APPLICATION OF IMAGE PROCESSING USING A CAMERA COMBINED WITH A ROBOTIC ARM FOR SORTING AND STORING PRODUCTS BY COLOR

Minh-Phuoc Dang [1], Phan-Hoang-Phuc Nguyen [2]*, Binh-Hau Nguyen [3], Hoang-Duc Tran [1], Le-Hien-Luong Tran [1], Thien-Quang Hang [1], Thanh-Lam Nguyen [1], Le-Phuc-Thang Nguyen [1]

[1] Ho Chi Minh City (HCMC) University of Technology and Engineering (HCM-UTE)
Vo Van Ngan Str., No. 01, HCMC, Vietnam
[2] LEGO Manufacturing Vietnam
No. 1, Road No. 3, VSIP 3 Industrial Park, Tan Uyen City, Binh Duong Province, Vietnam
[3] Posts and Telecommunications Institute of Technology (PTIT)
No. 97, ManThien street, HCMC, Viet Nam
* Corresponding author. E-mail: phuc.hoang@LEGO.com

Abstract: The application of automation in the classification of different types of products based on each criterion (color, size, shape) and automatic warehousing is an issue that is always of concern in large factories. However, conducting experiments in the factory without testing and risk assessment will bring many potential risks. By miniaturizing the model, combining similar tools when used in practice, a platform can be created in laboratories to simplify these complex systems into a simple model for in-depth research or teaching and learning in a university environment. Although the system is only a simulation or much smaller in scale than reality, this system still has full features, rich requirements to help students research. In this paper, we present a platform that meets the basic requirements.
Keywords: Image processing, sorting, storing, color.

1. Introduction

Processing and classification of goods have always been critical challenges in industrial production and warehouse management. Traditionally, these tasks rely heavily on human labor, where efficiency and accuracy of processing, sorting, and storing are limited by individual workers' perception, physical health, and fatigue levels. Consequently, this manual approach often results in reduced productivity, a high rate of defective products, and difficulties in warehouse inventory control. To overcome these limitations, development of automated systems using robotics and image processing has emerged as a significant trend in modern manufacturing industries [1], [2].

Recent advancements in sensor technology and computer vision have enabled the accurate detection and classification of products based on multiple criteria such as color, size, and shape.

The first large-scale application of color machine vision was in the food processing industry, specifically for high-speed sorting of fruits to identify and remove defective or improperly sized items as well as extraneous materials [3].

These breakthroughs paved the way for broader applications of automation in various industries.

Robots not only reduce human labor but also improve precision, flexibility, and process efficiency [4]. Many factories worldwide have implemented robotic systems to minimize labor costs and increase sorting accuracy, making such technologies a vital part of industrial automation [5], [6].

Current research and applications largely focus on utilizing automation equipment and computer vision algorithms to detect and classify products [7], [8].

However, most studies either concentrate on developing image processing algorithms or on optimizing robotic motion to replicate human tasks, with very few exploring complete solutions that combine perception and actuation [9].

The robot illustrated in Fig.1 represents a widely adopted warehouse automation system that demonstrates the integration of robotic arms for item handling and storage. It highlights the capability of robots to navigate and transport items efficiently, reducing human labor in logistics operations.

Fig. 1. Robots used in warehouses.

Fig. 2 presents ROBEE, a compact and student-friendly robot designed for research and educational purposes. These robots highlight the potential of smaller-scale models in providing a practical, cost-effective platform for students to explore and experiment with robotic automation [10], [11].

Fig. 2. ROBEE Robot.

Motivated by these developments, this study aims to design and implement a low-cost, easy-to-use robotic system that integrates a camera and robotic arm for product classification and storage based on color. By using compact hardware and simplified programming, the proposed model is well-suited for laboratory environments, enabling students to gain hands-on experience with image processing and robotic control technologies [12], [13].

However, in laboratory conditions, a smaller, student-friendly model. On that basis, research and training tasks can be applied to students. It is required to develop a cheap and easy-to-use model. Therefore, in this paper, we develop a classification model using a camera and a small robotic arm. The hardware model is developed from compact devices, simple in programming and processing.

