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Servo motor control in a color-based sorting system using the Internet of Things (IoT)

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ABSTRACT

Manual sorting of items based on color attributes is prone to errors and time-consuming. This study aims to design and implement an automated sorting system using the Siemens S7-1200 PLC, SIMOTICS S 1FL6 servo motor, GDS3011W color sensor for black-and-white detection, and E3F-DS30C4 photoelectric sensor for object presence detection. The system features both automatic and manual operation modes, controlled via the Simatic KTP 700 Comfort HMI, and supports remote monitoring through Node-RED as an IoT platform. The testing method involved validating servo motor positioning using a protractor and measuring rotational speed with a digital tachometer. The results showed that the servo motor successfully moved a white tube to a -90° angle as commanded and returned to 0° after a 5 second delay, maintaining a rotational speed of 200 mm/s. The GDS3011W and photoelectric sensors operated reliably within their specified detection ranges. IoT integration enabled real-time monitoring of the quantity and status of sorted objects.

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1. INTRODUCTION

The advancement of industrial automation technologies has become a fundamental factor in increasing production efficiency and product quality. One of the essential processes in modern manufacturing is the sorting system, especially in production lines that demand speed and accuracy in classifying products based on attributes such as color, size, or shape. Manual sorting is considered ineffective due to its dependency on a large workforce and the inconsistency caused by human fatigue. Tumanggor et al. reported that the human error rate in Fresh Fruit Bunch (FFB) sorting could reach up to 74% [1].

To address this issue, automated sorting systems based on sensors and programmable logic controllers (PLC) have been proposed. Aher et al. demonstrated that color-based automatic sorting systems could achieve 100% classification accuracy while significantly reducing the need for manual labor [2]. In line with the Industry 4.0 concept, modern sorting systems are also integrated with Internet of Things (IoT) technologies to enable real-time monitoring and control [3], [4]. Color sensors serve as the primary component in color-based sorting systems. For binary color classification, the GDS3011W digital sensor is often used due to its ability to differentiate between black and white with a direct digital output to the PLC. Compared to full-spectrum sensors like the TCS3200, the GDS3011W is simpler and more effective for industrial two-color sorting applications [5].

The PLC functions as the control core in industrial automation systems. Siemens S7-1200 is a modern PLC that supports the PROFINET communication protocol, enabling connectivity with various devices such as HMIs and cloud-based monitoring platforms [6]. This PLC is compatible with various sensors and actuators and can execute complex control logic swiftly and accurately [7]. To ensure precise motion control, industrial servo motors such as the SIMOTICS S-1FL6 are employed, driven by SINAMICS

V90 inverters. These motors provide accurate position and speed control, making them suitable for automated sorting systems [8], [9]. Position control of the servo motor is achieved through absolute and relative positioning methods, programmed using Siemens TIA Portal [10].

Integrating PLCs, sensors, servo motors, and IoT technologies enables the sorting system to operate automatically and be monitored across multiple platforms. Real-time data visualization can be performed using HMI, PC, or smartphones through platforms such as Node-RED [11], [12]. Node-RED simplifies the integration of visual interfaces with IoT devices and supports remote access [13], [14]. Several previous studies have explored the application of PLC- and HMI-based control systems. Syahputra and Bukit developed a capacitor bank control system using PLC and HMI [15], while Rimbawati et al. designed a voltage regulator using PLC [16], and Anarwati and Setiono implemented a DC motor speed monitoring system with HMI [17].The novelty of this research lies in the development of a dual-mode (manual and automatic) sorting system integrated with real-time IoT-based monitoring. The system is designed to display actuator position, object counts, and system status across multiple platforms simultaneously. This integration of control technology, color sensing, and data visualization supports the implementation of smart manufacturing and Industry 4.0 principles.

