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A Conveyor belt – based Sorting Industrial Robotics

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KEYWORDS

Arduino, Color Sorting System, Conveyor Belt Automation, TCS3200 Color Sensor, IR Proximity Sensor, Robotic Arm, Servo Motor, Industrial Automation, Embedded Systems, Pick-and-Place Mechanism.

ABSTRACT

This project presents the design and implementation of an Arduino-based conveyor belt color sorting robotic system for industrial automation applications. The system is developed to automatically detect, classify, and sort objects based on their colour with minimal human intervention. A TCS3200 color sensor is used to identify the RGB values of objects moving on a conveyor belt driven by a DC motor. An IR proximity sensor detects the presence and position of objects at the sensing point to ensure synchronized operation.

The Arduino microcontroller acts as the central control unit, processing sensor inputs and generating control signals for actuators. Based on the detected color, servo motors mounted on a robotic arm perform precise pick-and-place operations, placing objects into designated bins. The system also incorporates safety features such as an emergency stop push button and buzzer alert mechanism to enhance operational reliability and ensure user safety. Experimental evaluation demonstrates high sorting accuracy under controlled lighting conditions, consistent conveyor movement, and reliable robotic arm actuation. The proposed system offers a low-cost, scalable, and flexible automation solution suitable for small- and medium-scale industries, educational laboratories, and research environments. By reducing manual labor, improving accuracy, and enhancing productivity, the system contributes effectively to modern industrial automation.

INTRODUCTION

Automation has become an essential component of modern industrial systems to improve productivity, efficiency, and safety while minimizing human intervention. Industries such as manufacturing, packaging, food processing, and logistics require continuous monitoring and classification of products based on various parameters including size, weight, shape, and color. Among these parameters, color-based sorting is widely used in industrial applications such as food grading, recycling, pharmaceutical packaging, and product quality inspection. Traditional manual sorting methods are labor-intensive, time-consuming, and prone to human error, which often leads to inconsistent product quality and reduced production efficiency. Therefore, industries are increasingly adopting automated systems that integrate sensors, microcontrollers, and actuators to perform sorting operations efficiently.

Recent advancements in embedded systems and microcontroller platforms have enabled the development of cost-effective automation systems for industrial environments. Microcontrollers provide real-time processing capabilities and allow seamless integration of sensors and actuators for automated decision-making. The Arduino platform has become one of the most widely used development boards for embedded system applications due to its simplicity, flexibility, and open-source ecosystem. It enables the development of intelligent control systems capable of performing real-time sensing and actuation tasks in industrial automation systems [8], [9], [10].

Several research studies have focused on the development of automated color sorting systems using Arduino and color sensors. Dinica et al. presented an Arduino-based color sorting system capable of detecting and separating objects based on their color using sensors and servo motors, demonstrating efficient sorting performance for small-scale industrial applications [1]. Similarly, Rahman et al. developed an advanced conveyor belt color sorting system utilizing the TCS3200 color sensor and Arduino microcontroller, which accurately identifies RGB values and classifies objects accordingly [2]. These systems highlight the effectiveness of sensor-based color detection for industrial automation tasks.

In addition to sensor-based systems, researchers have also explored image processing and computer vision approaches for conveyor belt sorting systems. Sanwar and Ahmed proposed a conveyor belt sorting system using image processing techniques to classify objects based on visual characteristics [3]. Hernández-Molina et al. introduced an embedded vision-based conveyor inspection system designed to improve industrial inspection and sorting processes through automated visual analysis [4]. Although vision-based approaches provide high accuracy and flexibility, they often require complex hardware, high computational resources, and advanced image processing algorithms.

Robotic manipulation plays a significant role in automated sorting systems. Robotic arms equipped with servo motors enable precise pick-and-place operations for sorting objects into different bins or processing lines. Jadhav et al. developed a color sorting robotic arm using Arduino that demonstrates efficient object detection and placement using servo motor control [5]. Furthermore, modern smart conveyor systems incorporating IoT and computer vision technologies have been proposed to enhance industrial automation and monitoring capabilities [6].

The TCS3200 color sensor is widely used for color recognition in embedded system applications. It converts the intensity of detected light into frequency signals corresponding to red, green, and blue components, allowing accurate identification of object colors under controlled lighting conditions [7]. Combined with a microcontroller platform such as Arduino Uno, the sensor enables efficient detection and classification of objects moving on a conveyor belt. In addition, concepts from control systems and robotics ensure stable system operation and precise actuation of robotic manipulators in industrial automation environments [11], [12], [13].

