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SCARA Robot application for automatic Vending Machine movement based on HMI and IoT

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ABSTRACT

This design discusses the application of HMI and IoT-based SCARA robots to control and monitor the movement of vending machines. The purpose of this design is to be able to perform programming on the SCARA Robot using the RC-90B ontroller and Programmable Logic Controller (PLC), design interface designs for control systems, and monitor system responses using the Human Machine Interface (HMI) and Internet of Things (IoT). As well as testing the functional performance of the SCARA robot and Node-RED. This design is supported by the RC-90B controller, Siemens S7-1200 PLC, Seimens KTP-700 Basic PN HMI, and Node-RED. A series of programming processes and making system interfaces are carried out using Epson RC-7.0 software, TIA Portal, and Node-RED. In this design, a vending machine movement process will be made, namely: pick, place, and assembly materials using vacuum and gripper assistance. In addition, the author also uses the palletizing function in the material preparation process. Then take important data such as robot speed, cycle time, and success rate, where each product is tested and get the best results with a 0% error value.

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1. INTRODUCTION

The rapid development of technology has ultimately triggered the emergence of new discoveries, both in the form of product innovation and product quality development towards better progress to make it easier for humans to live their lives [1]. One example of this technological development is the vending machine. This vending machine not only provides convenience for customers in getting goods, but also improves the operational services of service providers. The development of vending machines in Indonesia certainly also needs to be supported by an increase in the need for automation solutions, especially in the food and beverage sector which has increased over the past few years. Along with the increasing customer demand and the existence of conventional vending machines that are widely available in public spaces, it is undeniable that in the field, they often face a number of difficulties and limitations [2]. To meet this, of course, a technology is needed that is able to alleviate various problems in the field of automation, one of which is the SCARA robot.

According to the 2018 World Economic Forum survey, based on the proportion of human and machine working hours, the percentage of work produced by machines will double between 2018 and 2022. In 2022, manual labor activity increased from 31% in 2018 to 44% in 2022, indicating that automation systems in industrial machines are one of the key elements in increasing industrial effectiveness [3]. This is a strong reason for the industry to choose to use robots as a substitute for operators who have various functions, with low production costs, and are more efficient in doing unsafe and repetitive work in a much shorter time [4]. Robots are one of the automation technologies and can carry out work without the need for human assistance [5].

Vending machine control is inseparable from the Programmable Logic Controller (PLC) [6]. PLC is generally used in industry to control actuators so that they can work automatically, so that PLC can support the process of programming data processing and parameter control better [7]. Related to robot parameter control, interfaces such as the Human Machine Interface (HMI) can help the system control process. With the HMI, it can be easier to display the system process, system status and control of the system that is running [8]. The application of the Internet of Things (IoT) allows vending machine business owners to monitor and manage their operational system data in real-time, thus helping in decision making and profitability needed in the vending machine business [9],[10].

2. METHOD

The method used to collect data from the system experiment uses the experimental method. The program design will determine whether the system will work according to the vending machine movement concept, so that the final results will be obtained as expected. The design will also facilitate the program creation process. Figure 1 shows the proposed system block diagram.

