Object Segregation System on Conveyor Belt Using Shape-Based Image Processing

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***Abstract*—This paper presents the design and implementation of an automated object segregation system for industrial applications. The system identifies, analyzes, and separates objects moving on a conveyor belt using shape-based image processing and weight detection techniques. A camera captures images of objects, and image processing algorithms are used to detect and classify objects based on their shapes such as circular, rectangular, or triangular. Simultaneously, a load cell sensor measures the weight of each object. Based on both shape and weight parameters, the system automatically segregates objects into different categories using a servo motor mechanism controlled by Arduino and ESP32-CAM. The proposed system improves accuracy, reduces manual effort, increases efficiency, and provides a cost-effective solution for industrial automation and smart manufacturing applications.**

I. INTRODUCTION

The project focuses on creating an automated object segregation system using image processing and weight measurement techniques. Unlike traditional color-based sorting systems, this system classifies objects according to their shape and weight. The ESP32-CAM module captures object images, while image processing techniques identify object shapes. A load cell sensor is used to measure the weight of objects on the conveyor belt. Based on the detected shape and weight, the system controls a servo motor to direct objects into their respective categories. This approach improves sorting accuracy and makes the system more reliable for industrial applications.

II. RELATED WORK

Several research works have been carried out in the field of automated sorting systems using different techniques. Many industries have adopted automation to improve efficiency and reduce manual errors in sorting processes.

In earlier studies, sorting systems based on shape detection have been developed using image processing techniques and microcontrollers. These systems commonly use cameras and image processing algorithms to identify the shape of objects and separate them accordingly. However, some of these systems have limitations in terms of accuracy, processing speed, and performance during continuous industrial operations.

Other research has focused on object sorting using parameters such as size, weight, and shape. These methods are effective but often require complex hardware setups and higher implementation costs. In addition, advanced image processing-based sorting systems provide high accuracy but may demand powerful computing resources and increased maintenance costs for small-scale industries.

Some automated systems also use conveyor belt mechanisms combined with robotic arms or actuators for sorting tasks. While these systems improve automation and reduce manual intervention, they can be expensive and difficult to maintain.

The proposed system in this project overcomes these limitations by using a simple and cost-effective approach based on shape detection and weight measurement using image processing techniques, ESP32-CAM, load cell sensor, and Arduino. The system identifies object shapes, measures their weight, and automatically segregates them on a conveyor belt. It provides a balance between accuracy, cost, and ease of implementation, making it suitable for small and medium-scale industrial applications.

III. SYSTEM ARCHITECTURE

The proposed system is designed using a combination of image processing techniques, sensors, microcontrollers, and actuators to achieve automatic object detection, shape identification, weight measurement, and sorting. At the core of the system is the Arduino Uno, which acts as the main controller and coordinates the entire operation. It receives input signals from various components such as the load cell, IR sensor, and ESP32-CAM module, and accordingly sends control signals to output devices including the display, relay, servo motor, and DC motor. The overall structure of the system is illustrated in Fig. 1

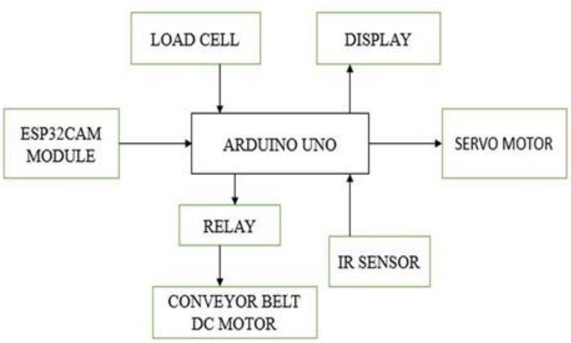


Fig.1. Block Diagram of Object Segregation System on Conveyor Belt Using Shape and Weight Detection with Image Processing

The process begins with the conveyor belt driven by a DC motor, which continuously transports objects through different stages of the system. An IR sensor is used to detect the presence of an object on the conveyor belt and sends a signal to the Arduino when the object reaches a specific position. Once detected, the conveyor belt can be temporarily stopped using a relay-controlled mechanism to ensure accurate measurement and image capture.

