Industrial Workspace Safety Enforcer: AI-Powered Robotic Compliance System

COURSE CODE – 22AIE214

TEAM 7

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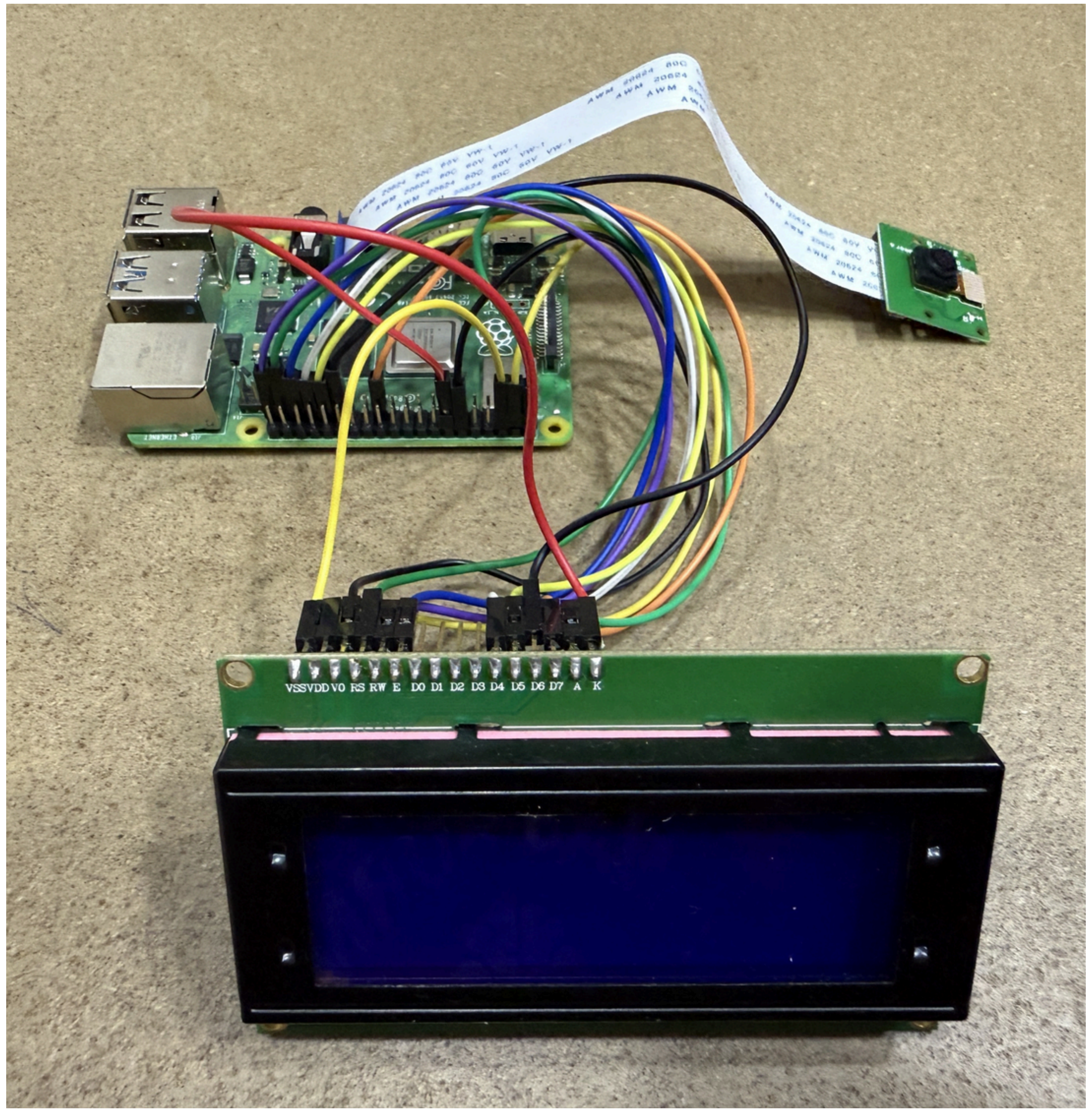
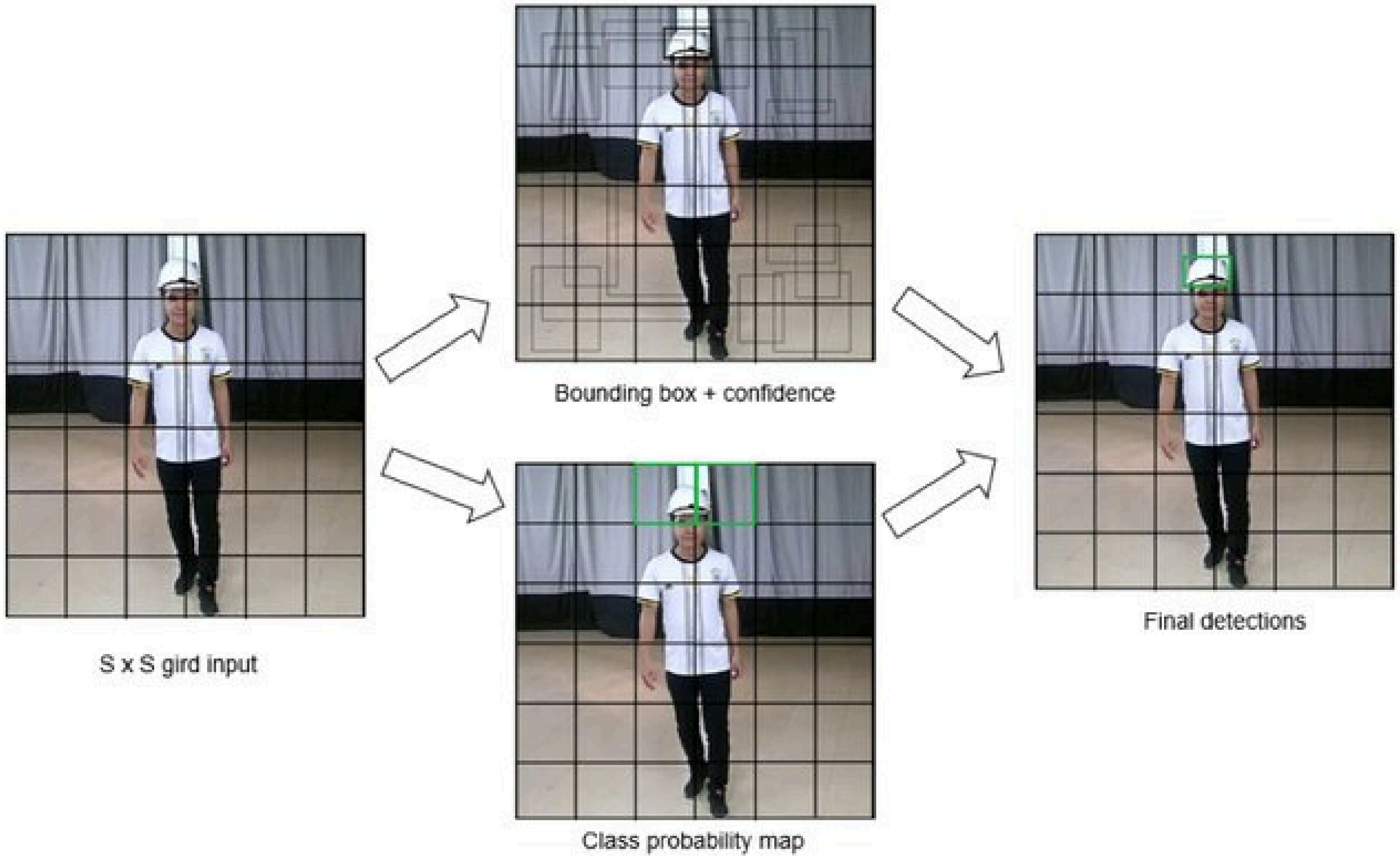
Introduction