2. METHOD

Explaining This research employs an engineering approach in developing an Internet of Things (IoT)-based automatic sorting system that classifies objects by color. The system is designed not only to perform sorting functions but also to support real-time monitoring and control through a web-based interface. The development began with the construction of the hardware configuration, followed by the integration of control logic, electrical design, communication protocols, and software for visualization. The overall hardware structure used in this system can be seen in Figure 1. It consists of several main components, including a Siemens S7-1200 programmable logic controller (PLC) as the central processing unit, a GDS3011W color sensor for detecting black and white objects, and a photoelectric sensor to trigger object presence on the conveyor. A DC motor is used to drive the conveyor, while a SIMOTICS S-1FL6 servo motor controlled by a SINAMICS V90 inverter performs sorting based on color detection. Additionally, a Siemens KTP700 Comfort human-machine interface (HMI) is installed as the user interface for manual or automatic control modes. All components are mounted on an acrylic-based frame that ensures mechanical stability and simplifies maintenance and testing.

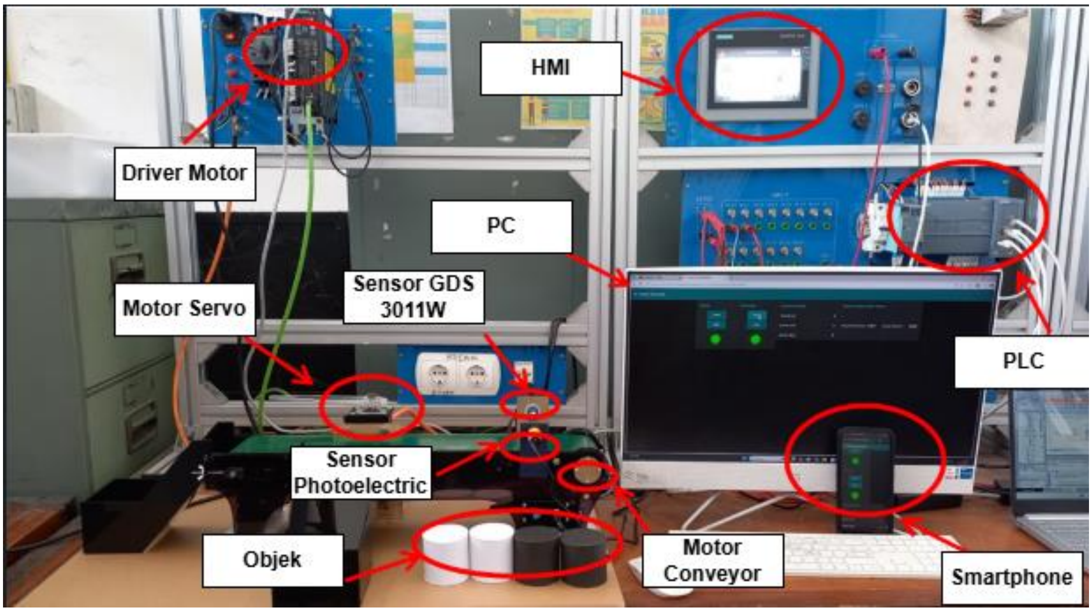

Figure 1. Hardware configuration of the IoT color sorting system.

The functional relationship among the hardware components is illustrated in the block diagram shown in Figure 2. This diagram explains the flow of data and control signals, beginning from the input sensors to the PLC, followed by actuator commands to the conveyor motor and servo motor, and finally to the monitoring devices. The diagram also highlights the communication network used for data exchange between the PLC and the visualization system.