A load cell integrated with an HX711 amplifier is used to measure the weight of the object, and the obtained data is sent to the Arduino for analysis. Simultaneously, the ESP32-CAM module captures images of the object. These images are processed using shape detection techniques to identify the object based on its shape characteristics such as circular, rectangular, or triangular forms. The classification result is then communicated to the Arduino for further decision-making.

Based on the detected shape and measured weight, the Arduino controls a servo motor to direct the object into the appropriate bin or section. The servo motor adjusts its angle to guide the object along the correct path. Throughout the process, a display unit provides real-time information such as object shape, weight, category, and system status, ensuring easy monitoring and operation.

IV. METHODOLOGY

The proposed system follows a systematic approach for automatic detection, shape identification, weight measurement, and sorting of objects using image processing techniques and a microcontroller-based control system. Initially, when the power supply is switched on, the Arduino Uno initializes all connected components such as the load cell, IR sensor, ESP32-CAM module, relay, servo motor, conveyor motor, and display unit.

The process begins with the conveyor belt driven by a DC motor, which transports objects through different stages. When an object reaches the sensing area, the IR sensor detects its presence and sends a signal to the Arduino. The Arduino temporarily stops the conveyor belt using a relay mechanism to ensure accurate image capture and weight measurement.

The weight of the object is measured using a load cell integrated with an HX711 amplifier module. The load cell operates on the principle of strain gauges, where the applied force is proportional to the generated electrical signal. The weight can be calculated using:

$$W = m \times g$$

$$m$$

$$g$$

$$Fg = mg \approx 78.4 \text{ N}$$

m=8kgF_g=78.4Ng=9.8 m/s^2 where W is weight (in

Newton),

m is mass (in kg), and g is acceleration due to gravity (9.81 m/s²).
The electrical output of the load cell is proportional to the applied force and can be expressed as:

$$Vout \propto F$$

This analog signal is amplified and converted into digital form using the HX711 module before being processed by the Arduino.
Simultaneously, the ESP32-CAM captures an image of the object. The classification process compares the captured image with predefined features. The accuracy of classification can be represented as:

$$Accuracy = \frac{Correct\ Predictions}{Total\ Predictions} \times 100$$

Based on the detected shape and measured weight, the Arduino determines the category of the object. The servo motor is then rotated to a specific angle to direct the object into the appropriate bin or section. The angular position of the servo motor can be represented as:

$$\theta = \frac{t_{pulse}}{T} \times 180^{\circ}$$

where $\theta$is the servo angle, $tpulse$is pulse width, and $T$is the total signal period.
Finally, the sorted object is directed to its respective section, and the conveyor resumes operation for the next object. The display unit continuously shows real-time information such as detected shape, object weight, object category, and overall system status.

V. IMPLEMENTATION

The proposed object segregation system is developed using an embedded microcontroller platform to enable continuous monitoring and automated sorting of objects based on shape and weight using image processing techniques. The system integrates sensing, processing, and actuation mechanisms to ensure accurate and efficient operation.

A. Hardware Platform Design

The hardware setup consists of an Arduino Uno as the main controller along with ESP32-CAM, load cell with HX711 amplifier, IR sensor, relay module, servo motor, DC motor, conveyor belt, and display unit. The Arduino Uno controls the entire system by processing input signals and sending commands to output devices.
The conveyor belt is driven by a geared DC motor which transports objects through different stages. The IR sensor detects the presence of objects on the conveyor belt, while the load cell measures their weight. The ESP32-CAM captures images of the objects, and image processing techniques are used to identify the shape of the objects such as circular, rectangular, or triangular. The servo motor is used to sort objects into different bins based on detected shape and weight. The relay module controls the conveyor motor, and the display unit shows real-time system information.

