Research Article

Smart Barcode-Based Sorting Using YOLO and Automatic Conveyor Belts

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Abstract: Automatic sorting of goods is an effective solution for improving efficiency and accuracy in distribution and logistics processes. This study developed an automatic barcode-based sorting system that utilizes cameras and image processing technology using Raspberry Pi and actuator control via Arduino. The camera is used to capture images of barcodes on objects moving on a conveyor belt, which are then processed by a Raspberry Pi to detect and read barcode data. The read data is sent to the Arduino to activate actuators such as DC motors and servos, which direct the objects to the appropriate sorting path. Proximity sensors are used to detect the presence of objects before scanning begins. Test results show that the system is capable of performing automatic sorting with a high success rate and quick response. This system has great potential for implementation in industrial production lines to replace manual sorting processes, which still frequently result in errors.

Keywords: Automatic Sorting, Barcode, Raspberry Pi, Arduino, Conveyor Belt

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1. Introduction

Automatic object sorting is an important component in the manufacturing and logistics industries. An efficient sorting process not only boosts productivity but also reduces operational costs associated with manual item grouping. For this reason, automated sorting technology based on belts and barcode scanners is widely adopted. Belt technology is used to automatically move objects to the appropriate position, while barcode scanners read the data contained in the barcode on the object to determine its category. Barcode-based automatic sorting systems offer many advantages. Using barcode scanning cameras, objects can be identified quickly and accurately, reducing the errors that typically occur in manual processes. Additionally, it is used as a data processor to process information received from the camera and then send commands to the system to direct objects to the correct location. The use of this technology also enables the system to operate automatically without requiring manual intervention, which is highly beneficial in improving efficiency and accuracy.

Automatic sorting using advanced technologies such as cameras and barcodes is increasingly necessary in industry to improve operational efficiency. One technology that is often used in sorting systems is the use of microcontrollers, which enable automated processes with more precise control. Research [31] developed a barcode-based microcontroller-driven goods sorting system that can improve the speed and accuracy of automatic goods grouping [1]. This system relies on barcode reading to identify and separate goods according to predefined categories. In addition, developments in the use of sensors and microcontrollers are increasingly supporting more complex sorting systems. In a study by Research [32], a sorting system using an Arduino Mega 2560 microcontroller successfully separated items based on dimensions, weight, and barcodes in accordance with the city's objectives [2]. The use of load cell sensors and ultrasonic sensors in this system enables more precise and efficient sorting processes, reducing the likelihood of errors in item separation.

More advanced technologies, such as the use of barcode-based information systems, are also increasingly being applied in automatic sorting systems. Some research developed an information system in a practical report that uses barcode scanning for automatic data management [3]. The application of this technology can improve efficiency in systems that require monitoring and grouping of objects based on input data, such as the grouping of items in a belt conveyor sorting system.

In addition, Other researchers also developed a product sorting system based on color using a single board computer, which shows how color-based sensors can be used to improve accuracy in the automatic sorting process [4]. Such a system can be integrated with camera and barcode technology to enrich the automatic grouping of objects based on several parameters, such as size, color, and weight.

Research on Conveyor Belt models using YOLO has been completed in research in references [1, 4, 10,21,22,25], also the combination of YOLO and also CNN Algorithm which is one of the essential parts of Artificial Intelligence as in research references [2], and Object Detection [5] and IoT as in research references [3], while Conveyor IoT based on references [6, 7], specifically on Lump Coal Mining Conveyor in research [8], and also Shipping Boxes extraction on Conveyor detection system in research references [9]. Further research on the Detection of Lump Coal, specifically completed in research references [11], YOLO was also optimized in computer vision on Tobacco Leaf in research references [12].

In research references [13], research on Longitudinal Tear detection of Conveyor belts was also completed using YOLO, and the development of YOLO and OpenCV research in [14]. Research with classification and tracking of items on conveyors was also researched in research [15,17,18,23,24], while research [16] specifically emphasizes Grape Picking Robot research and ensures the role of object detection and color detection from YOLO and OpenCV and other components, while fruit damage detection, especially Apples, has been completed and comprehensively discussed in research [19].In addition, not only agriculture, the financial and banking sectors can use Object detection technology to improve accuracy, as shown in research [20]. As well as various other research related to Object Detection or Computer Vision in various types or aspects of life have been completed in research [26,27,28,29,30].

2. Method

This research uses a systems engineering approach by building a prototype of an automatic barcode-based sorting system using the YOLO object detection algorithm integrated into a conveyor belt. The stages of the method include hardware design, software development, system integration, and comprehensive system performance testing.