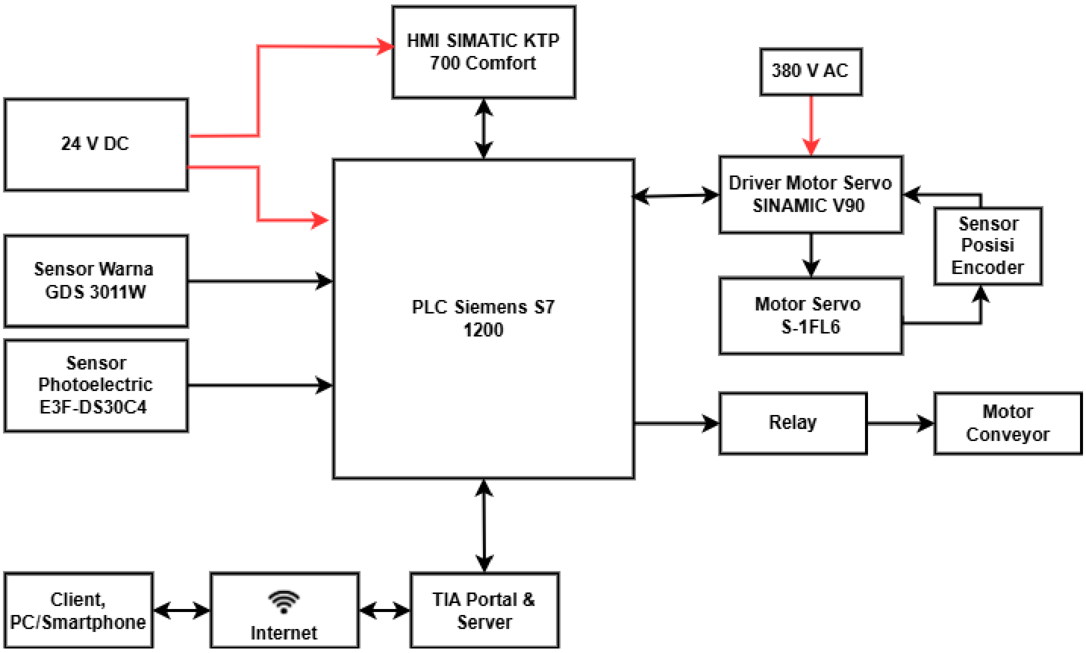

Figure 2. Block Diagram

The system's electrical layout can be seen in Figure 3. The diagram presents the connection scheme of each component, including power supply lines, sensor inputs, actuator outputs, and communication interfaces. The control system is powered by a 24V DC source, and PROFINET is used as the communication protocol to ensure reliable and high-speed data transfer between devices. Signal separation is applied to minimize noise and maintain electrical safety standards.

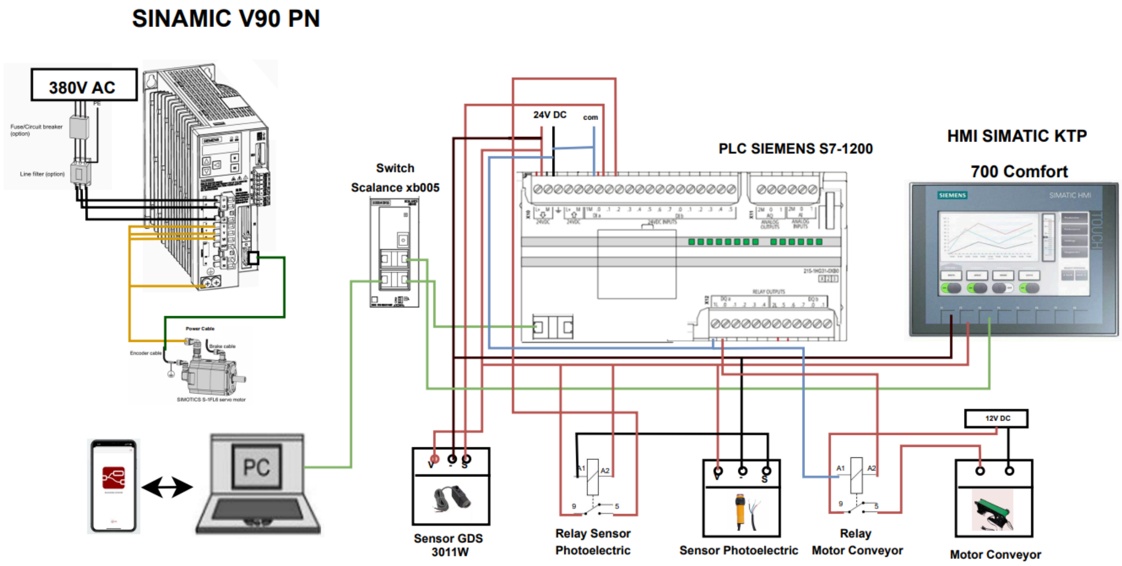

Figure 3. circuit Schematic

The logic flow of the sorting process is detailed in the flowchart provided in Figure 4. The chart describes the sequence of operations, starting with object detection by the photoelectric sensor, classification by the color sensor, and corresponding servo movement to direct the object. It also includes the incrementing of the object counter and resetting the servo position after sorting. This sequence operates continuously in automatic mode and can be interrupted or modified via manual input.

