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Automatic Classification System Color Of Bottle Detection Tool Using Tcs3200 Sensor Based On Arduino

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ABSTRACT
The increasing demand for automation in industries has led to the development of efficient and cost-effective classification systems. This study focuses on designing and implementing an automatic bottle color classification system using the TCS3200 color sensor, integrated with Arduino microcontroller technology. The system aims to detect and classify bottle colors accurately to streamline industrial processes, such as packaging and sorting. The TCS3200 sensor, capable of detecting a wide spectrum of colors, serves as the primary sensing device. It converts light intensity into frequency signals, which are processed by the Arduino microcontroller to determine the color of the bottle. The classification process involves predefined thresholds for Red, Green, and Blue (RGB) components, allowing the system to categorize bottles into specific color groups. Experimental results demonstrate that the system achieves high accuracy in identifying bottle colors under varying lighting conditions. The system is also highly scalable, making it adaptable to different industrial needs. This research concludes that the proposed solution offers a reliable, efficient, and low-cost alternative for bottle color classification in automated industrial applications.

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INTRODUCTION

The development of the world of technology is currently growing so rapidly and spreading to various aspects of human life. This development is supported by the availability of hardware. In other words, many companies automate their production. For example, the production process which was initially still done manually, such as in the process of separating goods, for example, beverage bottles. In the manual industrial process, it is carried out by human power and requires a large number of workers and makes the production process time longer. In addition, human error often occurs in this manual industry because it does the work repeatedly. To overcome this problem, companies that want a more effective and efficient production process make changes to production patterns by applying an automation system in their production.

As in selecting goods based on different colors, a tool will be needed that can sort these products automatically. With the presence of an automatic beverage bottle separator based on Arduino Uno, it can be used as a data processor from the TCS 3200 sensor and make it a final display in the process of sorting goods. Automatically, it will be very helpful in the production process of these products.

With the development of technology at this time. (nurhayati) Even the company is difficult to overcome, so the company adds workers as desired about the automatic drink bottle separator based on Arduino Uno with only 2 types of bottle colors that can be separated and that too using colors such as blue and red. Drink bottles that will be separated as desired will facilitate the work system in the company and will save costs, so the company will be so easy to sort drink bottles, based on previous research analyzing how the conveyor works to reduce collisions on goods that only work by analyzing. So the idea arose to design a bottle color detector using the Arduino Uno-based TCS 3200 sensor which will encourage companies to separate drink bottles that are suitable and unsuitable to be applied in other large industries.

Modern industries increasingly rely on automated systems to improve efficiency and accuracy in various production processes. One of the critical processes in many industries is the color classification of bottles, which is usually used in production lines for packaging or sorting. The use of automated technology in this process not only speeds up production but also reduces human error, thereby improving the quality of the final product.

Manual color classification is often labor-intensive and tends to produce variations in quality due to human fatigue or inconsistency. Therefore, a technology-based solution is needed that is able to perform color classification quickly, accurately, and consistently. This research focuses on the development of an automated system to detect and classify bottle colors using the TCS3200 color sensor controlled by an Arduino microcontroller. The TCS3200 sensor has the ability to detect light intensity in the red (R), green (G), and blue (B) color spectrum, which is then processed by the Arduino to determine the color of the bottle in real-time.

The designed system aims to meet the needs of the industry by providing a reliable, efficient, and cost-effective solution. In addition, this system is also designed to be able to work in various lighting conditions, thus increasing its flexibility in real applications. This research is expected to provide significant contributions in improving the efficiency of the production process in the industry, especially in lines that require color classification as an integral part of their operations. The main objectives of this research are to design, implement, and test an automatic bottle color classification system based on TCS3200 sensors and Arduino.

Literature Review

In the development of an automatic bottle color classification system, there are several theoretical bases that are the main basis, both in technical and implementation aspects. These theoretical bases include color sensors, microcontrollers, and digital data processing.

TCS3200 Color Sensor.

The TCS3200 sensor is a photodiode-based color sensor designed to detect light intensity in the red, green, and blue color spectrums. This sensor converts the light intensity it receives into a digital frequency signal that can be processed by a microcontroller. The main components of the TCS3200 include:

a. Photodiode, An element that detects light in the RGB spectrum.
b. Color Filter, Used to separate the red, green, and blue color components.
c. Light to Frequency Converter, Converts light intensity into a digital frequency signal.