Problem Statement :

Current systems for monitoring worker safety, such as checking if employees are wearing helmets, vests, masks, and boots, rely heavily on manual checks and human security personnel. These systems are prone to errors, leading to accidents if workers are not properly equipped. Such incidents endanger workers' health, cause financial losses, and damage the company's reputation.

This project aims to develop an automated system that scans workers at the entry gate to ensure they are wearing the required safety gear. If any PPE is missing or incorrectly worn, the system will trigger an alert, preventing the worker from entering the premises. This solution will reduce human error, improve safety, and enhance operational efficiency.

Challenges observed from previous work:

- Slow and Non-Real-Time Processing – Many earlier systems used computationally heavy models unsuitable for real-time inference, causing delays in safety checks.
- Limited Hardware Efficiency – Most prior implementations relied on expensive, high-power computing setups, making them impractical for widespread industrial adoption.
- Manual Inspection Dependency – Traditional methods often required human monitoring or intervention, reducing automation and efficiency in PPE compliance enforcement.

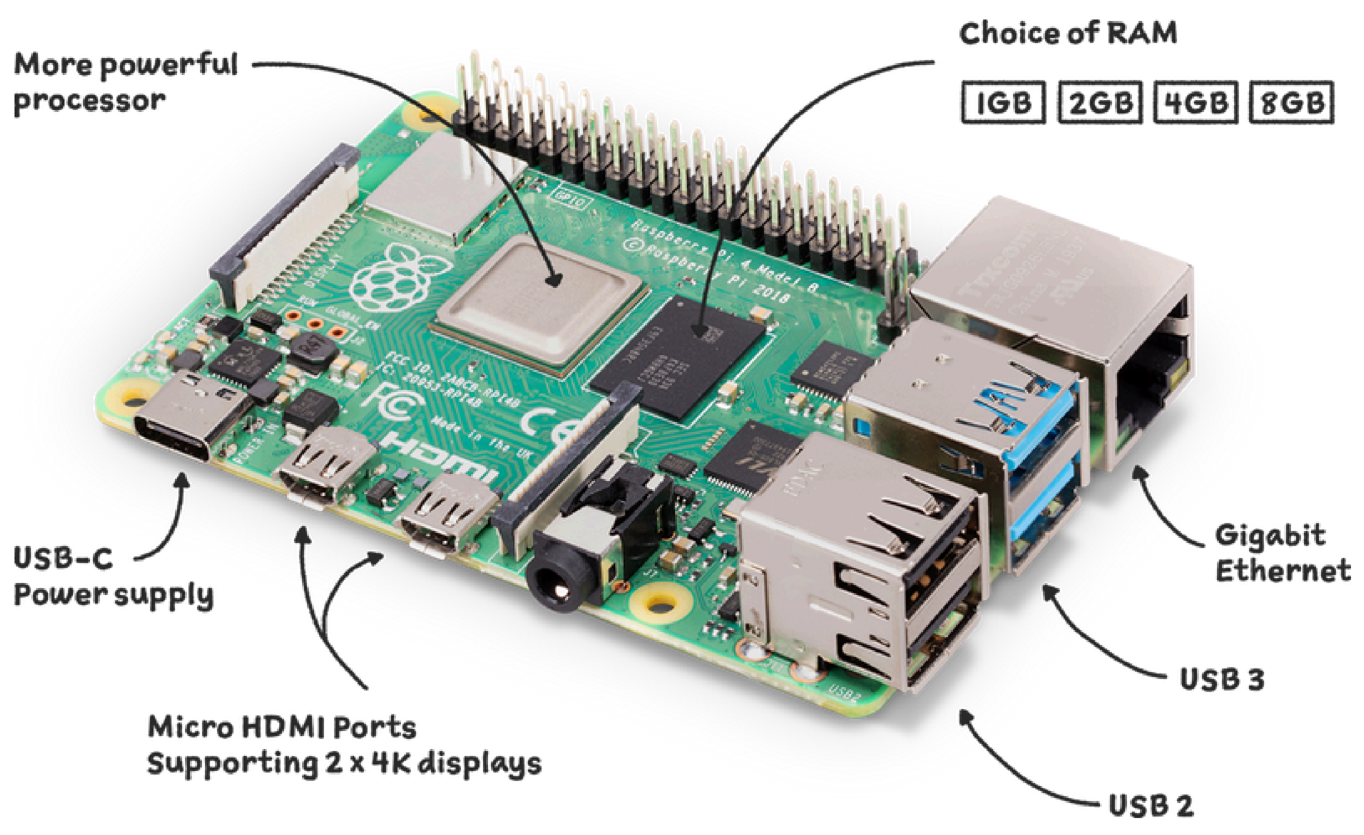
Objectives :

- To create an yolo-powered system for real-time PPE compliance monitoring using YOLOv8.
- To automate access control and decision-making based on PPE detection using Raspberry Pi.

- To develop a deep learning model for accurate PPE detection in industrial environments.
- To integrate computer vision with embedded systems for real-time inference and decision-making.

