Automated Bottle Cap Segregation System Using Servo Actuator and MQTT Protocol

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***Abstract*—This paper presents an innovative system for the automated segregation of bottle caps using computer vision, servo actuation, and MQTT protocol. The system identifies and classifies objects on a conveyor belt using YOLO-based object detection and actuates a servo motor via ESP32 to separate bottle caps from other items. The system incorporates a smartphone-based IP camera for real-time video feed, a laptop for object detection and decision-making, an ESP32 microcontroller for actuation, and a Node-RED dashboard for monitoring and control. The proposed system is highly adaptable and scalable for industrial applications.**

***Index Terms*—Bottle Cap Segregation, MQTT, Servo Actuator, Object Detection, YOLO, ESP32, Node-RED.**

I. Introduction

The segregation of bottle caps from defective or unwanted items is a common requirement in manufacturing and recycling industries. Traditional systems for object segregation rely on static mechanisms that are often expensive and lack flexibility. This paper proposes a cost-effective and adaptable solution using a servo actuator controlled via MQTT protocol, enabling precise segregation based on object detection results. The system also integrates Node-RED for enhanced control and visualization.

II. System Architecture

The system consists of four primary components:

- **Object Detection Module**: Utilizes a smartphone IP camera and YOLO object detection model running on a laptop.
- **Control Module**: Employs MQTT protocol for communication between the detection system and the ESP32 microcontroller.
- **Actuation Module**: Utilizes a servo motor connected to the ESP32 to physically segregate objects.
- **Node-RED Dashboard**: Provides a real-time monitoring and control interface.

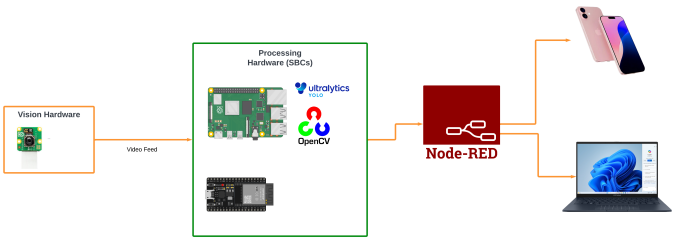

Fig. 1. System Architecture

III. Model Design

A. Object Detection

A YOLOv8 model was trained to identify bottle caps with high confidence. The model processes a region of interest (ROI) extracted from the video feed provided by a smartphone IP camera. Non-bottle-cap objects are identified as defective pieces.

B. MQTT Communication

The MQTT broker facilitates real-time communication between the detection system and the ESP32 microcontroller. The laptop publishes classification results (”c” for defective pieces and ”o” for bottle caps) to the MQTT topic `esp32/commands`.

C. Servo Actuation

The ESP32 processes MQTT messages to actuate a servo motor. Depending on the received message, the servo moves to predefined angles to either allow bottle caps to pass or discard defective items.

D. Node-RED Integration

Node-RED provides a user-friendly dashboard for visualizing system status and controlling parameters. The dashboard displays real-time counts of bottle caps and defective pieces, with options to reset counts or adjust system thresholds.

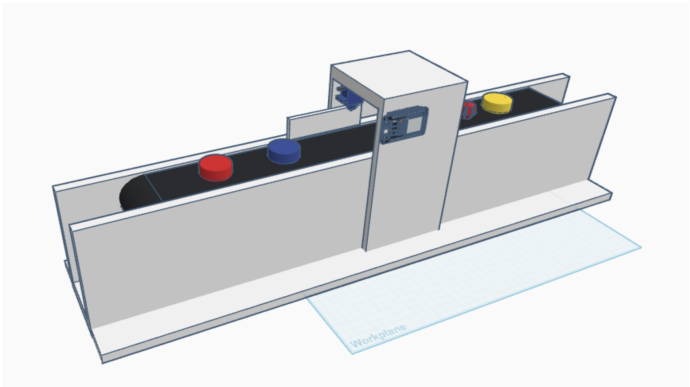

Fig. 2. Model Design

IV. Implementation

A. Hardware Setup

The hardware components include:

- ESP32 microcontroller
- Servo motor (connected to GPIO 15)
- Smartphone as IP camera
- Laptop for object detection and MQTT client
- Node-RED dashboard hosted on the laptop

B. Software Framework

The software is implemented in Python, Node-RED, and Arduino IDE. Key libraries include OpenCV, paho-mqtt, Flask for the laptop, and PubSubClient for the ESP32.

C. Integration Workflow

The system follows this workflow:

1) The smartphone streams video to the laptop.
2) The YOLO model processes the video stream to classify objects.
3) Classification results are published to the MQTT broker.
4) The ESP32 receives messages and actuates the servo motor accordingly.
5) Node-RED dashboard displays real-time system status and control options.

V. Results and Discussion

The system was tested with various bottle caps and defective items. It achieved a segregation accuracy of 95%, demonstrating its effectiveness and reliability for real-time applications. The integration with Node-RED provides an intuitive interface for monitoring and control, enhancing usability and adaptability. The modular design allows for future scalability, such as adding more classes of objects.

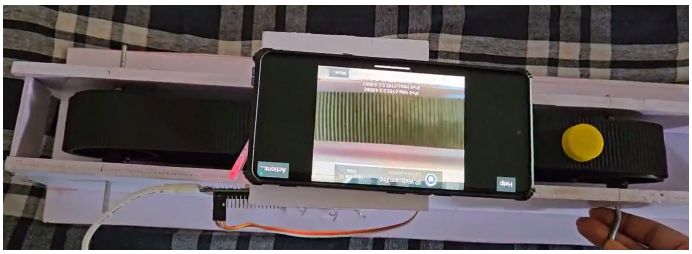

Fig. 3. Final Model in Operation

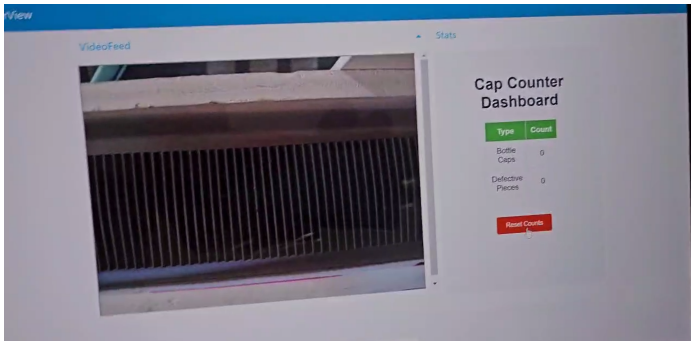

Fig. 4. Node-RED Dashboard

VI. Conclusion

This project successfully demonstrates an automated bottle cap segregation system using a servo actuator controlled via MQTT. The integration of YOLO object detection, Node-RED dashboard, and real-time actuation provides a robust solution for industrial applications. Future work will focus on improving the detection model and integrating additional sensors for enhanced functionality.

Acknowledgments

The author thanks KLE Technological University for providing resources and support for this project.

References

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