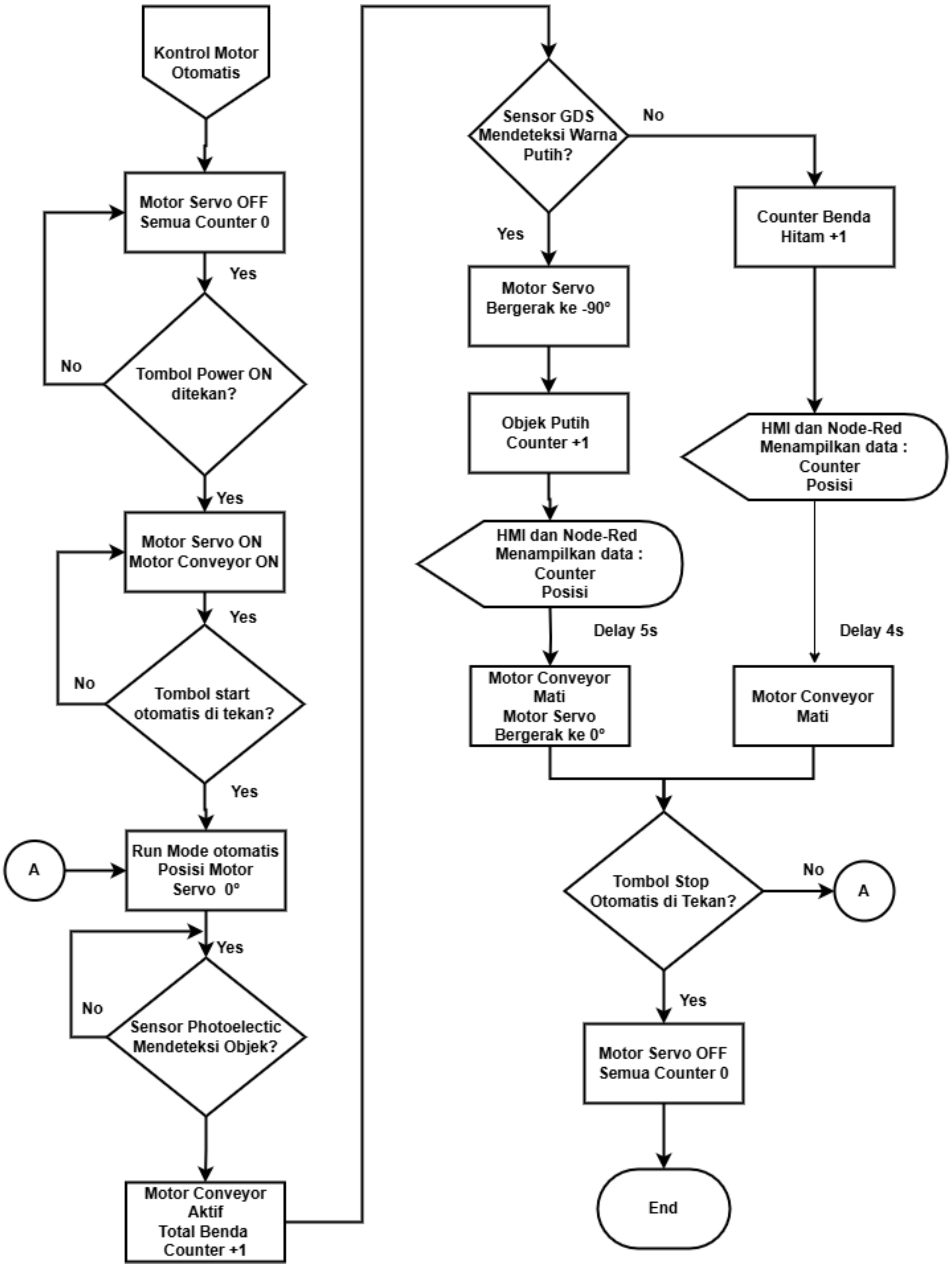

Figure 4. Flowchart

The software architecture and monitoring interface are shown in Figure 5. Subfigure (a) displays the Node-RED dashboard, which visualizes the number of detected objects, the current servo position, and system status in real-time. Subfigure (b) presents the flow logic within Node-RED, which handles data acquisition from the PLC and updates the dashboard for HMI, PC, or smartphone access. This enables the system to be monitored and controlled from multiple devices simultaneously, offering flexibility and transparency in operation. Overall, this method enables a fully functional color-based sorting system with integrated IoT capabilities, ensuring not only accurate object classification but also visibility and control across various platforms. The system supports Industry 4.0 goals by enabling intelligent, efficient, and remote-accessible automation.