2. Experimental Model

The experimental model was developed to simulate a simplified automated warehouse environment in which image processing, robotic manipulation, and PLC-based control operate together to perform color-based sorting tasks. This section describes the overall workflow of the system as well as the hardware components selected for implementation. The process flow is first illustrated to show the interaction between digital automation and physical automation, followed by the presentation of the actuators, sensor devices, and the complete robotic structure. Figs. 7 & 8 then provide the mechanical design in SolidWorks and the corresponding fabricated prototype used for experimental verification.

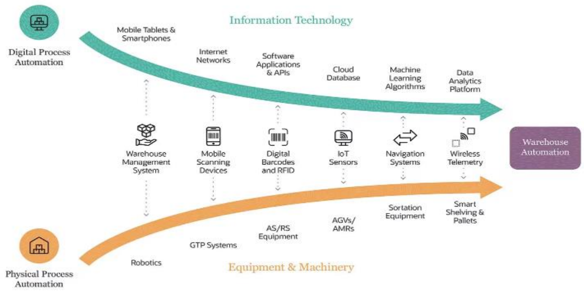

Fig. 3. Automated warehouse system process.

Fig. 3 presents the automated warehouse system process, depicting how digital and physical automation work together to streamline warehouse workflows. Description in Fig. 3:

- Digital Process Automation: Digital process automation uses data and software to reduce manual workflows. Automatic identification and data capture (AIDC) technology, such as mobile barcodes, is an example of digital automation in the warehouse.
- Physical Process Automation: Physical process warehouse automation is the use of technology to reduce employee movement and create more efficient workflows. Robots are an example of how this works in a warehouse [3].
- Warehouse automation: Warehouse automation works by using software and technology like robots and sensors to automate tasks. These products work in conjunction with existing tools like inventory management software. Warehouse automation helps ensure that critical business operations in your facilities meet customer demands. It starts with a warehouse management system (WMS) that automates manual processes and data collection, controls inventory, and supports data analytics. These systems integrate with other solutions to efficiently manage and automate tasks across different business functions and supply chains.

We choose step motor (Fig. 5) and DC motor (Fig. 6) as actuators of this project. The camera of this project is shown in Fig. 7.

Fig. 4. Step motor

Fig. 5. DC motor

Fig. 6. Camera

Thence, our designed robot is shown in Fig.7 and the real model is created as in Fig. 8.

In the experimental model, the robotic system was first designed in SolidWorks to determine the structural layout and actuator arrangement. Fig.7 shows the digital model, which includes a stable base, a 3-DOF arm driven by stepper motors, a DC-motor gripper, and a front-facing camera for color detection. Fig.8 presents the completed physical prototype built according to the SolidWorks design, using the same motor configuration and camera placement. This setup enables the system to capture images, process color information using OpenCV, and send the results to a Siemens PLC via Snap7 for object sorting.

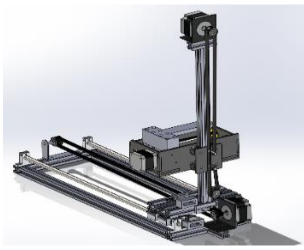

Fig. 7. Designed robot in SolidWorks.

Fig. 8. Robot arm after completion.

3. Control Method

3.1. OpenCV & Snap7

OpenCV, developed by Intel and initiated by Gary Bradski, was first released in 2000 and provides C++ libraries (with Python/Java support) for image processing, object recognition, tracking, and AR. Snap7, an open-source library by Davide Nardella (2013), enables communication with Siemens S7 PLCs (S7-300/400/1200/1500) for data exchange, monitoring, and remote control, useful in SCADA and industrial IoT

3.2. Algorithm Flowchart

In a vision-processing system integrated with a PLC, using a flowchart helps clearly illustrate the workflow between the camera, the color-detection algorithm, and the PLC. The figures below show the complete process, starting from device initialization, reading ROI data, detecting color regions, and finally sending the corresponding control signal back to the PLC. The flowchart is divided into two main branches: the branch for reading data and setting the ROI, and the branch for color processing, condition checking, and writing values to the PLC. The figure begins with the initialization of the camera and PLC connection. The program then continuously checks whether the ESC key is pressed to terminate the system, or proceeds to read the ROI parameters from the PLC. When the activation signal equals 1, the system processes the ROI by converting it to the HSV color space, iterating through the color list, detecting color regions using in Range and find Contours, and checking both the region size and the number of edges. If the detected region meets all conditions, the program draws the frame, adds the label, and writes the corresponding value to the PLC. Otherwise, it outputs a value of 0 and returns to the main loop.

