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Smart IoT-Enabled Parcel Sorting System Using ESP32 with Color and RFID Detection

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Abstract

This paper presents an automated parcel sorting system using ESP32, RFID identification, dual IR sensing, and TCS3200 color detection to categorize parcels accurately. A servo-based diverter sorts items into bins, while LEDs and a buzzer provide real-time feedback. The system integrates IoT monitoring through Arduino IoT Cloud, displaying parcel counts, detected colors, mismatch alerts, and system messages. The proposed solution aims to improve sorting accuracy, reduce manual labor, and enhance operational efficiency in logistics and warehouse environments.

Keywords: *ESP32, RFID, TCS3200, IoT, Color Sorting, Parcel Automation, Arduino IoT Cloud, Servo Motor, IR Sensor.*

I. INTRODUCTION

Modern logistics and warehouse industries demand fast, accurate, and automated parcel sorting. Manual sorting is slow, inconsistent, and often leads to errors. Technological advancements such as IoT, RFID, and intelligent sensors enable efficient automation.

This paper implements a smart IoT-enabled parcel sorting system using ESP32. The system uses RFID tags attached to parcels to determine the expected category, while a TCS3200 sensor detects the actual color. Dual IR sensors control the conveyor: one for detecting parcel placement and starting the conveyor, and the second for stopping it under the color sensor. A servo motor diverts parcels into appropriate bins based on logic, with buzzer and LEDs indicating correct or incorrect sorting. IoT Cloud updates provide real-time data monitoring.

II. SYSTEM ARCHITECTURE

The Smart IoT-Enabled Parcel Sorting System follows a structured methodology in which the ESP32 microcontroller coordinates parcel identification, validation, and sorting. The system block diagram is shown in Fig. 1.

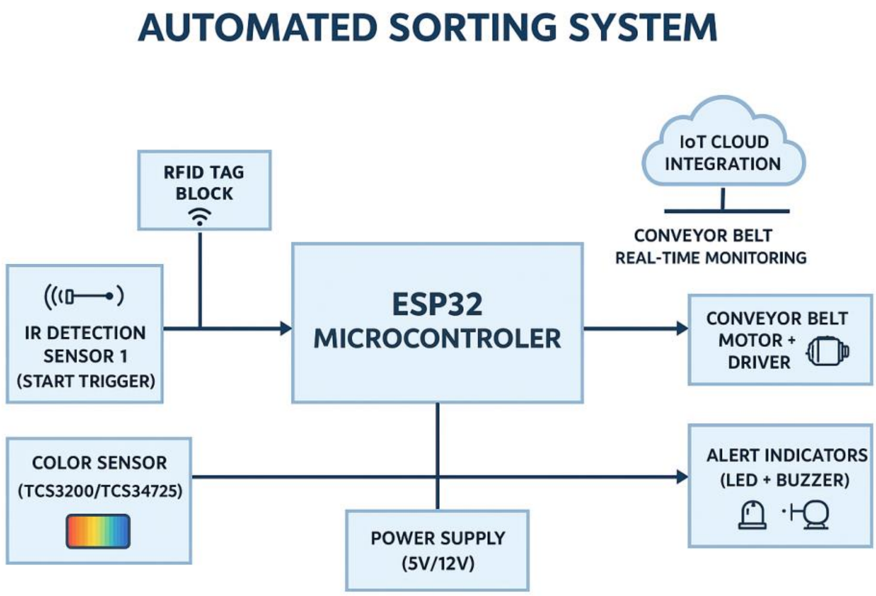

Fig. 1: System Block Diagram

The system begins by powering on the ESP32 and initializing all connected components such as the IR sensors, TCS3200 color sensor, conveyor motor, servo motor, LEDs, buzzer, and RFID tag blocks. When a parcel is placed on the conveyor belt, the IR sensor detects it and activates the conveyor motor through the L298N driver. As the parcel moves forward, it reaches the color detection area where the TCS3200 sensor reads the RGB values and sends them to the ESP32. The microcontroller processes these values and identifies whether the parcel is Red, Green, Blue, or Unknown.

Once the color is identified, the system checks whether the detected color matches the expected color for the current RFID tag block (Tag 1 for Red, Tag 2 for Green, Tag 3 for Blue). If the color does not match, the buzzer activates and the red LED glows to indicate an error. If the color is correct, the green LED glows to confirm successful detection. Based on the final color decision, the ESP32 commands the SG90 servo motor to rotate toward the correct bin. After sorting, the ESP32 updates real-time data to the Arduino IoT Cloud.