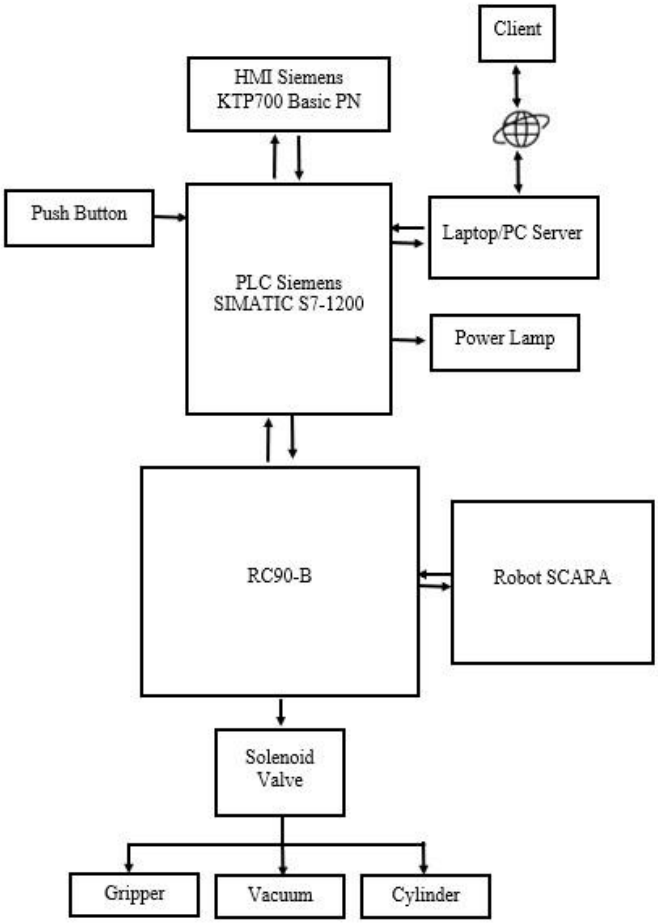

Figure 1. Block diagram of proposed system

Based on Figure 1, there are several blocks that have functions to support the vending machine work system, namely: a) RC90-B has a function as an input or output data processor that has control over the entire SCARA robot process [11], b) PLC Siemens SIMATIC S7-1200 has a function as an input or output data processor that provides instructions to the robot controller [12], [13], c) Client and HMI have a system controller function via a virtual interface display [14], d) Laptop/PC has a controller programming function, e) Solenoid Valve has a function to control the actuator when the output is given instructions by the controller [15], f) Pushbotton is an input that will provide instructions to the robot to turn on, and g) Power Lamp has a function as an output that provides an indicator.

All components are designed according to the working system of the vending machine. Figure 2 is a sketch of the vending machine that will be programmed.

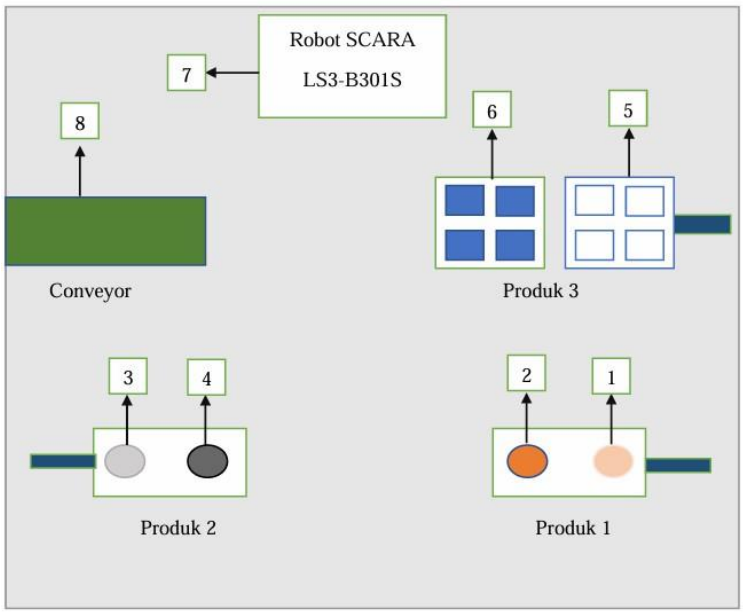

Figure 2. Sketch of Vending Machine with SCARA Robot

The following is an explanation of each of the vending machine work system designs: 1) Product Jig 1, 2) Product Pick Up Position 1, 3) Product Jig 2, 4) Product Pick Up Position 2, 5) Product Pallet Jig 3, 6) Product Pallet Position 3, 7) SCARA Robot. The vending machine sketch relates to the teaching process of each point and the I/O configuration that prevents movement from errors when giving instructions to the robot and other actuators such as cylinders, grippers, and vacuums.

In designing this vending machine, IoT technology is applied, the software used is Node-RED. The Node-RED working system is based on a flow-based programming model, the working principle of Node-RED is the vending machine control and monitoring system is always on a smartphone. The Node-RED flow design is presented in Figure 3.