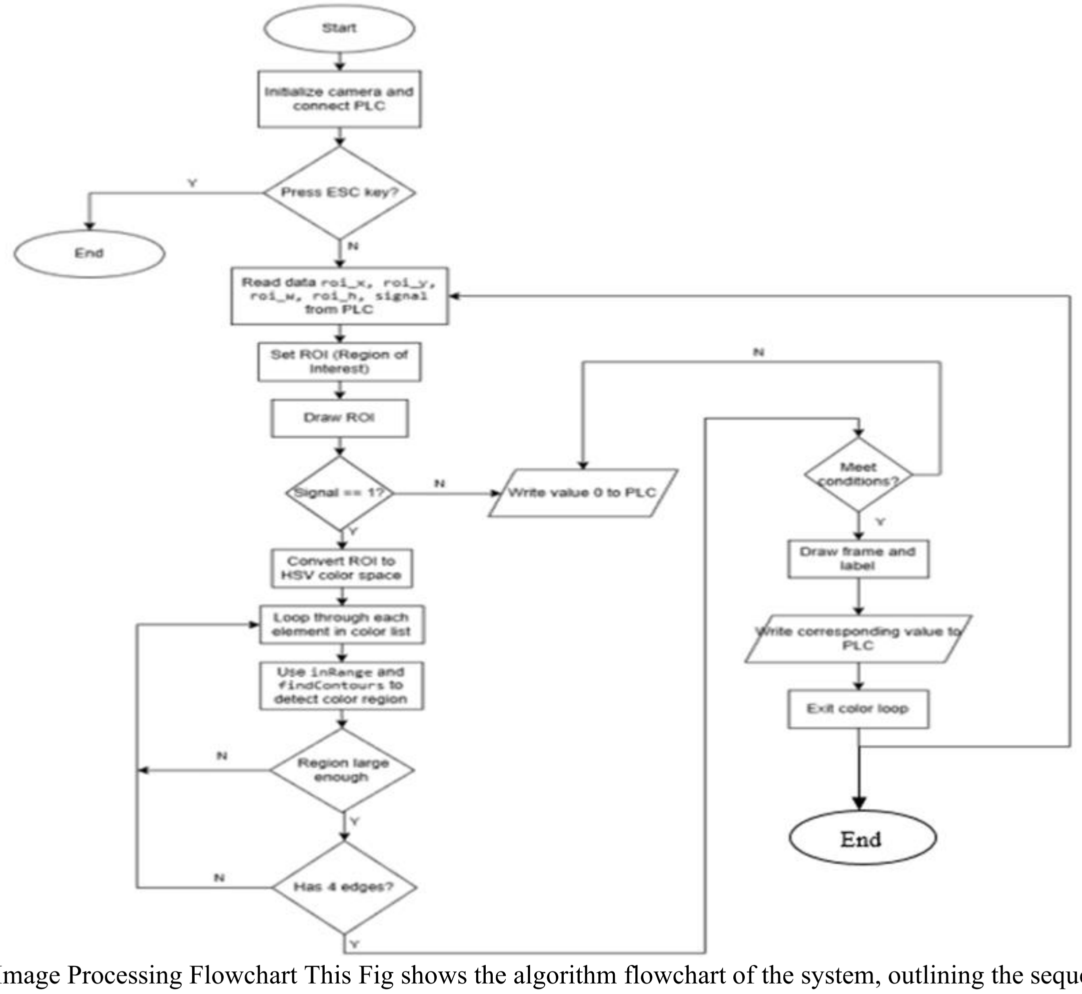

Fig. 9. Image Processing Flowchart This Fig shows the algorithm flowchart of the system, outlining the sequence of operations from image acquisition to color classification and actuation of the robotic arm.