III. WORKING MECHANISM AND FLOWCHART

The system flowchart is illustrated in Fig. 8. The process begins by scanning the RFID tag, which provides the expected color for the parcel. The ESP32 stores this expected color and the system waits until IR Sensor #1 detects a parcel. Once activated, the conveyor motor starts and moves the parcel toward the color detection point.

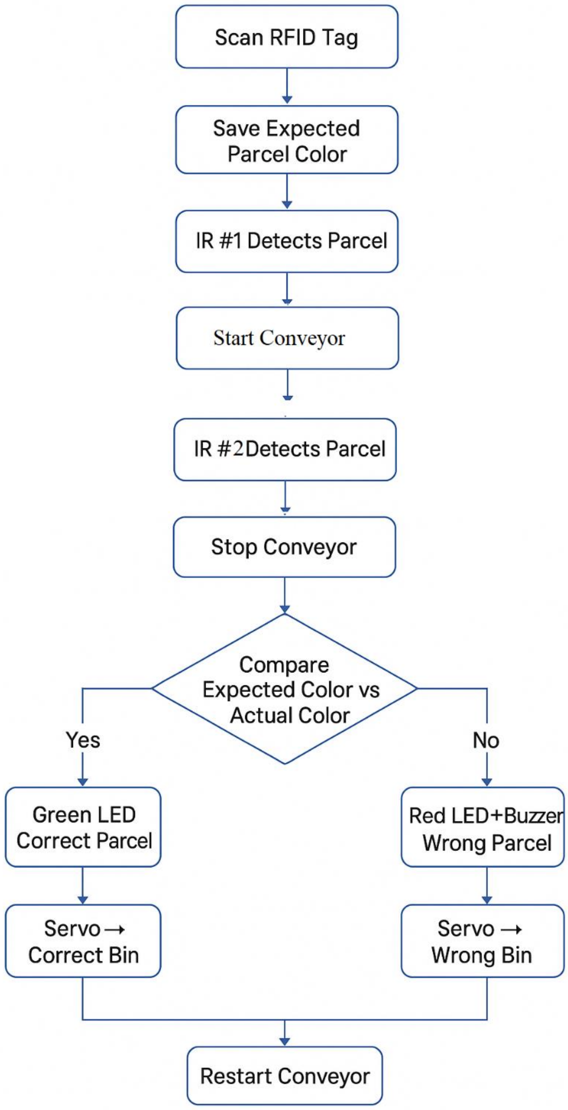

Fig. 8: System Flowchart

When the parcel reaches IR Sensor #2, the sensor activates and signals the system to temporarily stop the conveyor. The TCS3200 color sensor then reads the actual color. The ESP32 compares the detected color with the expected color from the RFID scan. If they match, the green LED activates and the servo routes the parcel to the correct bin. If they mismatch, the red LED and buzzer activate while the parcel is sorted based on its actual detected color. If the color is unrecognized, it is classified as Unknown and directed to a separate bin. After each sorting action, the servo resets to neutral and the system loops back for the next parcel.

IV. CIRCUIT DIAGRAM

The circuit diagram of the proposed system is shown in Fig. 9. The ESP32 (38-pin) microcontroller serves as the central processing unit, interfaced with multiple peripherals including RFID modules, IR sensors, the TCS3200 color sensor, servo motor, buzzer, LEDs, and a DC motor for conveyor operation.