This sensor is capable of working in a variety of lighting conditions, making it very suitable for industrial applications. A sensor is a device or electronic component that is used to change physical quantities so that they can be analyzed using an electrical circuit. For example, an ultrasonic sensor is a sensor that works by changing reflected sound waves into electrical energy Every color can be composed of basic colors. For light, the basic colors are Red, Green and Blue, or better known as RGB (Red Green Blue). Color is a certain spectrum found in perfect light (white). The identity of a color is determined by the wavelength of the light. Visible light is a part of the spectrum that has a wavelength between approximately 380 nanometers (nm) and 780 nanometers (nm) in air.

The visible light spectrum does not contain all the colors that can be distinguished by the human eye and brain. For example, unsaturated colors such as pink or purple and color variations such as magenta do not exist, because these colors are a mixture of several different wavelengths. Colors that contain only one wavelength are also called pure colors or spectral colors.

Arduino Uno Microcontroller

A microcontroller is a functional computer system on a chip, containing a processor core, memory (a small amount of RAM, program memory or both), and input-output equipment. In other words, a microcontroller is a digital electronic device that has input and output and control with a program that can be written or erased specifically, the way the microcontroller works is actually reading and writing data. A microcontroller is a computer on a chip that is used to control electronic equipment, which suppresses efficiency and cost effectiveness, literally it can be called a small controller where an electronic system that previously required many supporting components such as IC, TTL, and CMOS can be reduced/smaller and finally centralized and controlled by a microcontroller.

Arduino Uno is an electronic prototype for an open source microcontroller chip. Until now, Arduino software continues to be developed, as well as the Arduino board. Currently, there are many freely circulating boards that are compatible with Arduino, even some of them have been equipped with better and more complete facilities than the original Arduino board. Uno comes from Italian which means one. Arduino Uno is a board that uses the Atmega328 microcontroller chip as its control center. Arduino Uno has 14 digital input / output pins, also equipped with 6 analog inputs, an external oscillator using a 16MHz crystal, a USB connector, a jack for power supply, a header, for ICSP, and a reset button. The microcontroller is based on ATmega 328 (datasheet). Arduino has 14 digital input / output pins of which 6 pins can be used as PWM outputs, 6 analog inputs, a 16 MHz crystal isolator, a USB connection, a power jack, an ICSP header, and a reset button. To support the microcontroller so that it can be used, simply connect the Arduino Uno Board to the computer using a USB cable or AC power to a DC adapter or battery to run it. Arduino Uno is different from all previous boards in that it does not use the FTDI USB to serial driver chip. In contrast, the Atmega 16U2 (Atmega 8U2 up to version R2) is programmed as a USB to serial converter. Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground making it easier to put into DFU mode.

System Automation

Automation is a technology where processes or procedures are carried out without or with human assistance (Groover, 2007). Automation is a technology that applies mechanics, electronics, and computer-based systems to operate and run operations. There are 4 main elements in running automation, namely:

a. Power source to run the automation process
   The power source used to run an automated system is electricity. Electrical energy is widely available and easily converted into other energy.
b. Instruction Program
   The instruction program is the commands used to run an automated system so that it works according to its objectives and provides maximum results.
c. Control system
   The control system is a system that will recognize the status of the system, compare the status of the system with the automation procedure, set the target procedure and run it. Control systems in automation are divided into two, namely:
   a. Open loop control system
      This system is a control system that controls the automation system using the system input or system model that was given first. In this open loop system, the output or other variables in the system have no effect on the control of the input. Operational design in an open loop system, such as a machine movement that is ordered to move
   b. Closed loop control system
      This system is a system that has feedback to the system input from each output. In this system, each movement of the machine will be compared with the input parameters so that each parameter entered will affect the output and will automatically respond if an error occurs.

Automation systems in industry aim to improve the efficiency and accuracy of the production process. In the application of bottle color classification, this system:

a. Reduces dependence on manual labor.
b. Increases the speed of the production process.
c. Ensures consistency in color classification.

By using the TCS3200 sensor and Arduino, this system can work in real-time to detect and classify bottle colors automatically.