Motivated by these developments, this work presents the design and implementation of an Arduino-based conveyor belt color sorting robotic system for industrial automation applications. The proposed system integrates a conveyor belt driven by a DC motor, a TCS3200 color sensor for color detection, and an IR proximity sensor to detect the presence of objects. The Arduino microcontroller processes sensor data and determines the appropriate sorting action. Based on the detected color, a servo-motor-driven robotic arm performs pick-and-place operations to place objects into designated bins. Additional safety features such as an emergency stop push button and buzzer alert system are incorporated to enhance operational safety and reliability.

The proposed system provides a low-cost, scalable, and flexible automation solution suitable for small- and medium-scale industries, research laboratories, and educational environments. By integrating embedded systems, sensing technologies, and robotic manipulation, the system demonstrates an effective approach for implementing intelligent industrial automation. The overall architecture and working principle of the proposed conveyor belt color sorting robotic system are illustrated in Fig. 1.

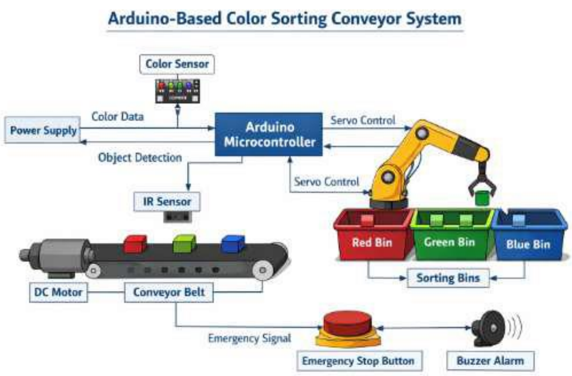

Figure 1 Conceptual architecture of the proposed system with IoT monitoring.

RELATED WORK

Automation and intelligent sorting systems have been widely studied in recent years due to their importance in modern industrial environments. Various approaches have been proposed that utilize sensors, embedded systems, robotics, and computer vision techniques to perform automatic sorting and classification of objects. This section reviews previous research related to conveyor belt sorting systems, color detection techniques, and robotic manipulation used in industrial automation.

Dinica et al. presented an Arduino-based color sorting system designed to automatically classify objects based on their color using a color sensor and servo motors. The system demonstrated reliable color detection and sorting accuracy, making it suitable for small-scale industrial automation and educational laboratory applications. The authors highlighted that microcontroller-based systems provide a low-cost and flexible solution for implementing automated sorting mechanisms [1].

Rahman et al. developed an advanced color sorting conveyor system using an Arduino controller and TCS3200 color sensor. Their system measured RGB values from objects placed on a conveyor belt and classified them into different categories. The experimental results showed that the TCS3200 sensor can effectively detect color variations under controlled lighting conditions, enabling accurate sorting operations in industrial environments [2].

Sanwar and Ahmed proposed a conveyor belt sorting system using image processing techniques. Their approach utilized digital image processing algorithms to identify object characteristics such as color and shape. The system was capable of detecting multiple objects simultaneously and classifying them accordingly. However, image processing-based systems generally require higher computational power and more complex hardware setups compared to simple sensor-based methods [3].

Hernández-Molina et al. introduced an embedded vision-based conveyor inspection system designed for industrial applications. The system integrates computer vision techniques with embedded hardware platforms to detect objects and perform inspection tasks on conveyor belts. The proposed approach improves inspection accuracy and automation capabilities but increases system complexity and cost due to the requirement of cameras and advanced processing units [4].

Jadhav et al. designed a color sorting robotic arm using Arduino that performs automated pick-and-place operations. The system uses a color sensor to detect the color of objects and servo motors to move the robotic arm and place objects into designated bins. The study demonstrated that robotic arms can significantly enhance the efficiency and precision of automated sorting systems in industrial environments [5].

Shreerang and Ajinkya proposed a smart conveyor belt sorting system based on computer vision and IoT technologies. Their system integrates real-time image processing with IoT connectivity for remote monitoring and control of industrial sorting operations. The study showed that IoT-enabled systems can improve monitoring and management of automated production lines, although such systems often require higher infrastructure costs and network resources [6].

The TCS3200 color sensor, widely used in many embedded applications, converts incident light intensity into frequency signals corresponding to red, green, and blue components. According to the technical specifications provided by Texas Instruments, the sensor offers high sensitivity and programmable output frequency scaling, making it suitable for color detection applications in automation systems [7].