Components Used:

- Raspberry Pi Model 4
- PiCamera2
- 16x2 Character LCD Display
- GPIO Pins
- Power Supply (5V, 3A)
- MicroSD Card 32GB
- Jumper Wires



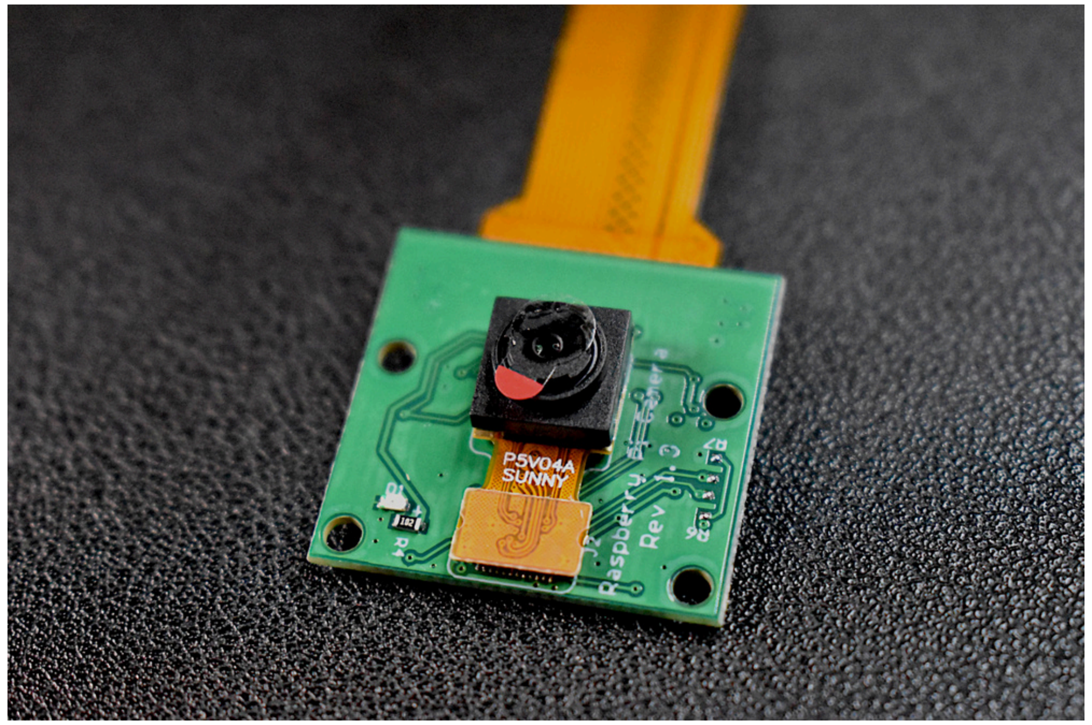
Usage of Raspberry Pi in the PPE Compliance System

The Raspberry Pi (Model 4B or 5) serves as the core processing unit in your system, handling the following tasks:

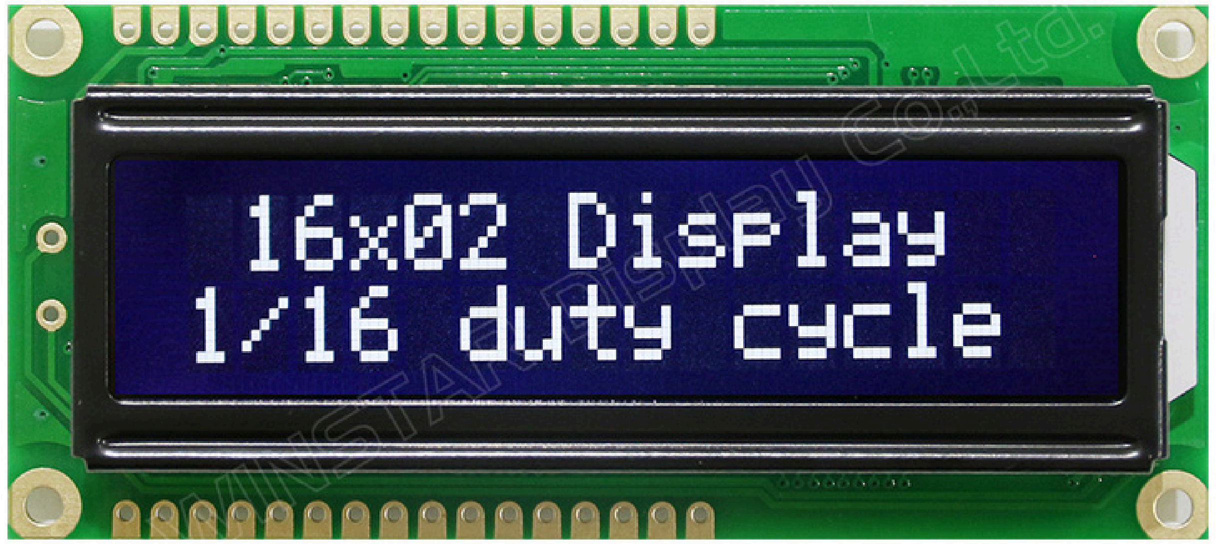
Running the YOLOv8 AI Model

Loads and executes YOLOv8 for real-time PPE detection.

Processes video frames to detect helmets, safety boots, and vests.



The PiCamera2 is used for real-time video capture to detect PPE compliance. It performs the following functions:
Capturing Live Video
The camera streams real-time video to the Raspberry Pi.
It is configured for RGB888 format at 640×480 resolution for optimal speed