The main function of the automation system is to control processes that do not or use little human assistance. The process of the system must be explained one by one to get a good and smooth automated system so that it can work on the desired objectives. Automation systems in industry aim to improve the efficiency and accuracy of the production process. In the application of bottle color classification, this system:

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The main function of the automation system is to control processes that do not or use little human assistance. The process of the system must be explained one by one to obtain a good and smooth automated system so that it can work on the desired objectives. Automated production systems can be classified into three types, namely (Groover, 2007):

a. Fixed automation
   Fixed automation is a system where the process sequence is determined by the equipment configuration. Economic applications for this type are found for product processes with very high demand rates and volumes.
b. Programable Automation
   Programable Automation is an automation system whose production is designed with different product configurations. The sequence of operations is controlled by a program, namely a set of instruction codes so that the system can read and interpret them. This type of automation is used for low to medium scale production volumes, for example Numerica Controlled (NC) machines and industrial robotics.
c. Flexible Automation
   Flexible Automation is an automation system that is capable of producing various forms. Flexible Automation is a continuation of Programable Automation.

METHOD

This research aims to design and analyze an automatic bottle color classification system using the TCS3200 sensor based on Arduino. The methodology includes several stages, starting from hardware design to testing and result analysis. Below are the steps in the research methodology

System Design

Main Components

a. TCS3200 Sensor, Used to detect bottle colors based on the intensity of reflected light.
b. Arduino Uno Microcontroller, Serves as the processor for data received from the TCS3200 sensor.
c. Servo Motor, Used to operate the classification mechanism based on the detected color.
d. LED Light, Provides additional lighting to ensure stable illumination during color detection.
e. Conveyor or Separator Container, Assists in moving and separating bottles based on their color classification.

Electronic Circuit Design

a. The TCS3200 sensor is connected to Arduino to read the frequency values of the colors (R, G, B).
b. The servo motor is connected to Arduino to execute actions based on the color classification results.

c. LEDs are used to provide uniform lighting on the bottles.

Software Design

a. The Arduino program is designed to read frequency data generated by the TCS3200 sensor.
b. Frequency values are converted into RGB (Red, Green, Blue) intensity values.
c. RGB values are compared with reference data to determine the bottle's color (e.g., red, green, blue, or others).
d. Based on the identification results, Arduino sends a signal to the servo motor to direct the bottle to the appropriate container.

Color Classification Algorithm

a. Collect frequency data from the sensor.
b. Convert frequency values into RGB intensity values.
c. Compare RGB values with the reference color table.
d. Identify the bottle color category and activate the servo motor to direct the bottle accordingly.

Testing Procedure

a. Bottles with various colors (e.g., red, green, blue, yellow) are placed in front of the TCS3200 sensor.
b. Frequency data generated by the TCS3200 sensor are recorded for each bottle color.

Validation of Color Classification

a. Measured RGB values are compared with reference data to ensure system accuracy.
b. Tests are conducted under different lighting conditions to evaluate system reliability.

Result Analysis

a. Evaluate the accuracy of color detection by calculating the classification success rate.
b. Analyze the system's response time, including data processing speed and bottle separation time.

Evaluation and Documentation

a. Analyze system performance based on accuracy and speed test results.
b. Identify system weaknesses and provide suggestions for further development.
c. Document research findings, including diagrams, tables, and supporting charts.

This methodology is expected to produce a bottle color classification system that is accurate, efficient, and applicable in real-world scenarios.

RESULT

Analysis and Design

In cases of color blindness that are not genetic, the disorder only occurs in one eye and this condition can continue to worsen. Patients with color perception disorders caused by disease often have difficulty distinguishing between blue and red. While in this case of color blindness due to hereditary factors, the disorder occurs in both eyes, but is not hereditary. Color blindness is more common in men than women. Based on research, 1 in 12 men experience color perception disorders. Many people assume that someone who is color blind can only see black and white, like watching a black and white TV. This

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assumption is not true. It is very rare to find someone who has total color blindness (has no color perception at all). People with color blindness disorders do sometimes have difficulty matching the colors of their clothes, but this is not a serious problem. He still can do normal activities, even drive a car. Indeed, sometimes he has difficulty distinguishing red, yellow and green on traffic lights, but this can be overcome by remembering their positions.