Microcontroller platforms such as Arduino Uno provide an efficient interface between sensors and actuators in embedded automation systems. Arduino boards are widely used due to their ease of programming, open-source architecture, and compatibility with various hardware modules [8]. Programming environments and development tools for Arduino allow rapid prototyping and implementation of control algorithms for industrial automation tasks [9], [10].

In addition, the design of automated robotic systems relies on principles from control systems and robotics engineering. Control theory ensures stable operation and precise motion control of actuators in automation systems [11]. Robotic manipulation techniques enable accurate positioning and pick-and-place operations in industrial robots [12]. Comprehensive studies on robotic systems and automation architectures highlight the importance of integrating sensors, controllers, and actuators to develop efficient industrial automation systems [13]. Furthermore, electronic circuit design and microprocessor-based control systems provide the foundation for implementing reliable embedded automation solutions [14], [15].

From the literature survey, it can be observed that several approaches have been developed for automated sorting systems using sensors, image processing, robotics, and IoT technologies. However, many existing systems either involve high computational complexity or expensive hardware components. Therefore, there is a need for a cost-effective and reliable sorting system that combines sensor-based color detection with robotic manipulation. The proposed Arduino-based conveyor belt color sorting robotic system aims to address this need by integrating a TCS3200 color sensor, IR proximity sensor, and servo-driven robotic arm to perform efficient and automated sorting operations.

PROPOSED SYSTEM

The proposed system presents an Arduino-based conveyor belt color sorting robotic system designed to automatically detect, classify, and sort objects according to their color. The system integrates sensing, control, and actuation components to achieve efficient industrial automation with minimal human intervention. The architecture of the proposed system consists of several modules including the sensing unit, control unit, conveyor drive mechanism, robotic sorting unit, and safety module. The overall structure of the system is illustrated in Fig. 2.

The sensing unit is responsible for detecting the presence of objects and identifying their color. An IR proximity sensor is used to detect the arrival of an object at the sensing position on the conveyor belt. Once an object is detected, the TCS3200 color sensor measures the RGB color values of the object by converting the intensity of light into corresponding frequency signals. These signals are then transmitted to the Arduino microcontroller for further processing.

The control unit consists of an Arduino Uno microcontroller, which acts as the central processing unit of the system. The microcontroller receives signals from the sensors and processes them to determine the color category of the detected object. Based on predefined threshold values for RGB components, the Arduino classifies the object into different color groups. After classification, the controller generates control signals for the actuators responsible for sorting the object.

The conveyor belt mechanism is driven by a DC motor that continuously moves objects toward the sensing station. The conveyor ensures smooth and controlled movement of items so that the sensors can accurately detect and analyze them. The speed of the conveyor belt can be adjusted depending on the processing time required for color detection and sorting.

The sorting mechanism consists of a servo-motor-driven robotic arm that performs pick-and-place operations. Once the Arduino identifies the color of the object, it sends control commands to the servo motors to move the robotic arm to the appropriate bin location. The robotic arm then picks up the object and places it into the corresponding container designated for that color category.

To improve operational safety and reliability, the system also incorporates a safety module. This module includes an emergency stop push button that immediately halts system operation in case of unexpected faults or hazards. Additionally, a buzzer alert system provides an audible warning signal when the emergency stop is activated or when a system error occurs.

The overall working process of the proposed system can be summarized as follows. Objects placed on the conveyor belt move toward the sensing region. The IR sensor detects the presence of an object and triggers the color sensing process. The TCS3200 sensor captures the RGB values and sends the data to the Arduino controller. The controller processes the data and identifies the color category of the object. Based on this decision, the robotic arm moves the object to the designated bin. The conveyor belt then continues to transport the next object for sorting.

The proposed system offers several advantages including low cost, easy implementation, scalability, and reliable sorting performance. By integrating embedded systems, sensors, and robotic manipulation, the system provides an effective automation solution suitable for small and medium-scale industries as well as educational and research environments.

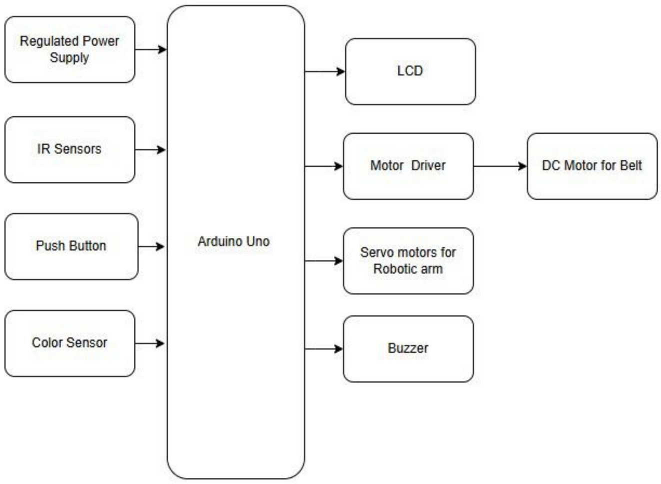

Figure 2 Block diagram of the proposed system with feedback and IoT.