3.2. Results

This section presents the main outcomes of the color-based classification system using image processing and PLC-controlled robotics. Since the results are primarily visual, each figure is briefly explained and followed by concise discussions to highlight differences between experiments and the scientific significance of the findings. Fig. 11–13 show the system's ability to recognize yellow, red, and blue objects with assigned color codes 3, 2, and 1 respectively. Among the three tests, blue provides the most stable detection because its HSV range is less affected by lighting, whereas yellow shows slightly more variation due to its broader spectral range. These observations are consistent with previous studies that report higher stability for cold-color detection in the HSV space. Fig. 14–17 illustrate how the detection results change when the ROI parameters are adjusted through the

PLC. Horizontal and vertical shifts maintain correct detection as long as the object remains within the ROI. Changing ROI width and height reveals that oversized ROIs introduce background noise, whereas undersized ROIs may cause partial or missed detection. These results emphasize the importance of proper ROI configuration and demonstrate the advantage of having a dynamically adjustable ROI compared to earlier studies that relied on fixed ROIs.Fig.18–21 show the complete workflow from color detection to robotic picking and placement. In all three cases, the robot correctly stores the object according to its assigned color code. Compared with studies that focus solely on image processing or robotic motion, the proposed system demonstrates the effectiveness of combining machine vision with PLC-based control in a compact and fully integrated setup suitable for laboratory training and small-scale automation.

Fig. 10 illustrates how the system detects yellow objects and assigns them a color data value of 3 for classification.

Fig. 11 shows the detection of red objects, which are assigned a color data value of 2 by the system.

Fig. 12 demonstrates the detection of blue objects, assigned a color data value of 1.

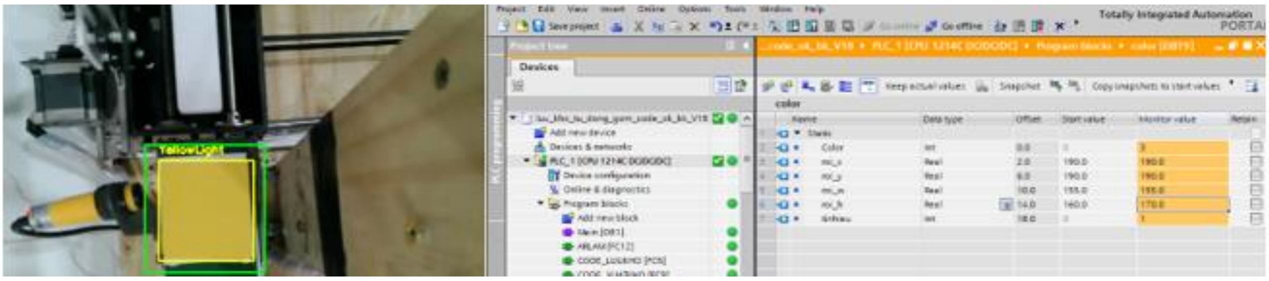

Fig. 10. Yellow will return result color data as number 3.

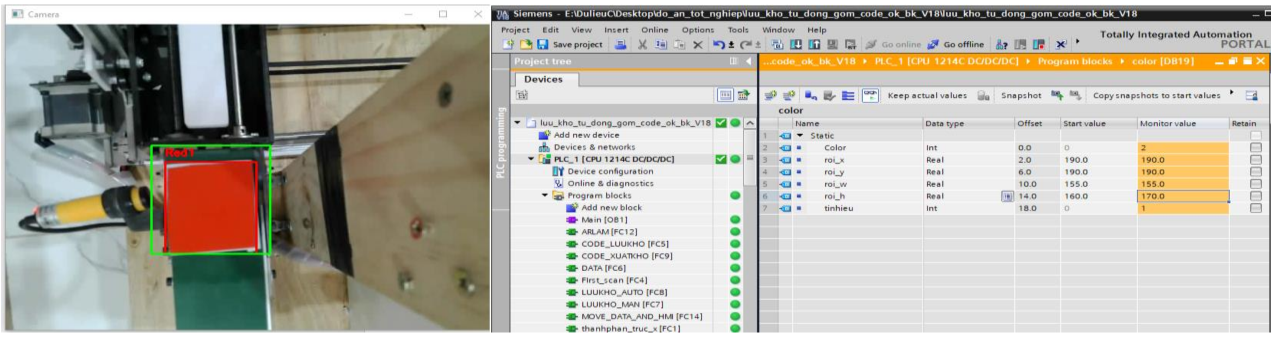

Fig. 11. Red will return result color data as number 2.

