
AI-Driven Parcel Sorting System Using QR Code Recognition and PLC Control

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Abstract.

The increase in parcel traffic caused by e-commerce and courier services has created a need for quicker and more reliable sorting methods. In many small and medium facilities, parcel sorting is still performed manually, which can lead to delays and routing mistakes. This paper presents a parcel sorting setup that uses QR code recognition with PLC-based control. Parcels move on a conveyor belt, and a webcam captures QR labels during movement. OpenCV is used to read the QR data, which is then sent through an Arduino Mega 2560 to a T-950 PLC. According to the decoded destination, the PLC activates pneumatic cylinders that push parcels into separate bins. Trials were carried out using 50 parcels for three destinations. The system achieved an overall sorting accuracy of 98% with an average response time below 200 ms. The developed setup can be useful in courier offices, warehouses, and training laboratories.

Keywords. Parcel Sorting; QR Code Recognition; PLC Control; OpenCV; Pneumatic Automation

1. INTRODUCTION

The logistics sector in India is gradually moving toward automation because of the growing number of e-commerce deliveries. In many smaller warehouses, parcel sorting is still done manually, which can be slow and may lead to routing mistakes. Manual handling also becomes difficult when parcel volume increases during busy periods. These issues create a need for simple and affordable automation systems. To address this problem, a low-cost parcel sorting system was developed using computer vision and PLC control. A standard HD webcam captures QR labels, while Python with OpenCV reads the destination details in real time [1]. An Arduino Mega 2560 is used as a communication link between the computer and the T-950 PLC. Based on the decoded destination, the PLC operates pneumatic actuators to direct parcels into separate bins. This setup provides a practical and economical alternative to expensive commercial sorting systems [3], [4]. It can be useful for courier offices, warehouse laboratories, and small to medium logistics facilities.

2. RELATED WORK

Recent studies indicate that computer vision is playing an important role in logistics and warehouse automation. Vision-based systems are widely used for package recognition,

inspection, tracking, and sorting, helping industries reduce manual effort and improve operational efficiency [1], [6].

Image processing techniques using cameras and OpenCV have also been applied for parcel identification, barcode reading, and QR label detection in logistics environments. These methods are suitable for real-time applications because they are cost-effective, flexible, and easier to implement than complex industrial vision systems [1]. PLC-based conveyor systems are commonly used in industries for automatic material handling and sorting because of their reliability, fast response, and simple control structure [3]. Pneumatic actuator systems controlled through PLCs are also widely used to divert products into separate bins or lanes in automated processes [4]. Recent work has additionally focused on parcel measurement, intelligent package recognition, and QR-based data registration to improve warehouse tracking and sorting performance [5], [7], [8]. Compared with earlier approaches, the present work combines QR code recognition using OpenCV, PLC control, and pneumatic sorting in one compact and low-cost setup suitable for small and medium logistics applications.

3. METHOD, EXPERIMENTS AND RESULTS

The developed system consists of a conveyor belt, webcam, personal computer, Arduino Mega 2560, relay module, T-950 PLC, solenoid valves, pneumatic cylinders, and sorting bins.

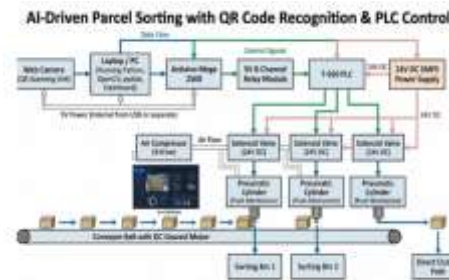


Figure 3.1. AI-Driven Parcel Sorting System Architecture (Author Developed)



Figure 3.2. Pneumatic Cylinder-Based Sorting Mechanism



Figure 3.3. T-950 PLC Controller

System performance was evaluated across 50 test parcels with QR codes for three destinations: Pune, Baramati, and Indapur. Table 2 summarizes the results, and Figure 6 shows the accuracy comparison.

During physical trials conducted at the VP Center of Excellence in Digital Manufacturing & Robotics, the system successfully identified and sorted all parcels destined for Pune and Indapur. One sorting error occurred in the Baramati batch because the QR label was partially obscured by the parcel packaging, preventing clear image capture by the webcam. The response time remained below 200 ms between QR detection and activation of the T-950 PLC-controlled pneumatic arm.

Table 2. Performance Evaluation of Parcel Sorting System

Destination	Total Parcels	Correctly Sorted	Accuracy (%)
Pune	20	20	100
Baramati	15	14	93.3
Indapur	15	15	100
Overall	50	49	98%



Figure 3.4. Experimental Setup



Figure 5. Parcel Sorting Dashboard

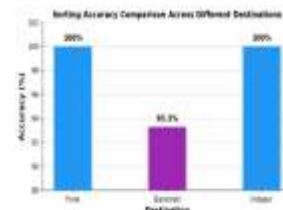


Figure 6. Accuracy Chart

4. DISCUSSIONS

During testing, the system operated reliably and maintained accurate sorting performance. All parcels for Pune and Indapur were sorted correctly, while one parcel in the Baramati batch was misrouted because the QR label was partially hidden during scanning. The average response time from detection to actuation remained below 200 ms, showing that the setup is suitable for small and medium parcel handling applications. Compared with manual sorting, the developed system reduces labor effort, improves consistency, and increases processing speed.

5. CONCLUSIONS

Motivation: This work was driven by the need to reduce the inefficiencies and high error rates associated with manual parcel sorting in small-to-medium logistics hubs in India.

Method Used: The system successfully integrated OpenCV-based vision processing with industrial T-950 PLC hardware, utilizing an Arduino Mega 2560 as a high-speed communication gateway to control pneumatic sorting actuators.

Key Findings: Experimental trials at the VP Center of Excellence demonstrated a high sorting accuracy of 98% for destinations like Pune and Indapur, while maintaining an industrial-grade response time of less than 200 ms.

Limitations and Future Work: The current system's reliance on ambient lighting can occasionally hinder QR decoding. Future research will focus on integrating Convolutional Neural Networks (CNNs) for damaged label recovery and implementing IoT-based remote monitoring for real-time warehouse management.

6. REFERENCES

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