METHODOLOGY

The methodology of the proposed Arduino-based conveyor belt color sorting robotic system describes the operational workflow used to detect, classify, and sort objects automatically. The system integrates sensing, data processing, decision making, and actuation mechanisms to achieve efficient sorting operations. The methodology mainly consists of four stages: object detection, color sensing, color classification, and robotic sorting.

Initially, objects are placed on the conveyor belt which is driven by a DC motor. As the conveyor moves, objects reach the sensing region where an IR proximity sensor detects their presence. The IR sensor generates a digital signal indicating that an object has arrived at the sensing position. Once the object is detected, the Arduino microcontroller activates the TCS3200 color sensor to measure the color of the object.

The TCS3200 color sensor detects the intensity of red, green, and blue components of the object surface. The sensor contains photodiodes with color filters that convert the incident light intensity into a corresponding frequency output. The frequency of the output signal is proportional to the intensity of the detected color component. The Arduino microcontroller measures these frequency values to determine the RGB characteristics of the object.

After obtaining the RGB values, the microcontroller performs color classification by comparing the measured values with predefined threshold ranges for each color category. Depending on the detected color, the controller determines the appropriate sorting location. The decision-making process is implemented through conditional logic in the Arduino program.

Once the object color is identified, the system activates the servo motors controlling the robotic arm. The robotic arm performs a pick-and-place operation by moving to the object location, grasping the object, and placing it into the corresponding bin assigned for that specific color. After the sorting operation is completed, the conveyor belt continues to transport the next object for processing.

To enhance operational safety, an emergency stop push button is incorporated into the system. When activated, the button immediately stops the conveyor motor and disables the robotic arm to prevent accidents. Additionally, a buzzer alert mechanism is used to provide audible warnings when the emergency stop is triggered or when abnormal conditions occur.

The overall methodology ensures synchronized coordination between sensing, processing, and actuation modules, enabling accurate and reliable color-based sorting operations.

RESULTS AND DISCUSSIONS

The experimental results of the proposed Arduino-based conveyor belt color sorting robotic system demonstrate reliable and efficient performance under controlled laboratory conditions. The TCS3200 color sensor accurately detected the RGB values of objects, and the Arduino microcontroller successfully classified and sorted them into their respective bins. The synchronization between the IR sensor, conveyor belt, and robotic arm ensured smooth and continuous operation without overlap or delay. The servo motor-based pick-and-place mechanism performed precise object handling with minimal error. Overall, the system achieved high sorting accuracy and consistent performance, validating its effectiveness as a cost-efficient automation solution for small- and medium-scale industrial applications.

Experimental Results

The proposed Arduino-based conveyor belt color sorting robotic system was designed, implemented, and tested under controlled laboratory conditions. The system was evaluated using objects of different colors (red, green, and blue) placed randomly on the conveyor belt. The color sensor successfully detected the RGB values of each object, and the Arduino microcontroller processed these values in real time to classify the objects. The DC motor-driven conveyor belt provided smooth and continuous motion, allowing objects to pass steadily through the sensing zone. The IR sensor accurately detected object presence and ensured proper synchronization between the conveyor belt and robotic arm operation. Upon successful color identification, the servo motors actuated the robotic arm to pick and place each object into its corresponding color-coded bin.

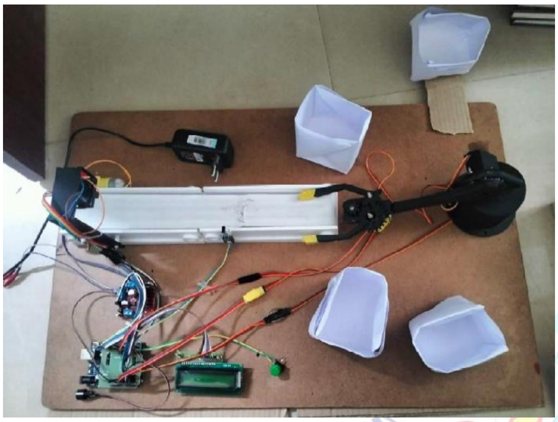

Figure 3 Experimental Setup of Conveyor Belt Color Sorting System

Sorting Accuracy Analysis

During experimentation, multiple trials were conducted to evaluate the sorting accuracy of the system. The color sensor demonstrated consistent performance when calibrated under uniform lighting conditions. The system correctly identified and sorted most objects into their designated bins with minimal delay. Minor inaccuracies were observed when objects had reflective surfaces or when ambient lighting conditions varied significantly. However, these errors were reduced through sensor calibration and fixed sensor-to-object distance. Overall, the system achieved high sorting accuracy, demonstrating its suitability for small-scale industrial automation.