The system algorithm is the flow of the system's work process which is the flow of input to output. The system algorithm is a step or stage of the system process to complete its tasks and functions. Where the determination of the algorithm used in each part of the system is the determination of the initial value and is continued with the process carried out by the system to maximize the performance of the tool as desired.

System Process Stages

Figure 1 System Algorithm

The application of fuzzy can be realized in the form of a system algorithm, where the only way to create a category of each number or data that is measured into a group or category according to the principle of fuzzy logic. The stages in fuzzy logic in this system are as follows:

1. Fuzzificationis a process to obtain the degree of membership from an input numeric value (crips).
2. Inference Ruleis the process of forming rules that will be used in a system.
3. Defuzzificationis the process of changing the results of reasoning in the form of output membership degrees back into numeric variables.

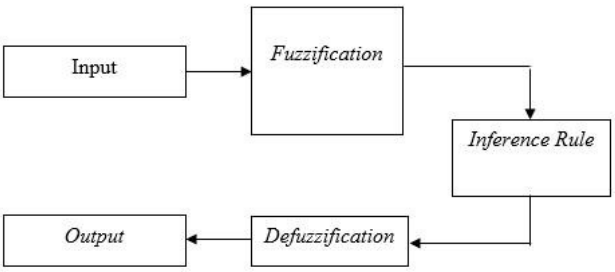

Figure 2 Fuzzy Process Block Diagram

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In the diagram above, the input from the ultrasonic sensor and LDR in the form of numeric values (crips) will be membered (fuzzification). From the existing membership degree, several rules (inference rules) will be formed that will be used in the system. From these rules, the output value is obtained which will be reprocessed into a numeric value (defuzzification). In this study, several variables are used as follows:

Table 1 Fuzzy Variables

Function	Variable Name	Name Set Fuzzy	The Universe The Talk	Domain (unit)
Input	Color	Blue	[162...234]	[0...162]
		Green		[160...174]
		Red		[172...234]
Output	This is in the form of Color	Blue	[0...500]	[0...200]
		Green		[150...350]
		Red		[300...500]

Create a membership function for each variable. Here are the membership functions:
Color membership function

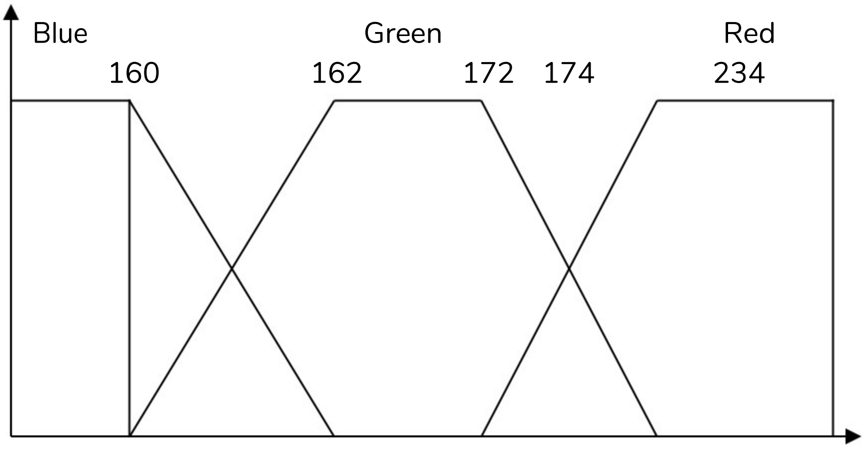

Figure 3 Color membership function

Color Membership Value :

$1 ; x <= 160$

$\mu Blue [x] = (162 - x) / (162-160)$

$0 ; x \geq 162$

$\mu Green [x] = (x-160) / (162-160) ; 160 \leq x \geq 162$

$1 = x \geq 162 \text{ or } x \leq 162$

$(174 - x) / (174 - 162) ; 162 ; \leq x \leq 174$

$\mu Red [x] = (x - 172) / (174 - 172)$

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Tool Design (Hardware)

Hardware design is a very important stage in making a tool, because by analyzing the components used, the tool to be made can work as expected. To get optimal results, first make a good design. Namely by paying attention to the nature and characteristics of each component used so as to avoid damage to the components used and make it easier to work on. Here are some important components to support the tool requirements that will be needed made :

*Arduino*is a microcontroller module that functions as an interface media and input/output process. Arduino is a microcontroller module that does not require additional design to use it, only a shield or appropriate device is needed to create additional projects.

