IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 12, April 2026
Impact Factor: 8.2

Automated Color-Based Block Segregation System Using Conveyor and IoT Sensors

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Abstract: *Efficient sorting and segregation of objects based on their color is essential in various industrial automation processes, recycling facilities, and manufacturing units. Traditional manual sorting methods are time-consuming, labor-intensive, and prone to errors. This paper presents an automated color-based block segregation system utilizing an ESP32 microcontroller, TCS230/TCS3200 color sensor, conveyor belt mechanism, and servo motors. The system identifies colored blocks in real-time as they pass through the conveyor and diverts them into designated collection bins based on their color. The proposed solution employs Internet of Things (IoT) integration for remote monitoring and system analytics. This low-cost, energy-efficient system demonstrates high accuracy in color detection and segregation, making it suitable for small-scale industries, educational institutions, and recycling centers.*

Keywords: IoT, Color Sensor, ESP32, Conveyor System, Automated Segregation, TCS230, Servo Motor

I. INTRODUCTION

Automation in industrial processes has become a necessity for improving efficiency, reducing operational costs, and minimizing human error. Sorting and segregation of objects based on physical properties such as color, shape, or size is a fundamental requirement in manufacturing, packaging, recycling, and quality control operations. Manual sorting requires significant human resources and is susceptible to fatigue-related errors, particularly in high-volume production environments.

Color-based sorting systems have widespread applications in agriculture for fruit grading, in recycling facilities for plastic waste segregation, in pharmaceutical industries for pill sorting, and in manufacturing for quality inspection. The integration of sensors, microcontrollers, and actuators enables the development of intelligent systems capable of performing these tasks autonomously with high precision and speed.

The objective of this project is to design and implement an automated conveyor-based color block segregation system using cost-effective components. The system utilizes the ESP32 development board as the central processing unit, the TCS230/TCS3200 color sensor for accurate color detection, servo motors for precise sorting mechanism actuation, and a DC motor-driven conveyor belt for continuous material flow. The system is capable of identifying three primary colors (Red, Green, and Blue) and directing blocks into respective collection bins through a servo-controlled diverting mechanism.

II. LITERATURE REVIEW

Industrial automation has witnessed significant advancements with the integration of embedded systems and sensor technologies. Automated sorting mechanisms have evolved from simple mechanical systems to sophisticated computer vision and sensor-based solutions. Research in this domain focuses on improving accuracy, speed, and cost-effectiveness of sorting systems.

Several studies have explored the application of color sensors in automated sorting. The TCS3200 color sensor has been widely adopted due to its ability to convert light intensity into frequency output, providing high sensitivity across the

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visible spectrum. Previous implementations have demonstrated its effectiveness in fruit sorting, recycling material separation, and quality control processes.

The ESP32 microcontroller has emerged as a preferred choice for IoT-enabled automation projects due to its dual-core processor, built-in Wi-Fi and Bluetooth capabilities, and extensive GPIO pins. Its processing power allows for real-time sensor data processing and wireless communication, making it suitable for smart manufacturing applications.

Conveyor belt systems integrated with servo-controlled diverters have proven to be efficient mechanical solutions for object sorting. The combination of continuous material flow with precise actuation enables high-throughput sorting with minimal mechanical complexity. This approach reduces the need for complex robotic manipulators while maintaining sorting accuracy and speed.

III. PROPOSED METHODOLOGY

The proposed system comprises hardware and software components working in coordination to achieve automated color-based block segregation. The methodology follows a systematic approach from block detection to final segregation.

A. System Architecture

The system architecture consists of the following major subsystems: material handling subsystem (conveyor belt and rollers), sensing subsystem (TCS230 color sensor), processing subsystem (ESP32 development board), actuation subsystem (servo motors and DC motor), and power supply subsystem. These components are integrated to form a closed-loop control system for automated segregation.

B. Hardware Components

The following table presents the key hardware components utilized in the system along with their specific functions:

TABLE I: SYSTEM COMPONENT

Sr. No.	Component Name	Function
1	ESP32 Development Board	Central processing unit with Wi-Fi capability for sensor data processing and motor control
2	TCS230/TCS3200 Color Sensor	Detects RGB color values of blocks passing through the sensing zone
3	SG90 Servo Motors (2 units)	Actuate diverter gates to direct blocks into designated collection bins
4	DC Motor	Drives the conveyor belt system for continuous material flow
5	Conveyor Belt Assembly	Black rubber belt with rollers and axles for block transportation
6	MDF Frame Structure	Laser-cut wooden frame providing structural support for the entire system
7	USB Power Bank	Provides portable power supply to ESP32 and associated electronics
8	Collection Bins (3 units)	Color-coded containers (Red, Green, Blue) for segregated block storage

III. RESULTS AND DISCUSSION

The prototype system was tested under controlled lighting conditions with blocks of uniform size and distinct primary colors. Testing involved processing 100 blocks (33 red, 34 green, 33 blue) through multiple trial runs to evaluate accuracy, consistency, and mechanical reliability.

The system achieved a color detection accuracy of 96.5 percent under standard fluorescent lighting with minimal ambient light variation. Misclassifications primarily occurred at color boundaries where blocks exhibited mixed color

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characteristics or surface reflections. The conveyor speed was optimized to 0.15 meters per second to balance throughput and detection reliability.

Servo motor actuation demonstrated consistent timing accuracy with a standard deviation of 15 milliseconds across repeated trials. The mechanical diverter mechanism successfully redirected 98 percent of correctly identified blocks into their designated bins, with failures attributed to timing synchronization issues or blocks positioned at the edge of the conveyor belt.

System limitations were identified in several areas. Performance degradation occurred under varying lighting conditions, requiring recalibration of color thresholds for different ambient light intensities. The current implementation supports only three primary colors and struggles with blocks having textured surfaces, gradients, or semi-transparent materials. Additionally, the single-sensor design creates a processing bottleneck at higher conveyor speeds.

Future enhancements could incorporate machine learning algorithms for improved color classification under variable conditions, multiple sensors for parallel processing to increase throughput, and integration with computer vision systems for shape-based sorting capabilities. The addition of feedback sensors at collection bins would enable closed-loop verification of successful segregation and automatic error detection.

IV. CONCLUSION

The version of this template is V2. Most of the formatting instructions in this document have been compiled by Causal Productions from the IEEE LaTeX style files. Causal Productions offers both A4 templates and US Letter templates for LaTeX and Microsoft Word. The LaTeX templates depend on the official IEEEtran.cls and IEEEtran.bst files, whereas the Microsoft Word templates are self-contained. This paper presented the design and implementation of an automated color-based block segregation system utilizing IoT-enabled sensors and microcontroller technology. The system successfully demonstrates the feasibility of low-cost automation for sorting applications in educational and small-scale industrial environments. The integration of the TCS230 color sensor with the ESP32 microcontroller provides an effective solution for real-time color detection and classification. The mechanical design incorporating conveyor belt transport and servo-actuated diverters offers a simple yet reliable approach to physical segregation. The prototype achieved satisfactory accuracy and throughput for its intended application scope while maintaining cost-effectiveness and ease of implementation. Future work will focus on enhancing robustness under variable environmental conditions and expanding the system's capabilities to handle a broader range of object characteristics.

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