2.1 System Design

The sorting system is designed to consist of three main components:

- Object transfer unit (conveyor belt) as a medium for object movement
- Camera and image processing system to detect and read barcodes using the YOLO method
- Control unit and actuator to regulate the direction of object sorting based on barcode classification.

The hardware used consists of a USB camera, a microcontroller (Arduino Mega/Raspberry Pi), a servo motor, and a conveyor system. The software was developed using Python with the OpenCV and Pyzbar libraries for barcode reading, and YOLOv5 for real-time barcode detection.

2.2 Barcode Detection and Reading

The soil moisture sensor and temperature sensor will read data periodically. This moisture and temperature data is sent to the ESP32 microcontroller for further processing. Barcode detection is performed using the YOLOv5 algorithm, which is trained using a dataset of various types of barcode images. The model detects the location of the barcode in the frame captured by the camera. Once the barcode is detected, the process continues with reading the barcode contents using the Pyzbar library. The data obtained from the reading is used to determine the appropriate category or sorting path.

2.3 Automatic System Integration

The barcode classification results are sent to the microcontroller via serial communication. The microcontroller then activates the actuator in the form of a servo motor that directs the object to the appropriate sorting lane. This process takes place automatically and in real time according to the classification results data.

2.4 Testing and Evaluation

The system was tested using several types of objects with different barcodes to evaluate performance based on the following parameters:

- Barcode detection accuracy, calculated from the number of barcodes successfully detected compared to the total number of barcodes tested.
- System response time which is the duration between barcode detection and actuator movement.
- The sorting success rate is the percentage of objects successfully sorted into the correct lane.
- Testing was conducted under both static and dynamic conditions (objects moving on a conveyor) to assess system performance under actual operational conditions.

2.5 Block Diagram and Flowchart

Furthermore, the diagram shows the architecture of an automatic camera and barcode-based sorting system divided into three main parts: Input, Process, and Output. In the input section, there is a proximity sensor that detects the presence of objects on the conveyor and a camera used to capture barcode images from the objects. Data from the camera is sent to the Raspberry Pi, which then processes the images using a barcode detection algorithm (e.g., YOLO). Once the barcode is recognized and classified, the Raspberry Pi sends a signal to the Arduino as the main controller. The Arduino controls the output to the output section, which includes the motor driver that operates the DC motor for the conveyor belt and the servo motor that functions as the sorting actuator based on the classification results. The integration between the Raspberry Pi and Arduino enables visual processing and mechanical control to operate synchronously, achieving an efficient automatic sorting process.

The flowchart illustrates the process of the automatic barcode detection and reading system using a camera and image processing. The process begins with the initialization of pins and variables necessary for device operation. After that, the camera is activated to capture images of objects moving on the conveyor. The captured images are then converted to black and white (B&W) to facilitate the visual barcode detection process. The next step is to scan the barcode from the converted image. The system then checks whether the barcode has been successfully detected. If it is not detected, the system will repeat the image conversion and scanning process. If the barcode is detected, the system will perform barcode encoding, which is the process of translating the barcode pattern into recognizable numeric or alphanumeric data. Once the data is successfully retrieved, the information is sent to the Arduino for further processing, such as actuator control or sorting items based on the read data. The process ends when transmission is complete.

This diagram illustrates the structured computer vision-based automation workflow supporting the intelligent sorting system.