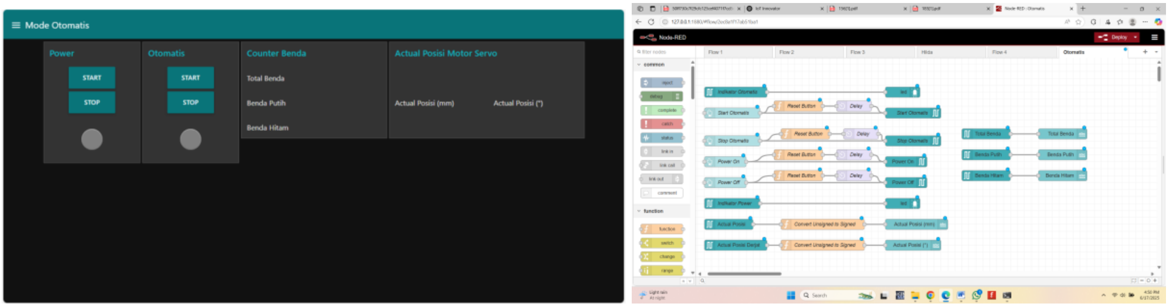

Figure 5. Software design (a) Data display on Node-Red and (b) Flow Program

3. RESULTS AND DISCUSSION

In automatic mode, the system operates entirely based on sensor detection. When the photoelectric sensor detects an object, the conveyor motor activates and directs the object toward the color sensor. If the color sensor detects a white object, the servo motor rotates to 90°, and the white object counter increases by one. This data is displayed in real-time via HMI and the Node-RED dashboard. After a 5-second delay, the servo motor returns to position 0°, preparing to receive the next object. Conversely, if the sensor detects a black object, the servo motor remains at position 0°, and the black object counter is incremented. This automatic sorting process was tested nine times, and its visual results are shown in Figure 6 and Figure 7.