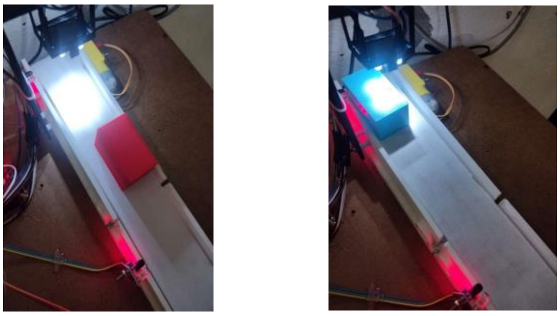

Figure 4 Sorted Objects in Red, Green, and Blue Bins

Conveyor and Robotic Arm Performance

The conveyor belt maintained a constant speed controlled through PWM signals from the Arduino. This ensured that objects reached the sensing area at predictable intervals, allowing reliable color detection. The robotic arm's servo motors provided precise angular movement, enabling accurate pick-and-place operations without object slippage.

The coordination between conveyor motion and robotic arm actuation was critical to system performance. Proper timing control ensured that the arm completed one sorting operation before the next object arrived at the sorting point.

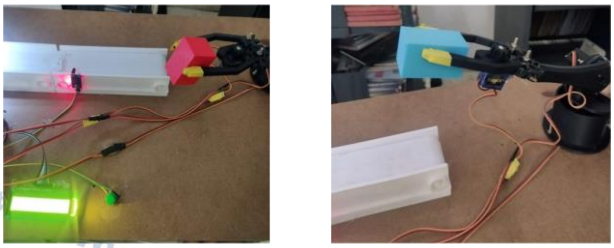

Figure 5 Robotic Arm Pick-and-Place Operation

Safety and Reliability Evaluation

The emergency stop push button and buzzer alert mechanism were tested to verify system safety. When the emergency stop button was pressed, the Arduino immediately disabled the conveyor belt motor and servo motors, and the buzzer was activated to alert operators. This rapid response confirmed the effectiveness of the safety features in preventing potential damage and ensuring operator protection.

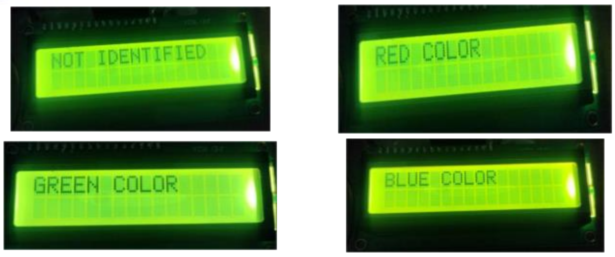

Figure 6 Emergency Stop and Buzzer Alert in Operation

The system remained in a halted state until manually reset, ensuring controlled recovery from emergency conditions.

CONCLUSION

The proposed Arduino-based conveyor belt color sorting industrial robotic system was successfully designed, implemented, and tested to automate the process of object sorting based on color. By integrating a color sensor, IR proximity sensor, conveyor belt

mechanism, and a servo-controlled robotic arm, the system achieved reliable real-time detection and accurate pick-and-place operations. The Arduino microcontroller effectively coordinated sensing, decision-making, actuation, and safety controls, ensuring smooth and continuous system operation. Experimental results demonstrated that the system provides high sorting accuracy, consistent performance, and reduced manual intervention under controlled conditions. The inclusion of safety features such as an emergency stop push button and buzzer alert significantly enhanced operator safety and system reliability. Compared to manual and semi-automated methods, the proposed system improves productivity, minimizes human error, and reduces operational costs. Overall, the project validates the feasibility of using low-cost embedded platforms for industrial automation tasks. The modular and scalable design allows future enhancements such as additional color detection, integration of machine vision, IoT-based monitoring, and adaptive control algorithms. Hence, the system is well suited for small- and medium-scale industries,
educational laboratories, and automation research applications.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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