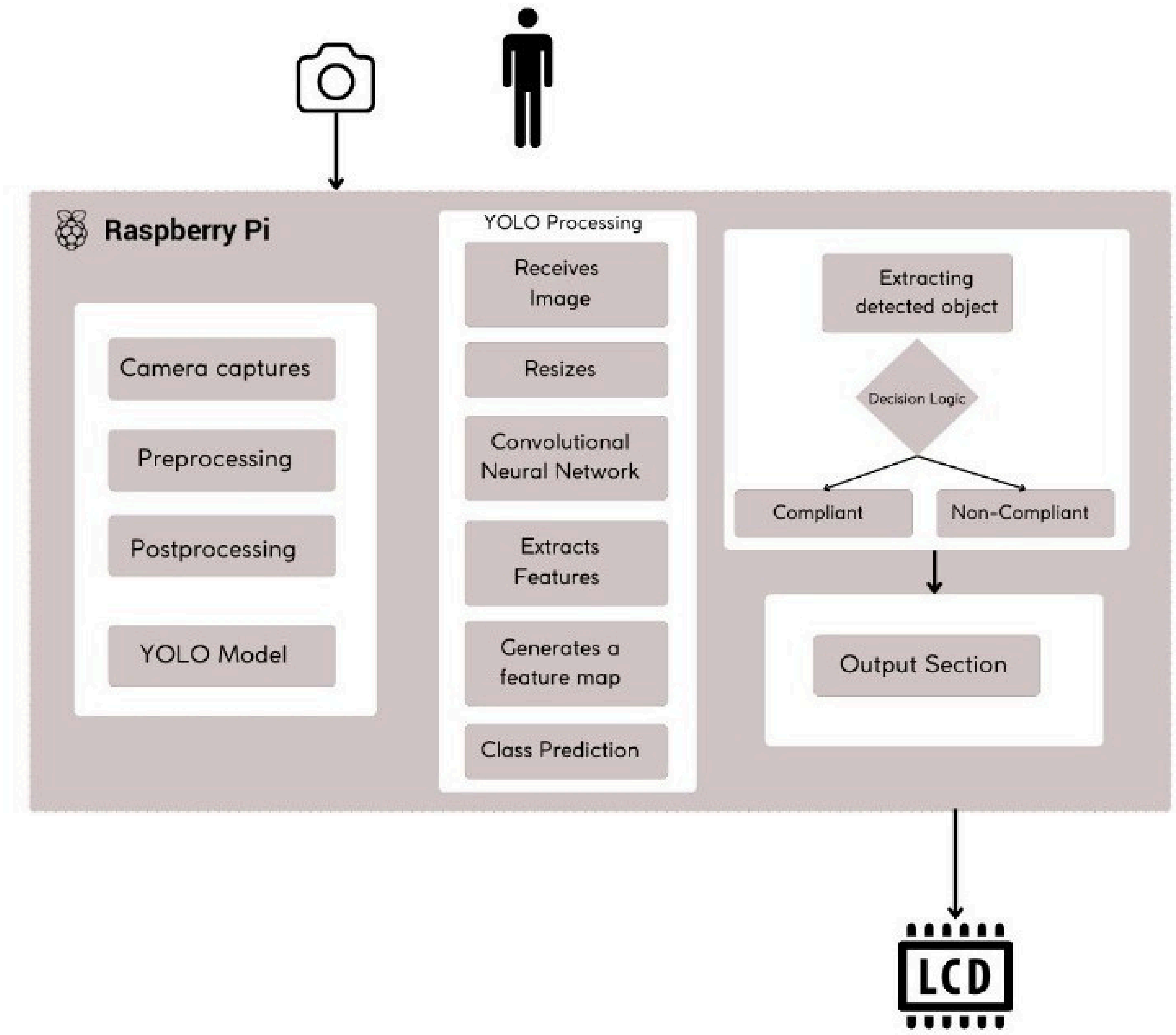


Usage of 16x2 Character LCD Display in the PPE Compliance System
The 16x2 Character LCD Display is used to provide real-time feedback on PPE compliance. Here's how it functions:

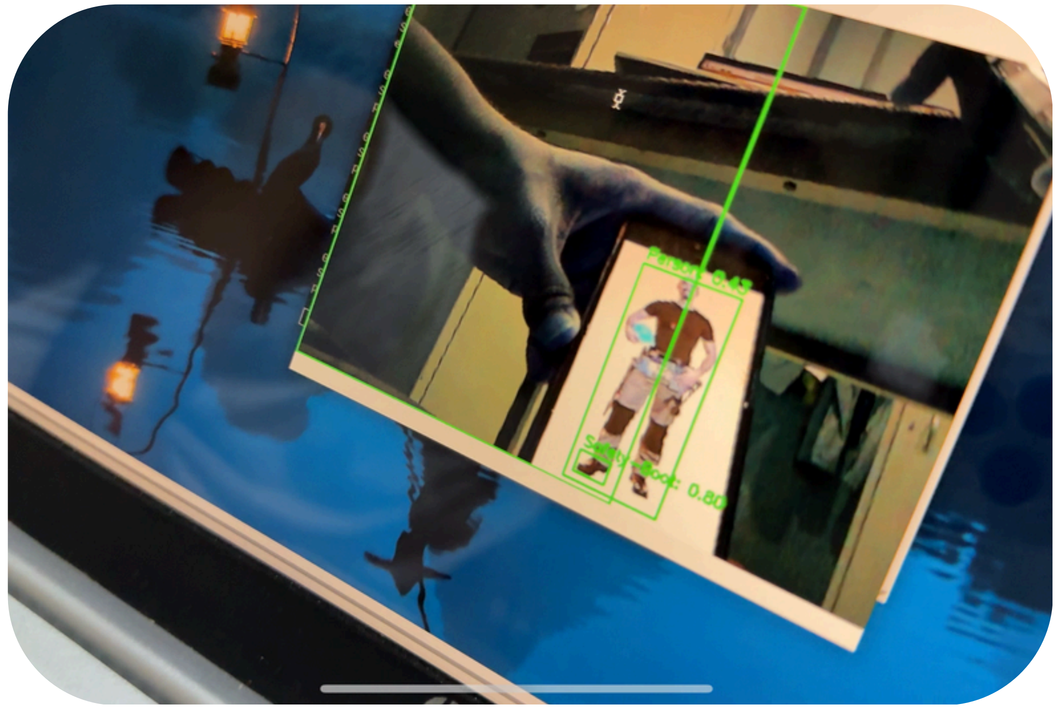
Displaying PPE Compliance Status

- Shows “Access Granted” when all required PPE is detected.
- Shows “Access Denied” if any PPE item is missing.