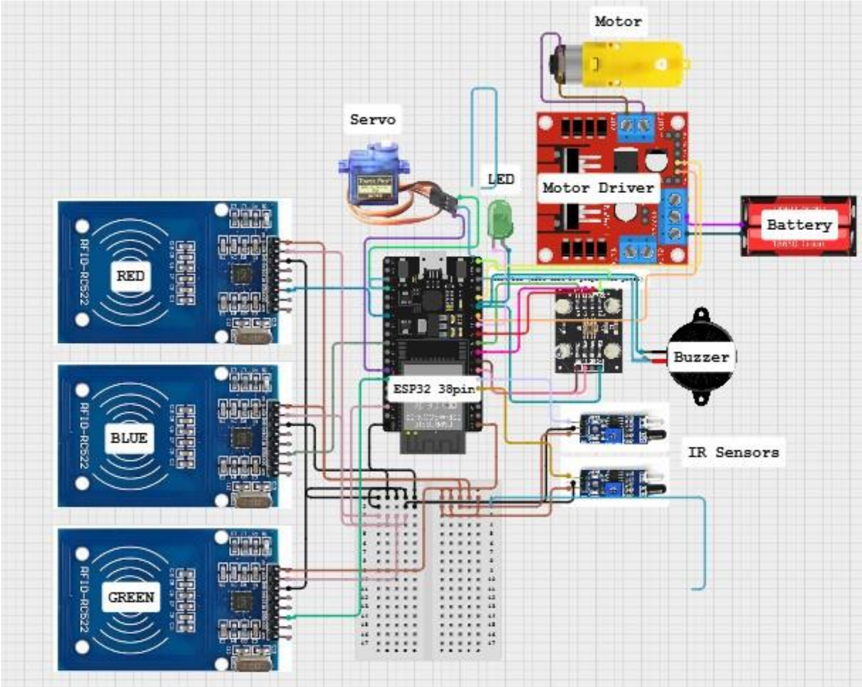

Fig. 9: System Circuit Diagram

The RFID modules communicate with the ESP32 to provide parcel identification. Two IR sensors are placed along the conveyor path for parcel detection and positioning. The TCS3200 sensor outputs RGB frequency values to the ESP32 for color classification. The servo motor is connected to the ESP32 for bin-direction control. LED and buzzer circuits provide visual and auditory feedback respectively. The conveyor DC motor is controlled via the L298N motor driver module.

V. RESULTS

The system was tested with multiple parcels of different colors to evaluate its performance. The RFID module successfully read the expected color information, and the IR sensors accurately detected the presence and position of the parcels on the conveyor. The conveyor motor operated smoothly, transporting items to the detection point without delay.

Fig. 10: Fabricated System Model

The TCS3200 color sensor effectively identified the color of each parcel, and the ESP32 accurately compared it with the expected RFID data. When the detected color matched the expected color, the system correctly classified the parcel and directed it to the appropriate bin using the servo motor. In cases of mismatch, the system activated the buzzer and red LED, alerting the user while still sorting the parcel based on its actual color.

Fig. 11: System in Operation — Sorting Results

The system also successfully handled unknown colors by directing them to a separate bin. The IoT dashboard displayed real-time counts of each category, confirming reliable operation. Table I presents the observation summary.

IoT Dashboard Interface and Monitoring

The IoT dashboard provides a real-time visual interface to monitor the performance of the sorting system. As shown in Fig. 12, it displays the count of sorted objects categorized as Blue, Green, Red, and Unknown, continuously updated as the system processes each parcel.

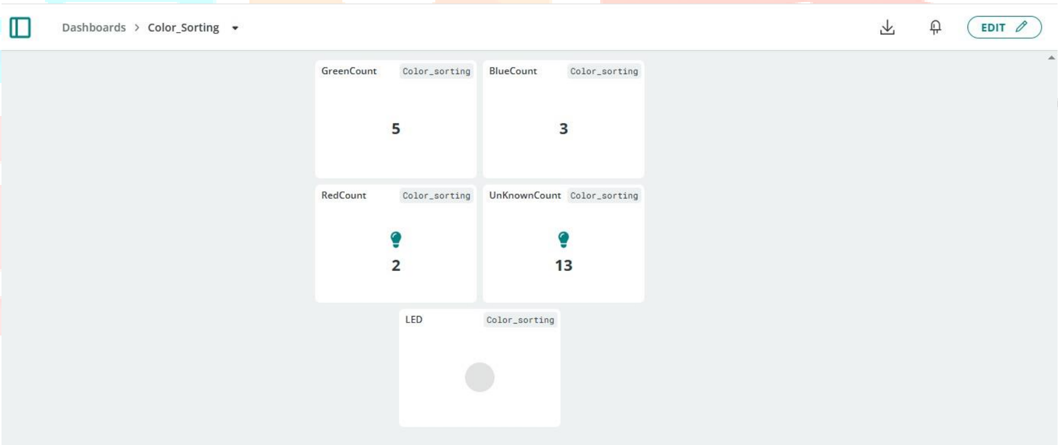

Fig. 12: Arduino IoT Cloud Dashboard

The interface is designed to be simple and user-friendly, allowing users to easily track system performance without requiring direct interaction with the hardware. The LED indicator on the dashboard reflects the system status visually. This remote monitoring capability improves usability and enables efficient supervision of the sorting process from any smartphone or browser.

VI. CONCLUSION

The main objective of developing an automated color sorting system using ESP32 was successfully achieved. The system was able to identify parcels using RFID technology and detect their actual color using the TCS3200 sensor. The integration of sensors and microcontroller ensured accurate data processing and real-time decision-making.

The sorting process was automated through the use of a conveyor system and servo motor, efficiently sorting parcels into respective bins based on color, while also identifying mismatches and unknown items. LED indicators and a buzzer provided immediate feedback, improving system reliability.

Real-time monitoring was achieved through the IoT dashboard, which displayed the count of sorted items in each category, allowing users to track system performance remotely. The project successfully combined automation, sensing, and IoT technology to create an efficient and intelligent parcel sorting system with applications in logistics, warehouse management, and industrial automation.

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