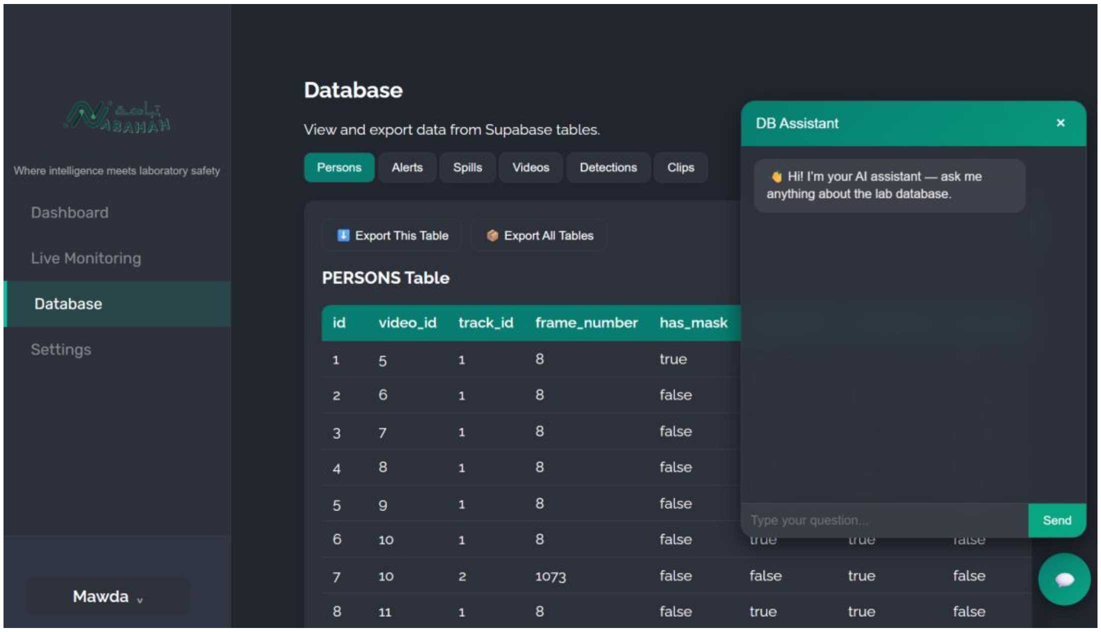

Figure 6: Database Interface

The database interface provides direct access to multiple Supa base tables like: person, alert, liquid videos, detections and clips. It allows users to view, filter and export data for analysis.

On the right side, the integrated DB Assistant support natural language queries, enabling user to interact with the database conversationally – for example: to retrieve incident statistics or detect missing PPE records

This interface streamlines data management and enhances the usability of ***Nabahah*** safety monitoring system

Evaluation

The evaluation phase aimed to measure ***Nabahah*** accuracy, speed, and reliability in real-world condition.

Testing

Testing was performed using the **Kaggle dataset** along with additional live video streams from controlled laboratory environments.

The model was evaluated under various conditions, including normal and low lighting, movement variability, and different camera angles.

Performance Matrices

Matric	Result	Description
MAP	%94	Overall accuracy of object detection
Precision	%93	Rate of correct detections among all alerts
Recall	%90	Ability to detect all existing hazards

Interface Time	0.8 s/frame	Speed of processing and alert generation

Table 10: Performance

Observations

- The system maintained **high detection accuracy** in different environments and lighting conditions.
- Real-time alerts were successfully generated with minimal delay.
- The FastAPI dashboard provided responsive performance and easy interaction for safety officers.

Conclusion & Future Work

Nabāhah demonstrates how artificial intelligence can revolutionize safety management across laboratory and industrial environments.

By integrating real-time PPE detection, hazard recognition, and centralized monitoring, the system enhances situational awareness and minimizes risks caused by human oversight.

The implemented architecture proves to be reliable, scalable, and efficient, capable of supporting continuous real-time operations.

Future work will focus on *expanding the system's adaptability to multiple industries*, improving detection accuracy under challenging conditions, and incorporating *predictive analytics* to anticipate potential hazards.

These advancements aim to evolve Nabāhah from a reactive safety tool into a *comprehensive, intelligent safety management platform.*

References

[1] KFUPM, "Showcase MVP of Personal Protective Equipment (PPE)," KFUPM Research Projects. [Online]. Available: https://r.kfupm.edu.sa/recl/research/projects/project-details/showcase-mvp-of-personal-protective-equipment-ppe [Accessed: Oct. 23, 2025].

[2] Z. Khodadad, "Academic Laboratory Safety Incidents Dataset," Kaggle, 2023. [Online]. Available: https://www.kaggle.com/datasets/zohrehkhodadad/academic-laboratory-safety-incidents-dataset

[Accessed: Oct. 23, 2025].

[3] Springer, "AI-based Laboratory Safety Systems," *SpringerLink Journal of Safety Research*, 2024. [Online]. Available: https://link.springer.com/article/10.1007/s10462-024-10978-x [Accessed: Oct. 23, 2025].

[4] MDPI, "Vision-Based Hazard Detection in Industrial Environments," *MDPI Sensors*, vol. 15, no. 18, 2024. [Online]. Available: https://www.mdpi.com/2071-1050/15/18/13990 [Accessed: Oct. 26, 2025].

[5] GitHub, "RanyV2 Edge-TTS," GitHub Repository. [Online]. Available: https://github.com/ranyv2/edge-tts

[Accessed: Oct. 25, 2025].

[6] Supabase, "Supabase-Py: Python SDK," GitHub Repository. [Online]. Available: https://github.com/supabase-community/supabase-py [Accessed: Oct. 25, 2025].

[7] TryoLabs, "NorFair: Lightweight Object Tracking," GitHub Repository. [Online]. Available: https://github.com/tryolabs/norfair [Accessed: Oct. 19, 2025].

[8] Altralytics, "YOLOv8 Tools," GitHub Repository. [Online]. Available: https://github.com/altralytics/altralytics [Accessed: Oct. 19, 2025].

[9] Databricks, "Retrieval Augmented Generation (RAG)," Databricks Glossary. [Online]. Available: https://www.databricks.com/glossary/retrieval-augmented-generation-rag [Accessed: Oct. 20, 2025].

[10] Arxiv, "Advanced RAG Techniques for Multi-Source Data," *arXiv preprint arXiv:2312.10997*, 2024. [Online]. Available: https://arxiv.org/abs/2312.10997 [Accessed: Oct. 20, 2025].