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Advance Fault Detection in Assembly Line Using PLC and Raspberry PI Integration

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ABSTRACT

This paper discusses an automatic bottle sorting system. It combines Programable Logic Controllers (PLC) and Raspberry Pie with a machine-informed AI model. AI checks the color, perfection and cap placement of the bottle during operation. The raspberry pie camera applies the AI model to identify bottles from the input. Then, PLC guides a robot arm for the position of bottles at 45 °, 90 °, or 270 ° angles depending on its color. The system weighs them with load cell and detects changes in the part. This stores all data for future analysis. The creators designed this system to function without traditional sensors. Instead, it depends on AI for visual inspections. This simplifies hardware by maintaining performance compared to industrial machines.

1. Introduction

Automation in manufacturing rapidly demands intelligent systems that are capable of checking multi-guardian quality. Traditional PLC-based systems rely on the discomfort sensor (eg, ultrasonic, IR) for tasks such as phil-level or cap detection, which lacks adaptability and scalability. The task replaces sensor-based inspections with a light AI model posted on a raspberry pie, which is capable of vision-based detection of color, liquid appearance and cap position. The PLC ensures accurate robotic activation, creating a hybrid architecture that merges industrial control with edge-AI flexibility.

Innovation:

- **Sensorless detection:** The AI model has been trained to classify the position of color, liquid and cap by using camera data.
- **Angular sorting logic:** Puts bottles on unique angles (45 °, 90 °, 270 °) depending on the robotic arm color.
- **Hybrid Edge-Industrial System:** Raspberry Pie handles AI invention, PLC executes activation.

2. System Design and Methodology

2.1 Hardware Architecture

1. Raspberry Pie module:

• Camera: PI camera V3 to take bottle images.

• Load sales: HX711 ADC (0-500g area) for weight measurement

• Communication: MQTT protocol to transfer the results of PLC detection**.**

2. PLC module:

O Checking: Siemens S7-1200 PLC for robot arm control.

O Actuators:

 Sarvo Motors: Adjust robotic angles (45 °, 90 °, 270 °).

 Transport tape: Synchronized with signs of detection through the stone motor.

- **Controller:** Siemens S7-1200 Plc for Robotic Arm Control.
  - **Actuators:**
    - **Sarvo Motors:** Adjust robotic arm angles (45 °, 90 °, 270 °).
    - **Conveyor belt:** synchronized with signs of detection via the stepper motor.

1. **Robotic Arm**:

- 4-DOF arm with gripper, programmed for color-specific angular placement.

2.2 AI Model Development

1. **Dataset Preparation**:

- **Training data:** 5,000 anotte images of bottles under separate light, angles and conditions.
  - **Label:** Color (red/green/blue), liquid filler (full/empty), cap position (attached/missing).
- **Augmentation**: Random rotations, brightness adjustments, and noise injection to improve robustness.\

2. **Model Architecture**:

- **Framework:** Tensorflow Lite for Edge Payment on Raspberry Pie.
- **Backbone:** Lightweight Mobilenetv2 (adapted to Raspberry Pie 4) for real -time estimate.
- **Affected Head:**
  - **Color classification:** Softmax output for red/green/blue.
  - **Liquid Phil Detection:** Binary Classifier (full/empty).
  - **Cap detection**: binary classifier (attached/missing).

3. **Training and Deployment**:
   - **Training:** 80:20 Learning transfer on Mobilenetv2 (Preetrand on Imangate) with 80:20 Train-Test Split.
   - **Infererance:** 15 fps on raspberry pi 4 (4GB RAM) using Tensorflow Lite interpreter.

2.3 Software Workflow

1. **image processing:**
   - **AI Innantry:** Captured image → Mobilentv2 → Multi-task classification (color, fill, hat).
   - **Weight measurement:** Calibrated through load cell data HX711.
2. **PLC Logic:**
   - The ladder diagrams trigger the robotic arm tragects based on the MQT payload (eg, "Green_90 ° _Full").

2.4 Integration Challenges

- **Flightness:** Adapted model size (8MB) to balance accuracy and estimate speed.
- **Edge-II calibration:** Aligning camera focus and lighting for frequent model performance.

3. Results and Validation

Parameter	**Performance**
Color detection	97% accuracy
Liqui fill detection	94% precision
Cap detection	93% precision
Weight measurement	±1.5g error (HX711 calibration)

Sorting speed	10 bottles/minute
Robotic arm accuracy	±2° angular error

Comparative Analysis:

- IR/ultrasonic sensor system outperform in dynamic environment (eg, different bottle size).
- The SCADA in credibility matches the system, but reduces the hardware cost by 40%.

4. Discussion

Advantages of AI-Driven Detection:

- **Flexibility:** New bottle design friendly (no hardware regeneration) through retrenching.
- **Cost reduction:** Ultrasonic/IR eliminates the sensor, reduces BOM cost.
- **Multi-task efficiency**: single camera and model handle color, phil and cap check.

Limitations and Future Work:

- **Light dependence:** Performing falls under extreme shadow/dazzle.
- **Scalability:** Extend more colors or complex defects using Yolov5.

5. Conclusion

The system displays a sensor-free, an-in-operated approach to the prooning industrial bottle, combining the computational power of raspberry pie with PLC reliability. The AI model receives high accuracy in multi-task detection, while modular design allows easy adaptation for diverse workflows. Future work will integrate Fedard Learning for model updates in depth cameras and production lines for 3D currency estimate.

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