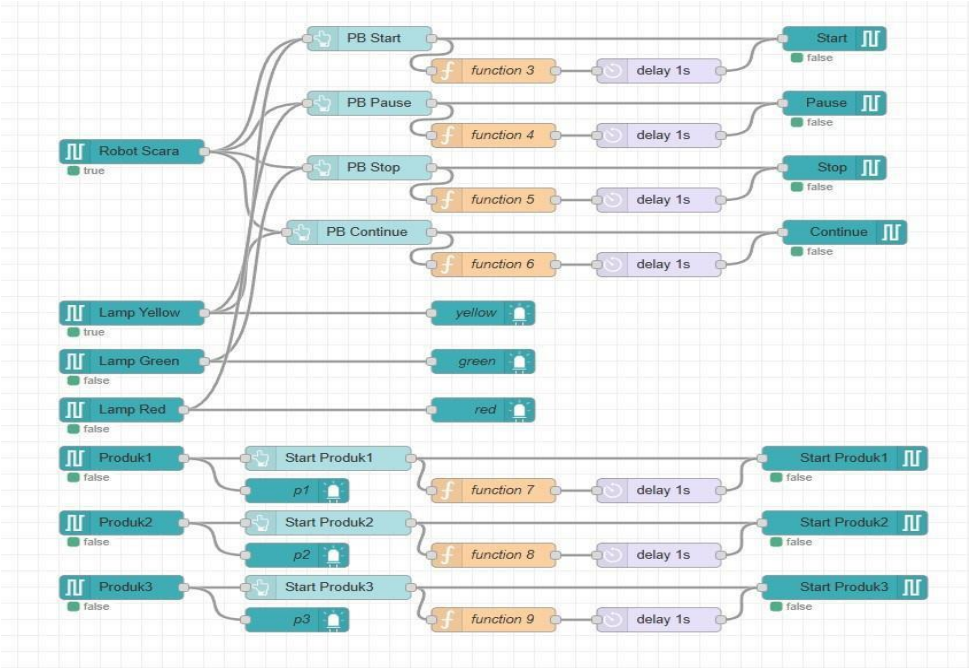

Figure 3. Flow Node-RED design

Figure 3 is the IoT visual flow consisting of several types of flows including S7 in, S7 out, function, UI LED, pushbutton, timer and UI text input. Each type of flow is connected to the PLC address in the ladder diagram.

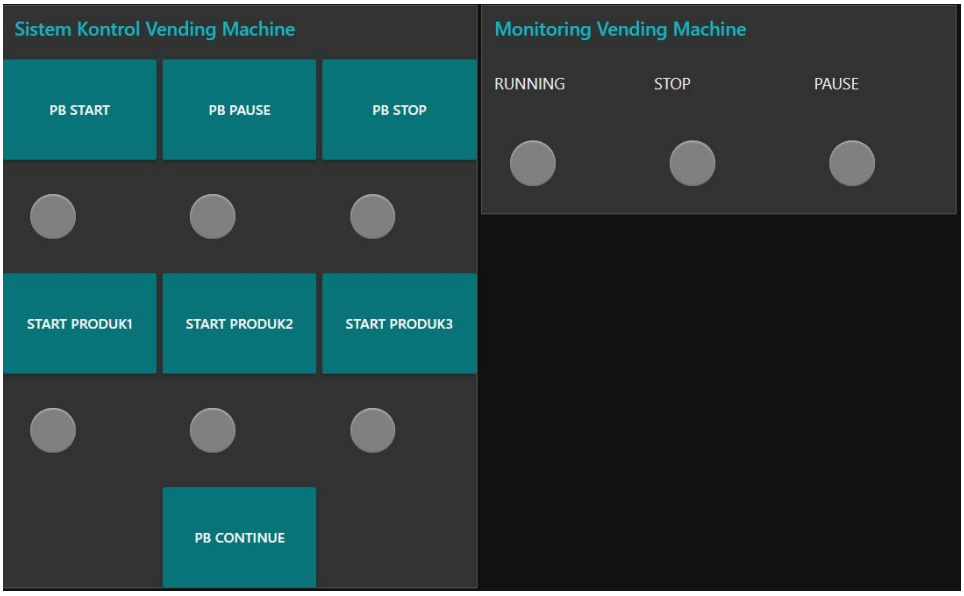

Figure 4. Visual display of the IoT interface

In order for this design to run well, a flowchart is needed in the automatic vending machine control system process [16]. The flowchart is presented in Figure 5.