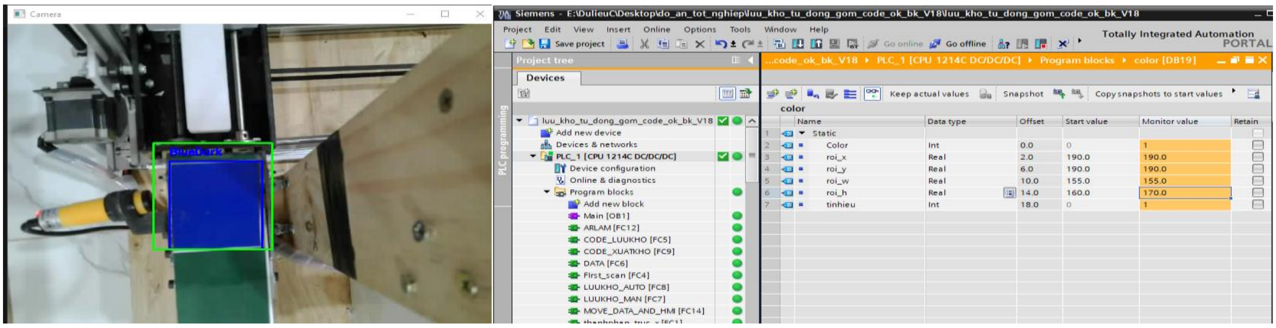

Fig. 12. Blue will return result color data as number 1.

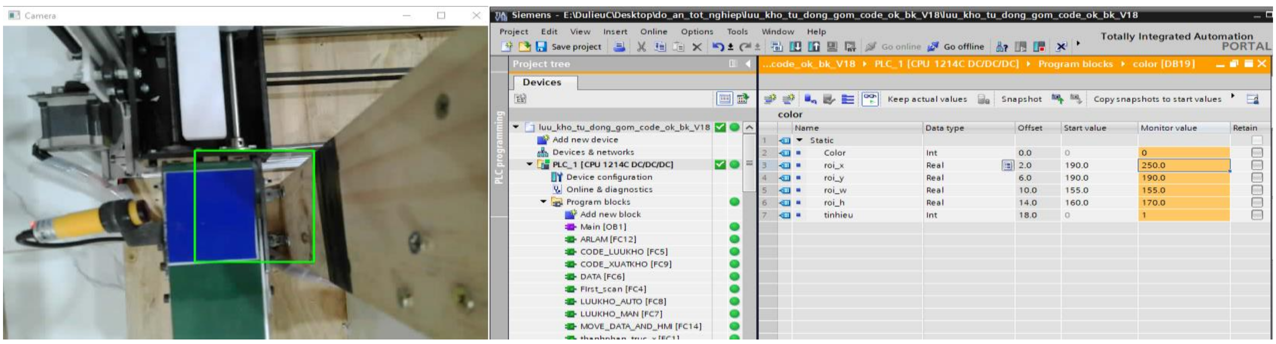

Fig. 13. Result when change the camera's recognition area position horizontally (change the value of the ROI_X variable from PLC.