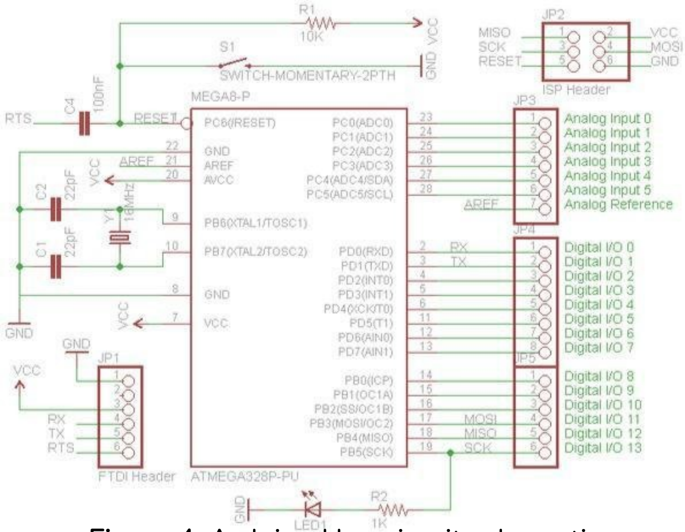

Figure 4. Arduino Uno circuit schematic

The working principle of the microcontroller circuit above uses input/output facilities which are functions to receive input signals and provide output signals. Input signals and output signals are digital signals 1 (HIGH, representing a voltage of 5 volts) and 0 (LOW, representing a voltage of 0 volts). Arduino Uno has digital and analog. In this design, several digital input/output pins are needed to control the servo, push button and 16x2 LCD, and several analog input/output pins to receive input from the TCS3200 color sensor.

TCS 3200 is an IC (Integrated Circuit) that converts light color to frequency. There are two main components that form this IC, namely photodiodes and current to frequency converters. The photodiodes on the TCS3200 IC are arranged in an 8 x 8 array with the following configuration: 16 photodiodes to filter red, 16 photodiodes to filter green, 16 photodiodes to filter blue, and 16 photodiodes without filters.

Table 2 Logic of Selectors S2 and S3 on Filter

S2	S3	Photodiode the active one
0	0	Filter Red
0	1	Blue Filter
1	0	Colorless
1	1	Filter Green

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The photodiode will output a current that is proportional to the level of the basic color of the light that hits it. This current is then converted into a square signal with a frequency proportional to the magnitude of the current. This output frequency can be scaled by adjusting the selector legs S0 and S1. The use of the output frequency scale S0 at logic low (0) and S1 with logic low (0) will cause the voltage to drop so that it will not produce a frequency output. By setting the scale S0 at logic low (0) and S1 at logic high (1), the output frequency that comes out is only 2% of the total output frequency. While by setting the scale S0 at logic low (1) and S1 at logic high (0), the output frequency that comes out is 20%. Table 3.3 Combination of S2 and S3 functions

Full frequency scale is the maximum frequency produced on each sensor output scale. On the scale S0 = 0 and S1 = 1, the maximum frequency output on the sensor is 12kHz. On the scale S0 = 1 and S1 = 0, the maximum frequency output on the sensor is 120kHz. And on the scale S0 = 1 and S1 = 1, the maximum frequency output on the sensor is 600kHz. Output Scaling can be seen in table 3.3.

Table 3 TCS3200 Output Scale

S0	S1	Output frequency scale
0	0	Power Down
0	1	2%
1	0	20%
1	1	100%

The use of this frequency scale is adjusted to the needs of the required application. For example, this tool uses a 100% frequency output scale to obtain the overall frequency. For output with a 100% frequency scale, TAOS Inc. as the manufacturer of the TCS230 sensor has conducted measurements and determined the frequency value in theory.