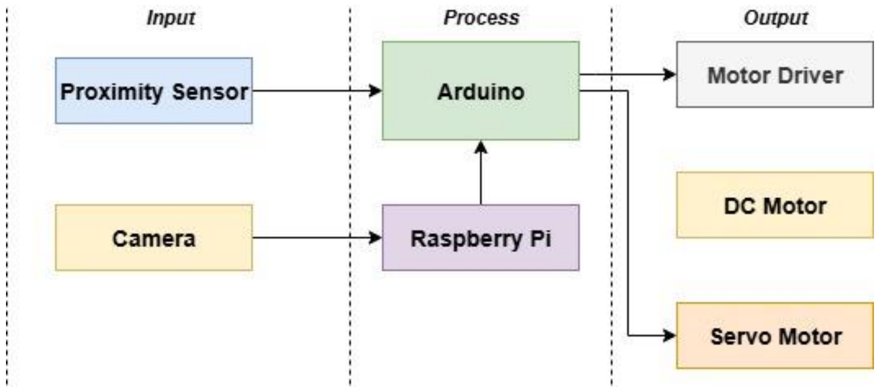

Figure 1. Block Diagram

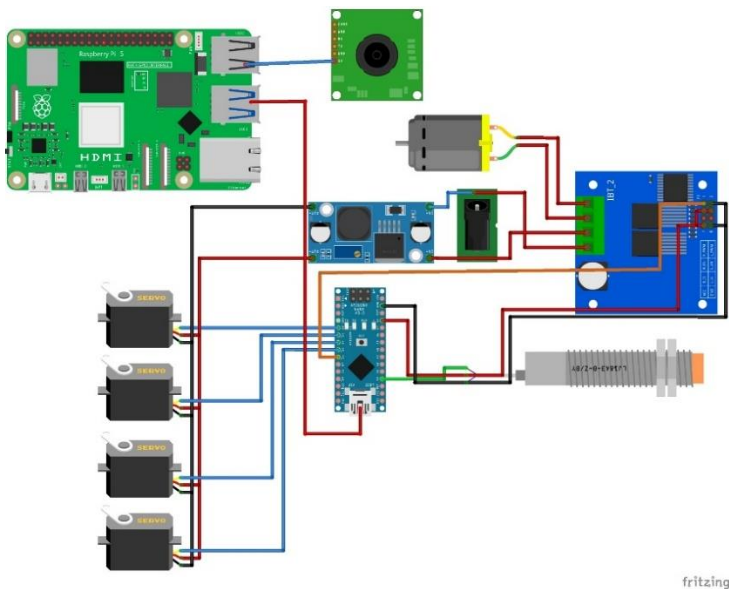

Figure 2. Wiring Diagram or Hardware Connection

Figure 1 specifically shows three essential parts in this research, namely input, process, and output, this is a very essential basis, where hardware inputs are proximity sensors and cameras, while processors are Arduino and Raspberry Pi, and outputs are Motor Driver, DC Motor and Servo Motor, these three components are interrelated. Moreover, Figure 2 shows that this Wiring Diagram is essential to know the technical relationship between processing hardware, input hardware, and output hardware, so that this system can run properly. While Figure 3 is a Flowchart system that shows this system is built from scratch with several functions such as activating the process on the camera, scanning barcodes, encoding the process of barcodes and sending data to Arduino, all of these systems are built for smoothness in the data transmission process and also builds the system as a whole.

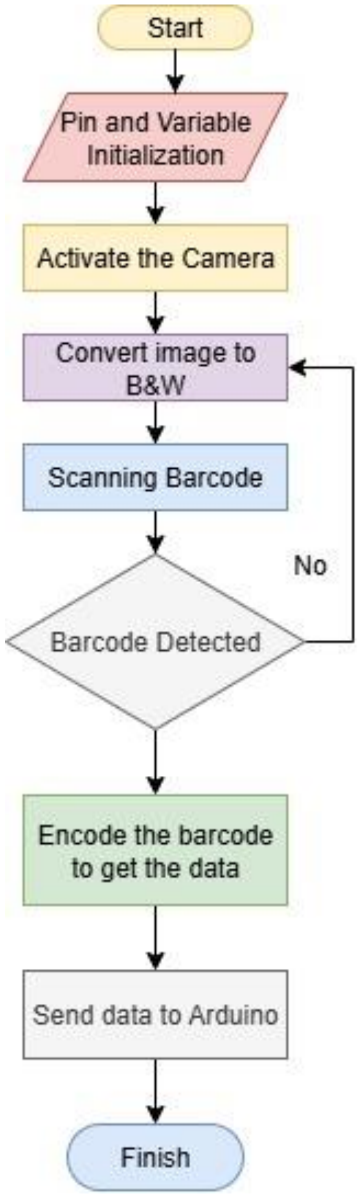

Figure 3. Flowchart Systems

3. Result and Analysis

Test results show that the system is capable of automatically responding to changes in humidity and temperature using Mamdani fuzzy logic. The soil moisture and temperature sensors function well in providing environmental data, which is then converted into a linguistic form for decision-making. When the soil is detected as dry and the temperature is high, the system activates the pump for automatic irrigation, while if the soil is moist, the pump does not turn on. Temperature and humidity data are successfully displayed on the LCD and monitored remotely via the Blynk app. Overall, the system operates stably, responsively, and effectively in automatically adjusting to the plants' water needs [13] [14].