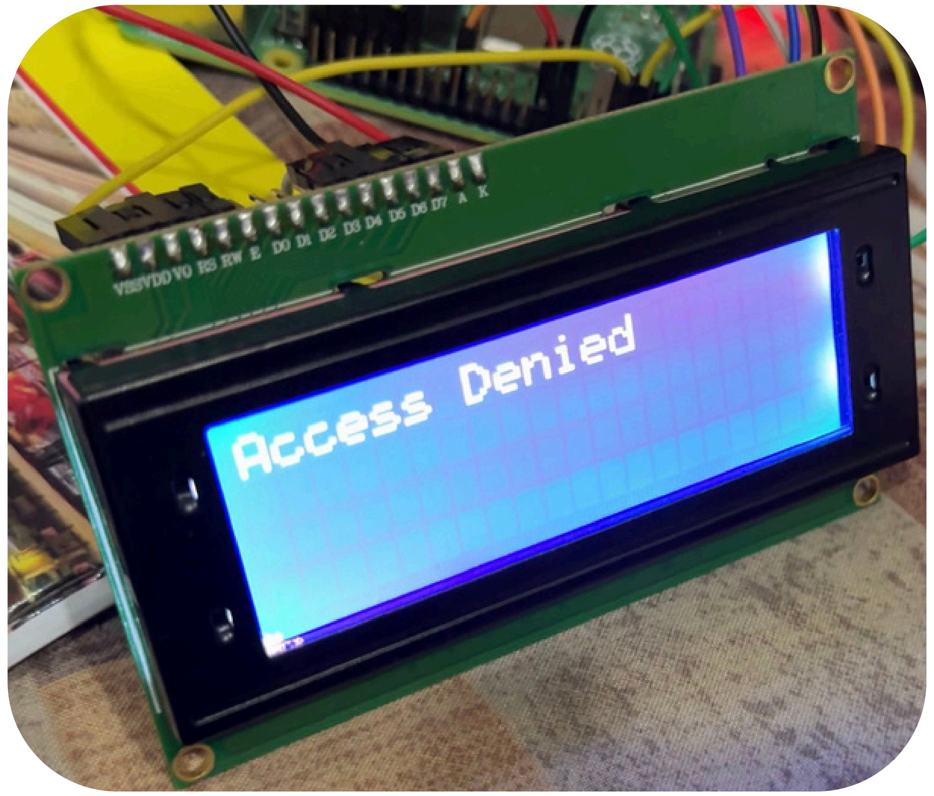
Methodology




Safety-Vest: 0.85




VSSVDD VO RS RW E D0 D1 D2 D3 D4 D5 D6 D7 A K
Access Granted


Access Denied

Literature Review

S.NO	Title	Author Journal Year	Methodology/Algorithms/Architecture used	Merits	Demerits	Research gap
1.	Automated University Gate Pass Monitoring System Using Deep Learning	• Patel Meghavi Kiritbha • Jyotsna C	• Deep Learning Model: VGG16 • Face Detection and Recognition • Face Detection and Recognition:OpenCV	• Accuracy: 98.34% (using VGG16). • Loss: 1.60% (after fine-tuning) • Immediate SMS notifications.	• Dependence on Environmental Conditions • Mask Detection Limitation • Enable Offline Functionality	• Handling Occlusions (e.g., Masks, Hair, Accessories) • Adaptability to Changing Conditions • Multi-Modal Authentication

S.NO	Title	Author Journal Year	Methodology/Algorithms/Architecture used	Merits	Demerits	Research gap
2.	DEVELOPMENT AND EVALUATION OF AUTOMATED GATE PASS SYSTEM	• Romy Jun A. Sunico • Elwin S. Argana • Marife M. Dumale	• Rapid Application Development (RAD) Model • System Development Life Cycle (SDLC) • **Modules Developed:** Gate Pass Module End-User Module Admin Module Reports Module Registration Module	• Efficiency • Real-Time Data • Scalability	• Limited Monitoring • Lack of Portability • Class Schedule Monitoring	• Broader Security Features • CCTV Integration: • Advanced Feedback Mechanism

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3.	A Systematic Comparison of Simulation Software for Robotic Arm Manipulation using ROS2	Florent P. Audonnet, Andrew Hamilton and Gerardo Aragon-Camarasa Published on: 13 Apr 2022	• The study conducts a systematic benchmark of ROS2-compatible robotic simulation software, evaluating Ignition, Webots, Isaac Sim, PyBullet, and Coppeliasim. Metrics include CPU/RAM usage, task success rates, and repeatability under headless and graphical modes. • Two robotic arm tasks—Pick-and-Place and Throwing—were used to assess long-term operations and simulation stability.	• Ignition and Webots demonstrated high task stability and success rates. • PyBullet and Coppeliasim were resource-efficient, ideal for machine learning tasks. • Webots emerged as a strong candidate for prototyping due to high repeatability.	• Most simulations, including Ignition and Isaac Sim, showed limitations in handling dynamic and complex tasks (e.g., cube throwing). • Resource-intensive options like Isaac Sim hinder real-world scalability. • Limited ROS2 compatibility and parameter tuning issues caused failures in scenarios requiring high precision.	• Existing simulation software cannot sustain repeatable, realistic digital twin models over time due to inadequate physics fidelity and dynamic feedback. • Future work should focus on integrating real-world feedback loops and optimizing resource usage for AI-based robotics research.