B. Signal Processing and Data Analysis

The system continuously collects data from sensors and the camera module. When an object is detected by the IR sensor, the Arduino temporarily stops the conveyor belt for accurate processing.
The load cell measures the weight of the object, and the ESP32-CAM captures the image for shape detection. The captured image is analyzed using image processing algorithms to identify object shape features. Simultaneously, the weight data is processed through the HX711 amplifier and sent to the Arduino.

Based on predefined conditions for shape and weight, the object is classified into a specific category. This multi-parameter analysis improves the accuracy, reliability, and efficiency of the sorting process.

C. Control and Actuation Mechanism

After classification, the Arduino sends control signals to the servo motor to sort the object into the appropriate section. The servo motor rotates to a specific angle to direct the object into the correct bin such as left, right, or center depending on the detected category.
Once sorting is completed, the relay is activated to restart the conveyor belt. This process continues automatically for all incoming objects. The display unit continuously provides real-time output such as

detected shape, object weight, sorting category, and system status for easy monitoring and operation.

D. System Operation Flow

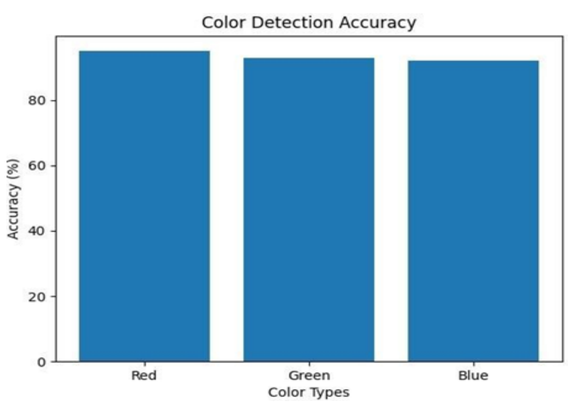
The system starts by initializing all components. The conveyor belt begins moving, and when an object is detected by the IR sensor, the conveyor temporarily stops. The ESP32-CAM captures the object image, and the load cell measures the object weight.

The Arduino processes both image and weight data to determine the object category. Based on the classification result, the servo motor directs the object into the appropriate bin. After sorting, the conveyor belt restarts automatically, and the process repeats for the next object.

The proposed object segregation system was successfully implemented and tested under different conditions. The system demonstrated reliable performance in detecting, classifying, and sorting objects based on shape and weight. The integration of sensors, image processing using ESP32-CAM, load cell sensing, and Arduino-based control ensured smooth and efficient operation.

A. Shape Detection Analysis

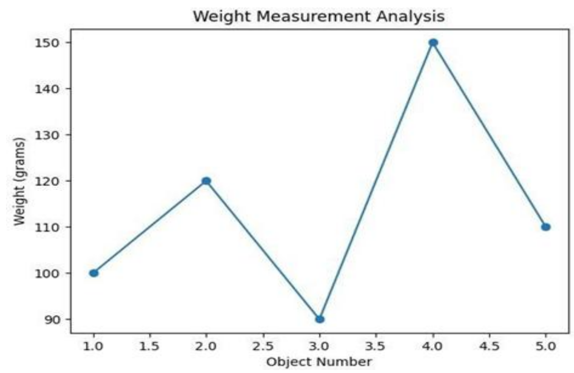
The ESP32-CAM module successfully identified objects of different shapes such as circular, rectangular, and triangular using image processing techniques.



The system showed high accuracy under proper lighting conditions. However, slight variations were observed when lighting intensity changed, which can be minimized using controlled illumination.