The first data in Table 1 is the actual measurement value, while numbers 2 through 6 are estimates if the Number of Objects is increased to 50, 75, 100, 150, and 200. From the value of no. 1, there are 30 objects tested and 29 are successfully detected, 29 or 96.7%. Successfully Read 228 or 96.6%, Overall Success Rate 93.3%, Detection Failure Rate 3.3%, and Reading Failure Rate is 3.4%. Moreover, the system efficiency analysis is as follows: Optimal Conveyor Speed 2.5 m/s, Maximum Throughput 92 items/minute, Total Processing Time 0.55 seconds per item, and System Utilization 76.7%. And also Comparison with other systems is as follows: vs Manual Sorting, 240% throughput improvement, vs Conventional Auto, 88.9% throughput improvement, vs Smart YOLO based 0.0% throughput improvement. For the project, daily performance is as follows: Maintain conveyor speed at 2.5 m/s for optimal performance, Focus on improving barcode reading accuracy (current bottleneck), Consider redundant detection systems for critical applications, and Monitor system performance during peak hours.

Table 1. Barcode Detection and Reading Accuracy, and estimate

No	Number of Objects	Barcodes Detected	Barcodes Read	Detection Accuracy (%)	Reading Accuracy (%)
1	30	29	28	96.7	93.3
2	50	47	45	94	90
3	75	71	68	94.7	90.7
4	100	94	90	94.0	90
5	150	140	135	93.3	90
6	200	186	180	93.0	90

Moreover, Figure 4 shows the comparison between Throughput vs Conveyor Speed, this comparison shows the value of items per Minutes versus the speed of the conveyor (m/s), where if the increase in items per Minutes increases, it will cause an increase in conveyor speed even though it is not always the case as in item 90 there is a decrease in speed even though it is not significant.

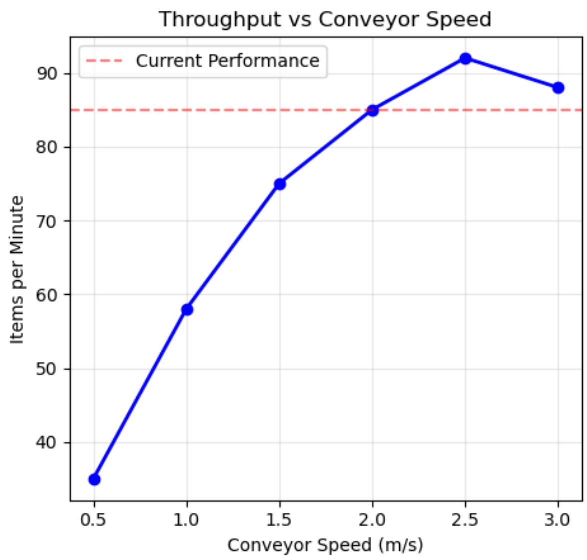

Figure 4. Throughput vs Conveyor Speed

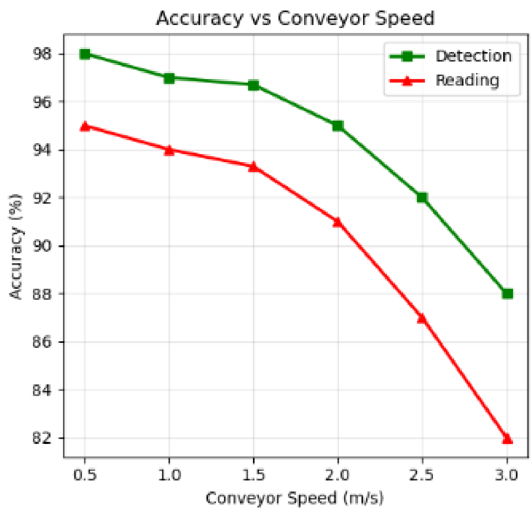

Figure 5. Accuracy vs Conveyor Speed

While the error between the detection and reading process is also not significantly 100% accurate, as shown in Figure 5, where the error can reach 3-6%, the specifics can be seen in Table 2.

Table 2. Data Extraction from Accuracy vs Conveyor Speed data

Conveyor Speed (m/s)	Detection Accuracy (%)	Reading Accuracy (%)	Error Gap (%)	Error Rate (%)
0.5	98.0	95.0	3.0	3.06
1.0	97.0	94.0	3.0	3.09
1.5	96.5	93.0	3.5	3.63
2.0	95.0	91.0	4.0	4.21
2.5	92.0	87.0	5.0	5.43
3.0	88.0	82.0	6.0	6.82