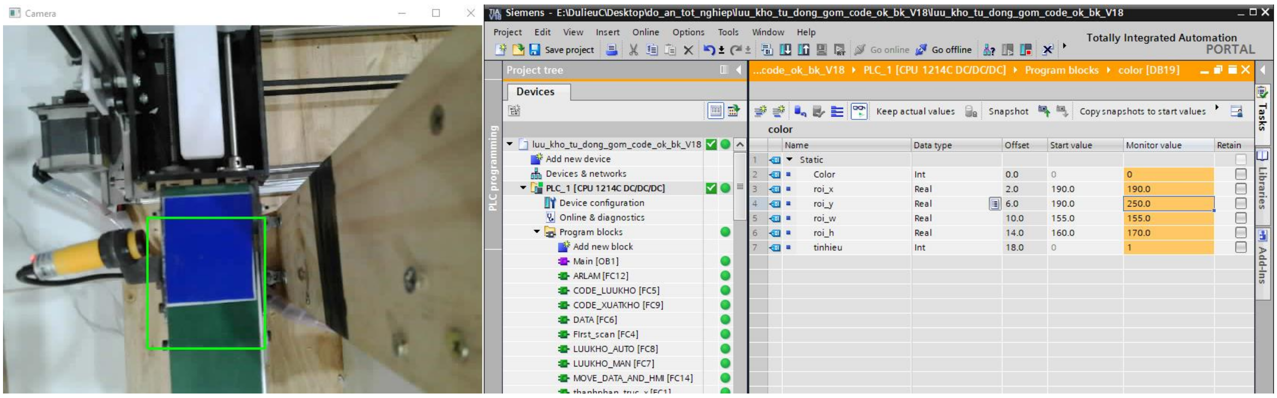

Fig. 14. Result when change the camera's recognition area position vertically (change value of the ROI_Y variable from PLC.

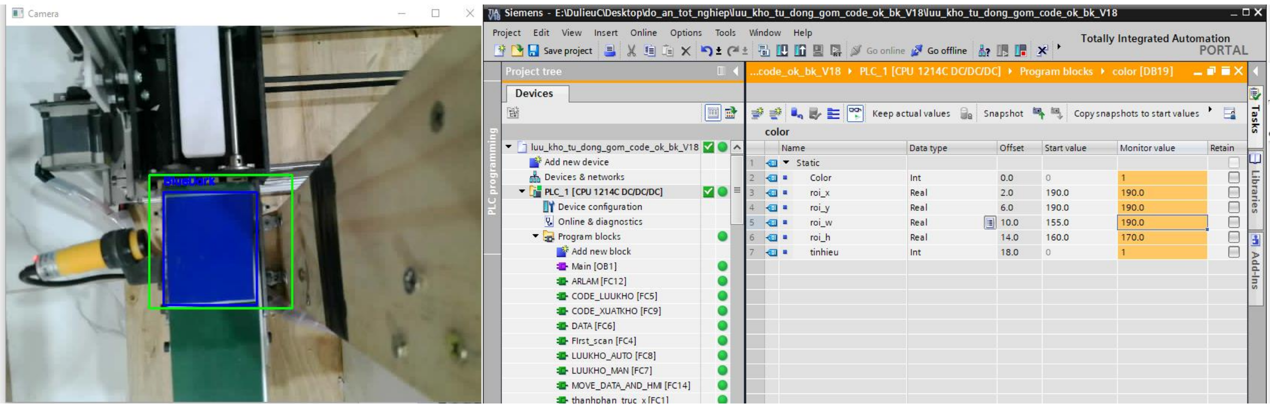

Fig. 15. Result when change the width of the recognition area (change the value of the ROI_W variable from the PLC.