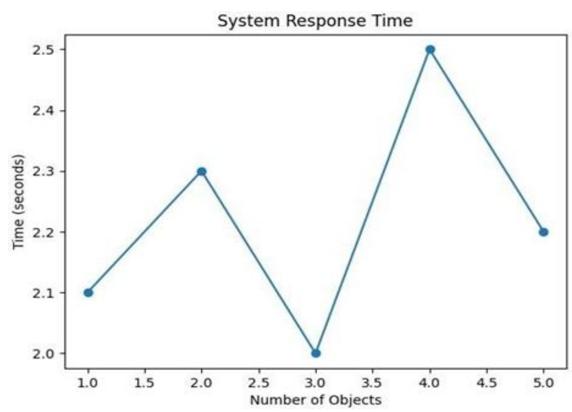
B. Weight Measurement Analysis

The load cell with HX711 amplifier provided accurate weight measurements of objects placed on the conveyor belt.



The system was able to differentiate objects based on predefined weight thresholds, enabling multi-parameter

A. Sorting Accuracy:

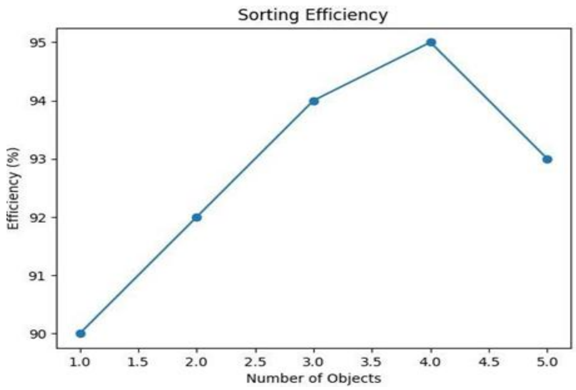


The servo motor successfully directed objects into appropriate bins based on the classification results obtained from shape detection and weight analysis. The sorting accuracy of the system was observed to be around 90–95%, depending on environmental conditions, object positioning, and lighting intensity.

The use of image processing with ESP32-CAM and weight sensing using the load cell improved the reliability and consistency of the sorting process.

B. System Efficiency

The conveyor system operated smoothly with the help of a geared DC motor, ensuring continuous movement of objects throughout the sorting process.



The relay-based control mechanism allowed precise stopping and restarting of the conveyor belt, improving overall system efficiency and reducing processing errors. The automated system reduced manual effort and increased sorting speed compared to conventional manual sorting methods.
compared to traditional sorting methods.

C. Performance Evaluation
The system performance was evaluated using parameters such as classification accuracy, response time, throughput, and sorting consistency. The results indicate that the automated system provides better reliability, minimizes human error, and improves industrial productivity.

D. Performance Parameter Calculation
The performance of the proposed object segregation system was evaluated using standard classification metrics such as Accuracy, Precision, Recall, and F1-Score. These parameters help in measuring how correctly the system identifies and sorts objects based on shape and weight.
Accuracy:
Accuracy is the ratio of correctly classified objects to the total number of objects processed.

$$Accuracy = \frac{TP + TN}{Total}$$

Accuracy = (18 + 1) / 20
Accuracy = 19 / 20 Accuracy
= 95%

Precision:
Precision indicates how many of the objects identified as a specific category are actually correct.

$$Precision = \frac{TP}{TP + FP}$$

Precision = 18 / (18 + 1)
Precision = 18 / 19 Precision
= 94.7%

Recall:
Recall measures how many actual objects were correctly identified by the system.

$$Recall = \frac{TP}{TP + FN}$$

Recall = 18 / (18 + 1)
Recall = 18 / 19 Recall
= 94.7%

F1-Score:
F1-Score is the harmonic mean of Precision and Recall.

$$F1 = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

F1 Score ≈ 0.95

These results indicate that the proposed system achieves high accuracy and reliability in automated object classification and sorting. Minor errors observed during testing were mainly caused by variations in lighting conditions and improper object positioning on the conveyor belt.
Overall, the system demonstrated efficient, accurate, and consistent performance in industrial object segregation applications.