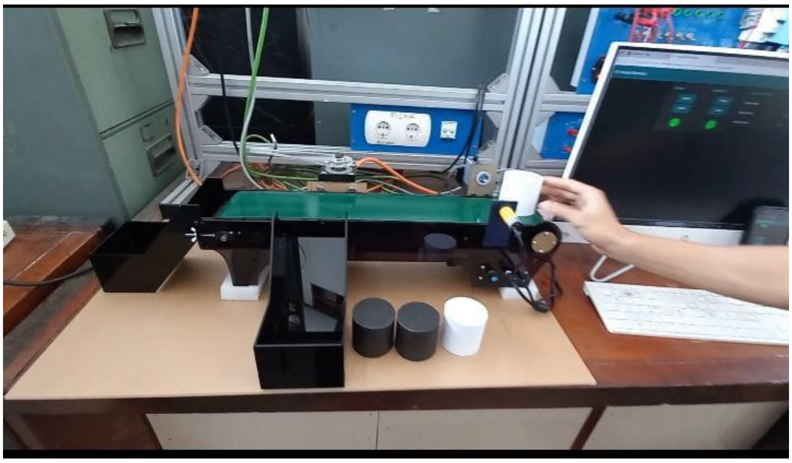

Figure 6. Test display of white object detection

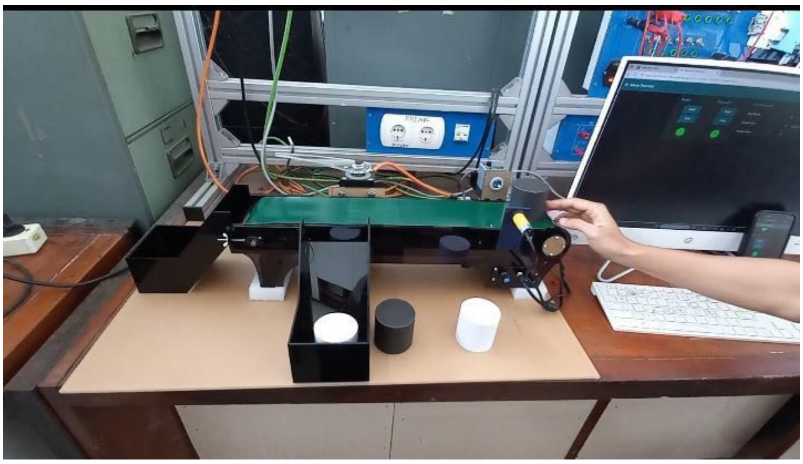

Figure 7. Test display of black object detection

The results of this sorting process are presented in Table 1, which summarizes the object color and the corresponding counter values.

Tabel 2. Sorting Results in Automatic Mode Based on Color Detection

No	Object Color	Counter		Total Objects
		Black	White	
1	Black 1	+1		1
2	White 1		+1	2
3	Black 2	+1		3
4	White 2		+1	4
5	Black 3	+1		5
6	White 3		+1	6
7	Black 4	+1		7
8	White 4		+1	8
9	Black 5	+1		9

The data in Table 1 confirms that the sorting process functions as expected. Black objects do not trigger servo movement and are counted in the black category, while white objects activate the servo to rotate to 90°, incrementing the white object counter. This mechanism illustrates the system's ability to accurately detect and classify items in real-time. To further explain the relationship between color detection, servo positioning, and monitoring feedback, Table 2 presents an extended dataset integrating the monitoring platform (HMI, PC, and smartphone).

Table 2. Color Detection, Servo Positioning, and Monitoring Integration

Object Color	Servo Position (°)	Counter	Monitoring Counter			Total Object
			HMI	PC	Smartphone	
White 1	-90	+1	+1	+1	+1	1
Black 1	0	+1	+1	+1	+1	2
White 2	-90	+1	+1	+1	+1	3
Black 2	0	+1	+1	+1	+1	4

Table 2 demonstrates that the detected data is not only used for actuator control but also synchronized with monitoring platforms. The system successfully displays position data and object count on three different devices: HMI, PC, and smartphone, in real-time. This validates that the IoT integration within the sorting system allows for seamless and simultaneous monitoring across multiple platforms. Figures accompanying this section show the interface and counter visualization on each device, verifying that the control and monitoring logic are consistent across the system architecture. The implementation supports Industry 4.0 concepts by ensuring transparency, traceability, and responsiveness in the object sorting processthis section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [14], [15]. The discussion can be made in several sub-sections.

4. CONCLUSION

This study successfully designed and implemented an automatic color-based sorting system integrated with Internet of Things (IoT) technology. The system detects black and white objects using the GDS3011W sensor, processes data through the Siemens S7-1200 PLC, and controls servo motor movement to perform automatic sorting. Test results show that the system operates accurately and responsively, with real-time data monitoring displayed via HMI, PC, and smartphone, supporting Industry 4.0 implementation. In the future, this system has the potential to be developed for multi-color classification, adaptive control, and integration with cloud-based data logging, making it applicable in various industrial sectors to improve sorting efficiency and accuracy.

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