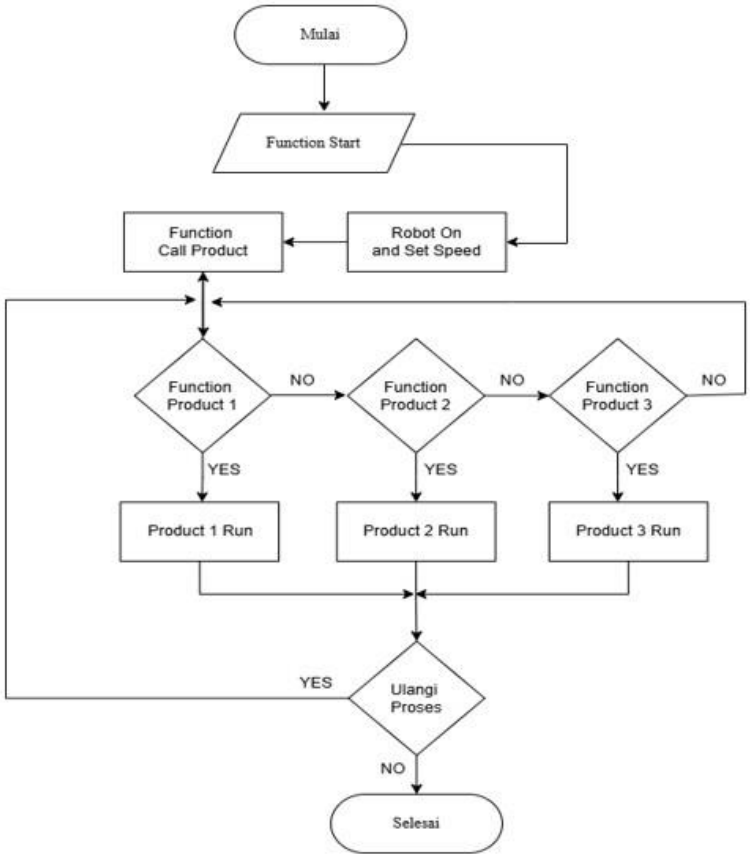

Figure 5. Vending machine flowchart

The flowchart above explains the process when the system starts working. The program is transferred to the controller and when the start button is pressed, the input will give instructions that the Robot is On with the programmed speed and is ordered to the product function, in this product function which will call each product to be processed.

3. RESULTS AND DISCUSSION

The results of this test will be used as a benchmark for the success of the vending machine work system, and the performance will be analyzed based on the results of the test, then conclusions can be drawn regarding the effectiveness and efficiency of the SCARA Robot on the vending machine. Hardware testing is carried out to evaluate the performance of the components used in the hardware. The testing process consists of testing the speed of the SCARA Robot, actuators and the design of the robot controller program. In order to obtain the effectiveness, accuracy and precision values before being used for the vending machine. The devices used in the vending machine can be seen in Figure 6.