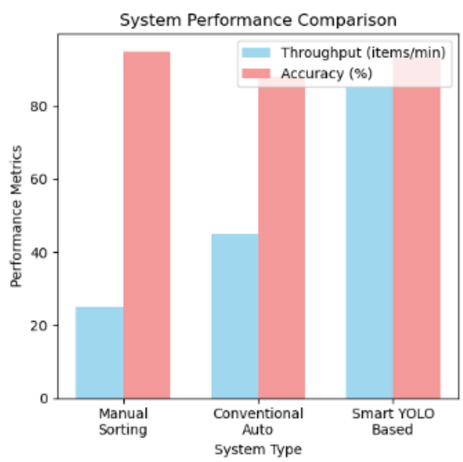

Figure 6. System Performance Comparison

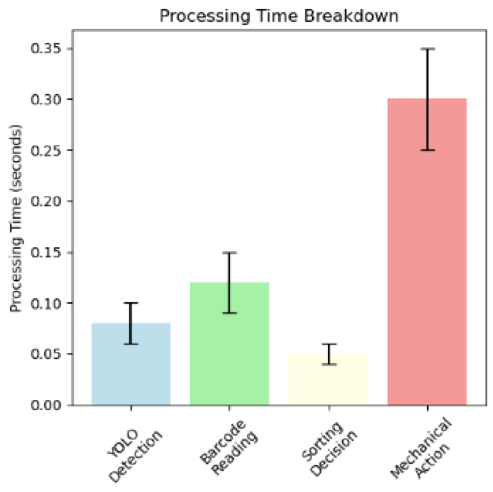

Figure 7. Processing Time Breakdown

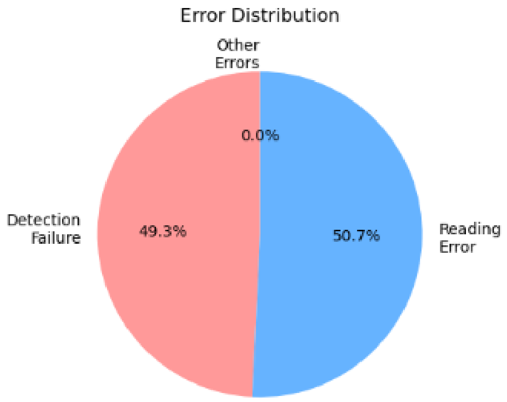

Figure 8. Error Distribution

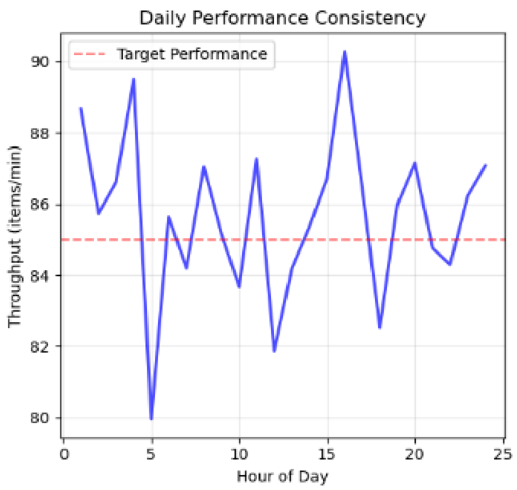

Figure 9. Daily Performance Consistency

While Figure 6 specifically shows a comparison between Manual Sorting, Conventional Auto System Type, and Smart YOLO based, in terms of Throughput and Accuracy, YOLO has the best performance. While Figure 7 is the Processing Time Breakdown obtained in terms of Mechanical Action, Barcode Reading, and YOLO Detection has a different processing value (second), and this shows a significant difference in performance. So that in the system built there is no 100% accuracy value, all have certain approaches and different errors (Figure 8), as shown in the Error Distribution in Figure 8, that Reading Error has a large error of 50.7%, while Detection Failure is 49.3%, and this shows that Reading Error has a slightly larger error than Detection Failure. And also affects the Daily Performance Consistency, which is shown in Figure 9, where the Throughput value compared to the hour of day has a fluctuating value up and down from 0 hours to 25, ranging from 80 to 90 items/min.

4. Conclusions

An automatic barcode-based sorting system using a combination of Raspberry Pi, camera, and Arduino Nano successfully designed an efficient and accurate object classification process on a conveyor belt. The Raspberry Pi is responsible for capturing and processing barcode images, while the Arduino controls actuators such as servos for sorting and DC motors for conveyor movement. With the help of proximity sensors, the system can detect the presence of objects in real-time and initiate the scanning process automatically. The integration of hardware and software results in a system capable of automatically identifying and grouping objects without human intervention, making it highly suitable for application in logistics and manufacturing industries. The system also offers high flexibility for further development, such as adding additional sensors (weight, color) or expanding the types of barcodes and their classifications. Approaches can be made to provide an estimate of the error value and also the throughput value, which is to provide the best estimation and performance that can be obtained from the system built.

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