Electronic Design

The overall electronic design of the color detection tool uses ready-made components, such as Arduino Uno, TCS3200 color sensor, LCD, 7805 regulator, trimpot and buzzer. Arduino Uno has 14 digital pins and 6 analog pins that can be used as input and output. In the fruit sorter that will be made, the TCS3200 color sensor is connected to the Arduino analog pin.

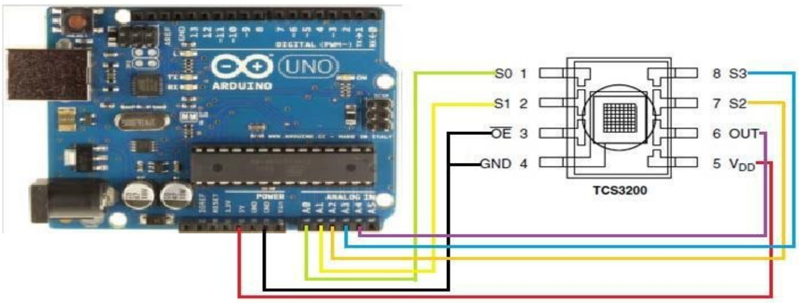

Figure 5 Color Sensor Circuit on Arduino

The pins used by the TCS3200 color sensor on Arduino are:

1. Pin A0 is connected to S0
2. Pin A1 is connected to S1

3. Pin A2 is connected to S2
4. Pin A3 is connected to S3
5. Pin A4 is connected to Out

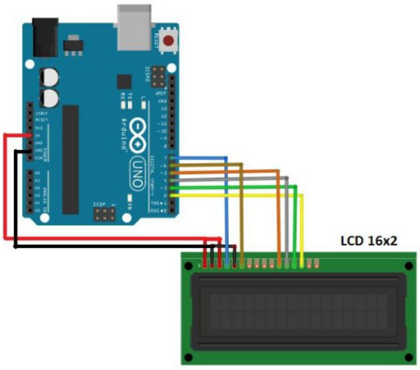

Figure 6. LCD circuit on Arduino Uno

In figure 7 below you can see the entire fruit sorting system based on color which has been designed on the Arduino Uno pin.

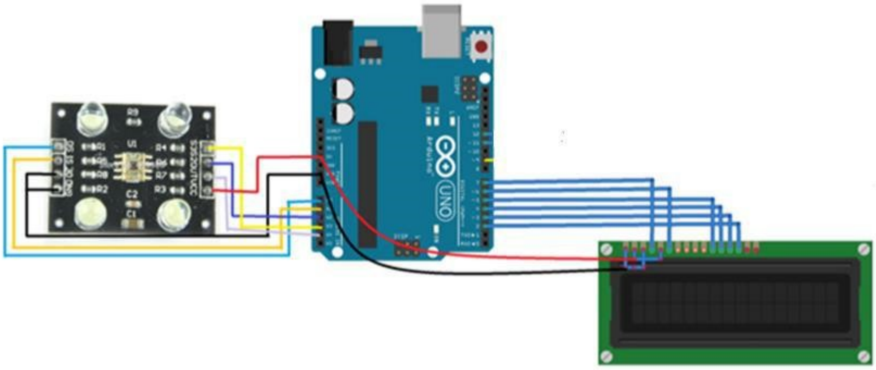

Figure 7 Overall system circuit

CONCLUSION

From the research and development of the automatic bottle color classification system using the TCS3200 sensor based on Arduino, the following conclusions can be drawn: The TCS3200 sensor effectively detects the color of bottles by measuring RGB intensity values. The classification algorithm implemented in the Arduino microcontroller successfully identifies and categorizes bottle colors with high accuracy under stable lighting conditions. The integration of hardware components, such as the TCS3200 sensor, Arduino microcontroller, servo motor, and LED lighting, allows the system to operate efficiently. The servo motor directs bottles into designated containers based on their detected color, showcasing the system's ability to automate the classification process. The system performs reliably in normal lighting environments. However, inconsistencies in external lighting or reflective surfaces on the bottles may impact color detection accuracy. Adding proper shielding or calibrating the sensor can further improve performance.The system demonstrates fast response times for detecting and classifying bottle colors, making it suitable for real-time applications, such as sorting in recycling facilities or industrial settings. This system has the potential to be expanded for use in various industries, including manufacturing, waste management, and packaging, where color classification is critical.

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