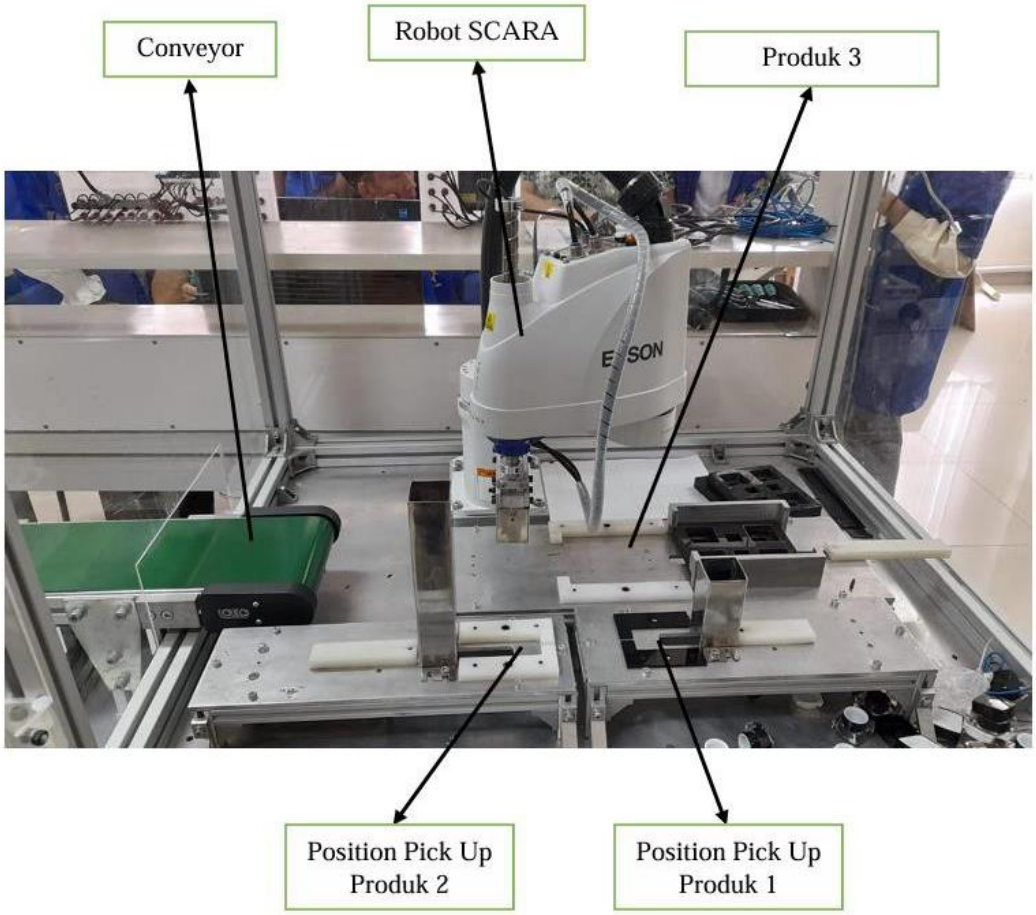

Figure 6. Vending machine display

This section explains the test results and data obtained during the design process using the SCARA Robot to perform Pick and Place and Assembly of products. For confirmation, this test was carried out on products 1, 2 and 3 with variations in speed and cycle time that will be set in the program, which are used for this experiment, namely products 1, product 2 and product 3. In order to determine the most accurate results, by finding the average of the data.

Product 1 experiment used three varying speeds, which were to provide a comparison of the success obtained during the robot process of picking up and placing product 1. The speed variations used were 60%, 70%, 80%, with high power and each speed was tested 10 times. A summary of the data conducted during the experiment is described in Table 1.

Table 1. Test data with 60% speed on product 1

Attempt Number	Speed Robot	Cycle Time	Success rate
1	60%	4.115	100
2	60%	4.101	100
3	60%	4.1	100
4	60%	4.102	100
5	60%	4.101	100
6	60%	4.101	100
7	60%	4.097	100
8	60%	4.098	100
9	60%	4.104	100
10	60%	4.101	100
Mean		4.102	100

The experiment was carried out 10 times and there were several different results. In this robot speed, the success rate of product 1 obtained was 100% and the average cycle time was 4,102 if rounded up to 4 seconds. Product 2 testing uses the robot speed according to what has been done in the program. By using three varying speeds, which is to provide a comparison of the success obtained during the robot process of picking up, assembling and placing product 2. With the working principle of product 2, the speed variations that can be used are 40%, 50%, 60%, with high power and each speed is carried out 10 times to obtain data in repetition, and to draw conclusions. Table 2 describes the results of product 2 testing.

Table 2. Test data with 40% speed on product 2

Attempt Number	Speed Robot	Cycle Time	Success rate
1	40%	6.052	100
2	40%	6.048	100
3	40%	6,048	100
4	40%	6,049	100
5	40%	6.051	100
6	40%	6.05	100
7	40%	6.052	100
8	40%	6.05	100
9	40%	6.051	100
10	40%	6.05	100
Mean		6.05	100

The working principle of product 3 uses the pallet and assembly method, so the experiment was carried out 5 times with a speed of 10% that has been done in the program. To determine whether the robot can work accurately and precisely by considering the level of product success and the time required when operating. Table 3 explains the summary of data carried out during the experiment.

Table 3. Test data with 10% speed on product 3

Attempt Number	Speed Robot	Cycle Time	Success rate
1	10%	40.268	100
2	10%	40.207	100
3	10%	40.205	100
4	10%	40.208	100
5	10%	40.215	100
Mean		40.22	100

Software testing is done to evaluate the performance of the components used in the software. The testing process consists of testing each function used in the Node-RED flow and the integration between HMI and Node-RED or vice versa. In order to get an efficiency value before being used for vending machines. The first experiment was carried out to ensure the integration of the HMI to the Visual IoT Dashboard Node-RED or vice versa, here some of the visuals that will be used are the PC server as the master for the IoT by connecting it to the PLC using Ethernet. Smartphones and HMIs are also test visuals. The testing stage by pressing the basic control pushbutton, such as start, stop, pause, then it can be known whether when the basic

control function gives a signal to the PLC whether it will be responded to by the Robot. To find out whether when PB start is pressed Robot On and when PB stop and PB pause are pressed Robot Off, one of the indicator lights will provide information that the system is running according to the design. Figure 7 shows the HMI, PC server and smartphone displays.

Figure 7. Display of HMI, PC server and smartphone, a) Activation of Product 1 button on HMI, b) Activation of Product 2 button on HMI, c) Activation of Product 1 button on PC server, d) Activation of Product 2 button on PC server, e) Activation of Product 1 button on smartphone, f) Activation of Product 2 button on smartphone

4. CONCLUSION

Based on the test results that have been carried out, it can be concluded that using SCARA robots is more efficient in running the process, because this robot has a good level of precision and stability. The visual design of the Internet of Things (IoT) and Human Machine Interface (HMI) that was designed was successfully applied to the system to control and monitor the vending machine system.

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