E. Latency Analysis
The total system response time includes object detection, image capture, image processing, weight measurement, and sorting action.
The observed delay was approximately 1–2 seconds per object, ensuring smooth and near real-time operation of the conveyor-based sorting system.

F. Power Consumption Analysis
The system was designed to optimize power consumption by activating components only when required. The conveyor motor, servo motor, and relay

module operate only during movement and sorting operations, reducing unnecessary energy usage.

Power Observations

- Stable power consumption during continuous operation
- Higher power usage only during motor activity
- Low power consumption during idle condition
- Efficient utilization of embedded hardware components

The optimized power usage makes the proposed system suitable for small and medium-scale industrial automation applications.

G. Latency Analysis:

The system response time includes object detection, image processing, and sorting action. The total delay observed is around 1–2 seconds per object, ensuring smooth and near Realtime operation of the conveyor system.

H. Power Consumption Analysis:

The system uses optimized power by activating components only when required. Motors and servo operate only during movement and sorting, reducing energy usage.

Power Observations:

• Stable power consumption during operation
• Higher usage only during motor activity
• Low power in idle condition

VI. DISCUSSION

The experimental results demonstrate that the proposed object segregation system can effectively identify and sort objects based on shape and weight using sensor data and image processing techniques. The integration of the IR sensor, load cell, and ESP32-CAM ensures accurate detection, shape recognition, and classification of objects moving on the conveyor belt. The observed results confirm that the system can reliably distinguish between different object categories and perform sorting with high accuracy.

The use of a multi-parameter classification approach improves the reliability of the system by combining both shape detection and weight measurement instead of relying on a single parameter. This combined analysis enhances sorting accuracy and reduces the chances of misclassification. The servo motor mechanism further ensures precise placement of objects into the correct bins, making the system suitable for automated industrial applications.

The system also demonstrates acceptable response time, allowing near real-time operation of the conveyor mechanism. The controlled stopping and restarting of the conveyor belt using a relay module ensures proper synchronization between object detection, image processing, weight measurement, and sorting stages. Additionally, optimized activation of system components helps reduce unnecessary power consumption, making the system energy-efficient for continuous operation.

However, the system performance may still be affected by environmental factors such as lighting conditions, object positioning, camera alignment, and sensor calibration. Variations in these conditions can lead to minor errors in shape detection and classification. Therefore, proper calibration and controlled operating conditions are necessary to maintain consistent system performance.

Overall, the proposed system provides an efficient, reliable, and low-cost solution for automated object segregation in industrial environments. The system successfully combines image processing, weight sensing, and embedded control to improve automation and reduce manual effort. In future work, the system can be enhanced by incorporating advanced image processing methods or machine learning algorithms to further improve classification accuracy, adaptability, and real-time performance in complex industrial applications.

VII. CONCLUSION

The proposed automated object segregation system has been successfully developed using Arduino Uno, ESP32-CAM, load cell sensor, IR sensor, and other supporting components. The system is capable of detecting and sorting objects based on shape and weight using image processing techniques with good accuracy and reliability. The integration of sensors, embedded control, image processing, and actuator mechanisms ensures smooth and efficient operation of the conveyor-based sorting system.

The developed system reduces human effort, minimizes sorting errors, and increases overall productivity compared to traditional manual sorting methods. The combination of shape detection and weight measurement improves classification accuracy and enhances the reliability of the segregation process.

Although environmental factors such as lighting conditions, object positioning, and sensor calibration can slightly affect performance, the system performs effectively under controlled operating conditions. The automated conveyor mechanism, relay control, and servo-based sorting provide stable and near real-time system operation.

With the increasing demand for industrial automation and smart sorting systems, the proposed system offers a cost-effective, scalable, and efficient solution for object segregation applications. Future improvements can include the implementation of advanced image processing algorithms, artificial intelligence, and machine learning techniques to further enhance accuracy, adaptability, and real-time performance in complex industrial environments.

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