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4.	Robots in Inspection and Monitoring of Buildings and Infrastructure: A Systematic Review	Srijeet Halder and Kereshmeh Afsari Published on: 10 February 2023	• The paper employs a systematic review approach, analyzing 269 papers using bibliometric and qualitative content analysis methods to categorize robot types, applications, and research challenges in building and infrastructure inspection. • Focus areas include autonomous navigation, sensing, and multi-robot collaboration. Robots studied range from UAVs to hybrid and underwater robots.	• Robotics enhances efficiency, safety, and frequency of inspections, reducing human errors. • Robots like UAVs and UGVs offer diverse inspection capabilities, especially in hard-to-reach or hazardous areas. • Multi-robot systems and AI-driven autonomous navigation provide scalable solutions for large-scale inspection tasks.	• Challenges include limited indoor navigation (e.g., GPS signal loss), dependency on infrastructure, and high costs of advanced systems. • Specialized robots like wall climbers or marine vehicles have constrained applications based on surface or environmental conditions. • Data overload and noise during robotic inspections complicate real-time analysis and decision-making.	• The review highlights gaps in achieving real-time, autonomous decision-making, integration of multi-sensor data, and cost-effective robotic designs for inspection. • Future research should focus on improving robustness in navigation, scalability for multi-robot systems, and combining AI with real-world feedback for adaptive performance.

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5.	Development of an Automated Railway Level Crossing Gate Control System using PLC	• Rumana Tasnim • Abu Salman Shaikat • Kamruzzaman Sarkar • Md. Ismail Mahmud • Mohammad Ali • Md. Tarikul Islam Year: 2019	• The paper presents the development of an automated railway level crossing gate control system using a Programmable Logic Controller (PLC). It employs reflective type photoelectric sensors to detect trains and obstacles at the crossing. The system utilizes PLC to control the operation of the gate through motors, ensuring safety by automatically closing or opening the gates based on the train's presence or any detected obstacle.	• The system improves safety at railway level crossings by automating gate control. • It reduces accidents caused by human error in manually operated systems. • The system operates with a fast response time, ensuring minimal traffic delays. • The prototype is cost-effective and reliable.	• The initial investment for setting up the system may be high. • The system is designed for small-scale applications and may require adjustments for wider deployment. • The system is sensitive to sensor placement and environmental conditions that may affect sensor performance. • The research does not address long-term maintenance and operational costs.	• The initial investment for setting up the system may be high. • The system is designed for small-scale applications and may require adjustments for wider deployment. • The system is sensitive to sensor placement and environmental conditions that may affect sensor performance. • The research does not address long-term maintenance and operational costs.

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6.	Implementation of Intelligent Automated Gate System with QR Code - An IOT System to Help Gate Management	• Erman Hamid • Lim Chong Gee • Nazrulazhar Bahaman • Syarulnaziah Anawar • Zakiah Ayob • Akhdiat Abdul Malek Year: 2018	• This paper presents a QR code-based Intelligent Automated Gate System (IAGS) that uses QR codes for staff authentication. The system includes a motion sensor, servo motor, Arduino microcontroller, and piezo buzzer. The gate opens when an authorized QR code is scanned, and an email notification is sent if unauthorized access is detected. The system also records all staff check-ins and check-outs, enhancing security.	• Cost-effective compared to high-tech gate systems. • Provides real-time email notifications for unauthorized activities. • The system is highly accurate, with a 99% recognition rate for QR code scanning. • Records staff entry/exit activities for security purposes.	• The system requires internet connectivity for email notifications, which may be a limitation in areas with weak internet connections. • QR code reading can be affected by insufficient lighting, which may delay or prevent scanning. • The system's reliance on cameras and sensors may introduce privacy concerns. • The QR code is prone to loss or damage, which could affect its functionality without updates.	Although the paper presents a robust solution for small companies, future improvements could include adding SMS/WhatsApp notifications and integrating voice communication for enhanced interaction with security staff. Additionally, the use of IP cameras instead of USB cameras could improve the system's cost-effectiveness and monitoring capabilities.