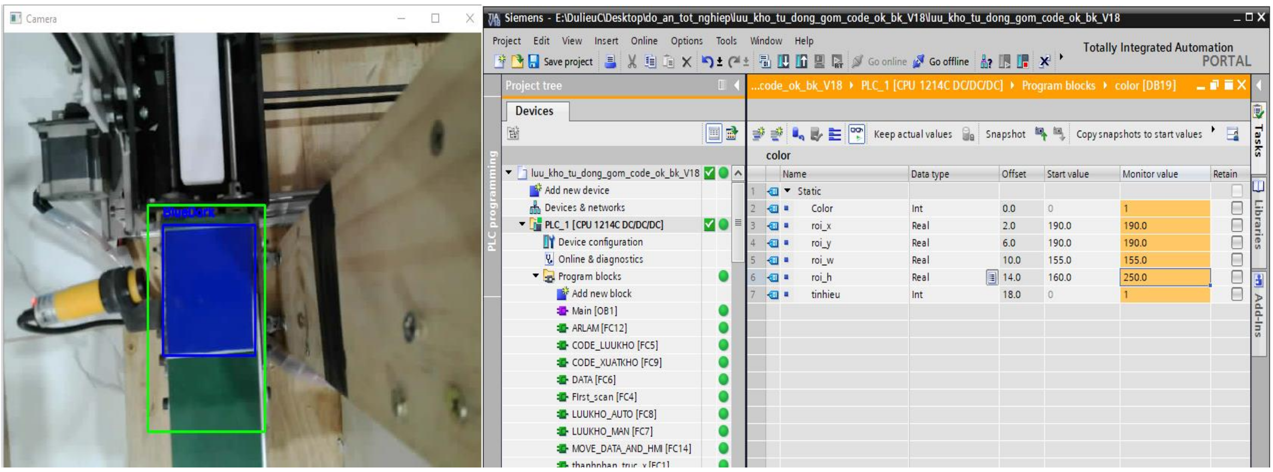

Fig. 16. Result when change the height of the recognition area (change the value of the ROI_H variable from the PLC.

After the color has been accurately identified, the data is linked to the PLC, combined with the gripper supported by the available programming functions from Siemens, we will get the exact storage result corresponding to the request given before. (Here we set the requirement that each different color is saved on a different floor).

Actual results are shown in the images attached below.

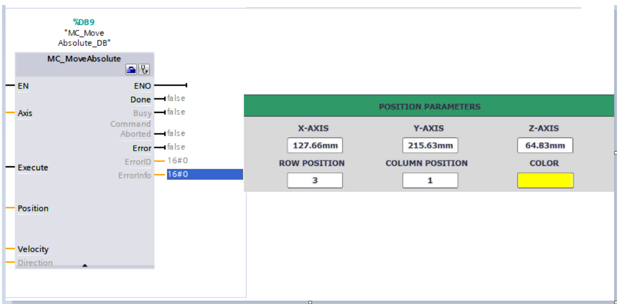

Fig. 17. Absolute precision control block of gripper position supported by Siemens.

Fig. 17 illustrates the absolute precision control block for the gripper position, supported by Siemens programming functions.

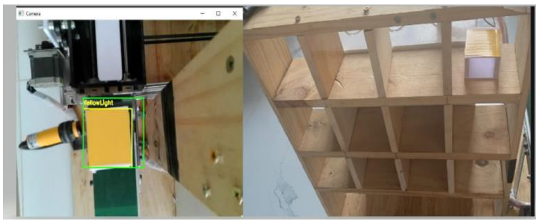

Fig. 18. Results when the yellow object is recognized and stored.

Fig. 18 presents the result when the system successfully recognizes a yellow object and stores it in the assigned compartment.

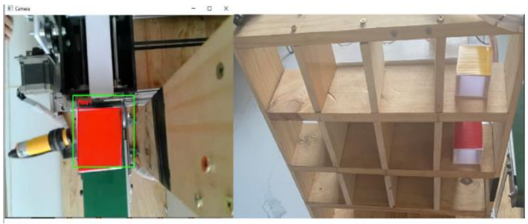

Fig. 19. Results when the red object is recognized and stored.

Fig. 19 presents the result when the system recognizes a red object and directs it to the correct storage location).

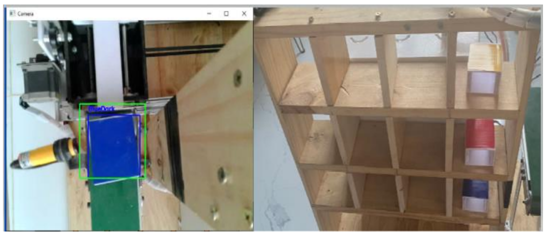

Fig. 20. Results when the blue object is recognized and stored.

Fig. 20 shows the system's operation when detecting and storing a blue object in the appropriate compartment.

4. Conclusions

In this study, we successfully developed a compact robotic system integrating image processing and a robotic arm to classify and store objects based on their colors. The system can detect colors accurately using a camera and process this data through a PLC to control a robotic gripper for precise item placement.

This model not only demonstrates key principles of automation and computer vision but is also cost-effective and suitable for educational environments.

The project achieves its goal of simulating warehouse automation on a small scale and provides students with a practical platform for learning about industrial robotics and control systems.

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5. References

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