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AI-Based Smart Segregation System

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ABSTRACT

The increasing demand for high-quality agricultural produce necessitates efficient and accurate sorting systems. This paper presents an AI-based smart segregation system designed to automate the sorting of tomatoes, leveraging advanced technologies such as deep learning, image processing, and robotic automation. The system integrates a conveyor belt, ultrasonic sensors, a high-resolution camera, a weigh scale, and robotic arms to classify tomatoes into reject, ripe, or unripe categories based on visual and weight parameters. Using the YOLOv8 object detection model trained on a dataset of 731 tomato images, the system achieves high precision in real-time classification, validated through extensive testing. Results demonstrate significant improvements over traditional manual sorting methods, reducing labor costs, minimizing errors, and enhancing operational efficiency. The system's scalability and adaptability suggest its potential for broader agricultural applications, paving the way for future advancements in automated farming practices.

Keywords: ***Artificial Intelligence, Machine Learning, Tomato Sorting, Image Processing, Robotic Automation, Agriculture***

1. INTRODUCTION

Agriculture underpins global food security and economic stability, yet traditional post-harvest sorting methods—dependent on manual labor—suffer from inefficiency, inconsistency, and high costs.

The integration of artificial intelligence (AI) and automation offers a transformative solution. This study introduces an AI-based smart segregation system optimized for tomatoes, addressing these challenges through advanced sensing, imaging, and robotic technologies.

The system automates tomato classification into reject, ripe, or unripe categories using parameters such as size, color, shape, defects, and weight. By minimizing human intervention, it enhances accuracy, reduces operational expenses, and ensures consistent quality—benefits critical for farmers, processing facilities, and the agricultural supply chain.

2. SYSTEM OVERVIEW

The system comprises a conveyor belt, an HC-SR04 ultrasonic sensor, a 720p web-camera, a 3 kg load cell with HX711 amplifier, NEMA 17 stepper motor-driven robotic arms, and a Raspberry Pi 4 controller. Its operation follows four stages:

1. Detection: An ultrasonic sensor identifies a tomato, pausing the conveyor.
2. Imaging: A camera captures an image, analyzed by the YOLOv8 model for classification.
3. Weighing: A robotic arm transfers the tomato to a weigh scale.
4. Sorting: A second arm places the tomato into designated bins based on class and weight.

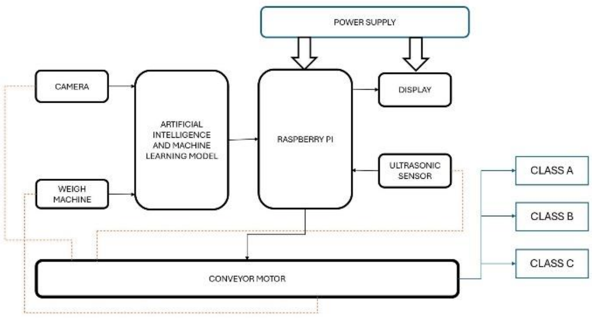


Fig1: System Overview

3. IMPLEMENTATION

Python orchestrates system integration. The YOLOv8 model, trained on annotated images, classifies tomatoes with high accuracy. The conveyor, triggered by the ultrasonic sensor, transports tomatoes, while robotic arms perform pick-and-place tasks based on AI and weight data.

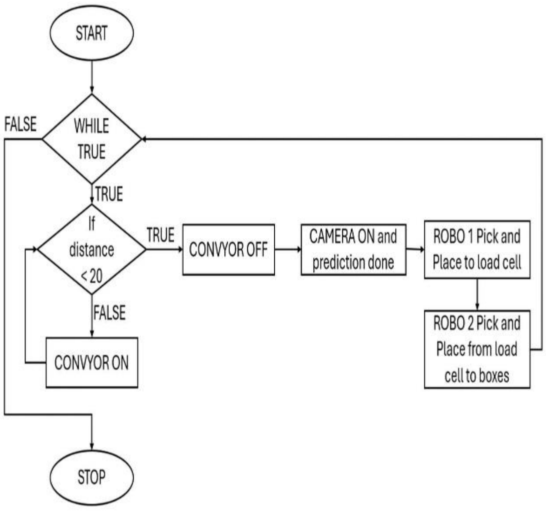
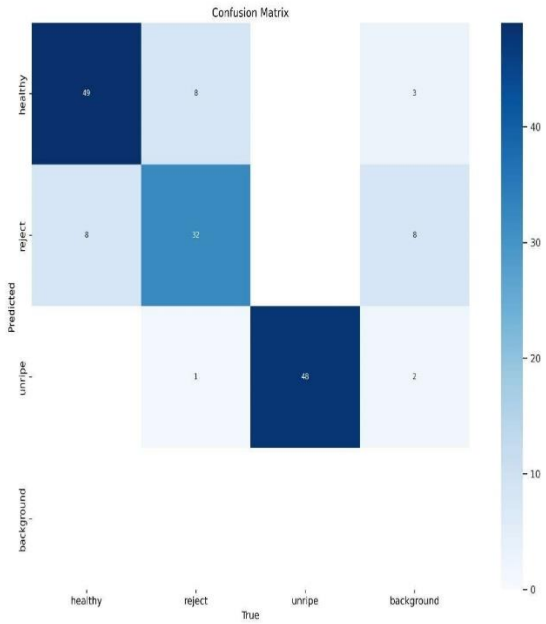


Fig 2: Flow Chart of the System

4. RESULTS AND ANALYSIS



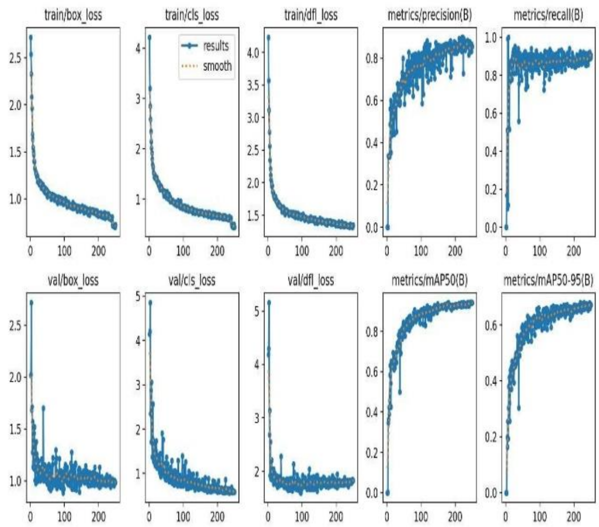


Fig 3: Confusion Matrix and Precision and Loss Curve for 250 epochs

Fig 4: Test Result for each category

Fig 5: Test Result with Accuracy Percentage

7. DISCUSSION

This system revolutionizes agricultural sorting by automating quality control with deep learning and robotics, overcoming manual method limitations. Economic analysis indicates cost-effectiveness, with initial investments offset by reduced labor and waste. Future enhancements may include multi-produce sorting, hyperspectral imaging, and integration with harvesting and logistics systems.

6. CONCLUSION

This study showcases AI's potential to transform agriculture via a smart tomato segregation system. Its high accuracy and efficiency establish a new standard for automated sorting, offering scalable solutions for productivity and quality enhancement. The findings highlight technology's role in advancing sustainable farming practices.

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