Design of Sorting Machine Prototype in Electronic Circuit Based on NI-MyRIO 1900

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Abstract. Nowadays, the laboratory at STTN-BATAN prepares and returns components to the storage area manually, where this has the disadvantage of the possibility of making a significant mistake. Therefore, a prototype of a sorting machine is made that can sort electronic components automatically on the conveyor. The sorting machine is made with the 1900 NI-MyRIO controller. Components that pass above the conveyor are taken. Images from components will then be processed by means of color pattern matching which will compare the image of the component with the template that has been stored in the program. The object in this study is a resistor component that is above a PCB, with a large resistor that is different. The PCB that has been compared with the template will be passed from the conveyor for a certain time and then driven by a servo motor to the storage area with a separator block. In addition, the type of resistor and the amount will be read and displayed on the user's computer. From the test results, it was found that the accuracy of the sorting machine was 91% with precision being 93%.

1. Introduction
The Institute of Nuclear Technology (STTN) is one of the vocational schools in Indonesia with a focus on education in the field of nuclear sciences. Currently, component storage management is carried out manually by the laboratory assistant (the process of returning components is based on sorting manually through the laboratory assistant), which has the potential to make quite a large error because it is greatly influenced by the physical condition of the laboratory assistant. This is due to the absence of an automatic sorting machine which can choose components according to the type of component. Sorting is the process of rearranging objects that should be arranged with a certain pattern, so that they are arranged regularly according to certain rules. There are several types of sorting machines available today, one of which is a sorting machine that uses conveyors [1].

This sorting machine uses myRIO as a controller and the camera as an eye replacement sensor. The machine will be operated using LabVIEW software based on a color pattern matching algorithm and then the number and type of components sorted are displayed[2]. Color pattern matching is a unique approach that combines color and spatial information to quickly find color patterns in an image. It uses the technology behind color matching and gray pattern matching synergistically to find color patterns in color images. Color pattern matching places reference patterns in an image even when the pattern in the image is rotated and slightly scaled. When a pattern is rotated or scaled on the image, color pattern matching detects the features of the image in the form of a pattern in the picture, the position of the pattern in the picture, the orientation of the pattern, as well as some examples of patterns in the image if any. In automatic machine vision applications, the visual appearance of the material or component
being examined may change due to factors such as part orientation, scale change, and lighting change. Color pattern matching maintains its ability to find reference patterns and provide accurate results regardless of these changes [3].

The object used in this study is a PCB that contains resistors with different resistor sizes. The automatic sorting machine will facilitate the laboratory work, especially in the process of returning components that have been used by students to storage areas according to their type.

2. Materials and Research Method

2.1 Initial Data Retrieval

The initial data retrieval is done to obtain information on various devices and get an overview of the system to be made in general. This process is done by taking data tools and materials from various sources to see which ones are suitable with the needs of the sorting system. The results of initial data retrieval is the design of the system to be designed. The Fig. 1 shown the design of the sistem.

![Figure 1. Design of The System](image1)

2.2 System Hardware Design

Wiring design was made for the conveyor system and camera wiring. Then the hardware design is arranged including the size and dimensions of the conveyor as well as the supporting device and its sorting chamber, such as LED lamp [4]. The design of conveyor system and camera is shown on Fig. 2 and Fig. 3.

![Figure 2. Conveyor System Wiring Diagram](image2)
Figure 3. Camera Wiring Diagram

The conveyor has a length of 1 meter and a width of 10 cm made of acrylic material with a sorting chamber located in the middle of the conveyor. Sorting room itself has a length of 20 cm, height 15 cm and width of 10 cm according to the width of the conveyor. In this conveyor a pulley of 1.2 cm in diameter is used, then given a gear of 3 cm in diameter. The sketch of the conveyor frame and its design from the top view shown in Fig.4 and Fig.5.

Figure 4. Sketch of The Conveyor Frame

Figure 5. Design From The Top View

In this tool the installation and testing of components used such as camera installation, lighting, DC motor and L298N driver, servo motor, and wifi installation on myRIO.

2.3 System Software Design

The sorting system is programmed using LabVIEW 2018 which will also be the interface between the user and the tool. In summary, there are two major programs to control the sorting system, namely the actuator control program and the image processing program for sorting [5]. Overall, the block diagram of the sorting system is shown in Fig.6.
The state diagram of the program created is shown in Fig. 7.

**Figure 6. Block Diagram of The Sorting System**

The program structure in this system is producer-consumer queues, where there are 2 main parts, namely the producer as the program head who controls the course of the consumer section. In addition there is a loop stop button that will stop the program running. In the producer section there is a sensor reading program, the reading results will control the program in the consumer section where in that section there is a DC motor control program, image capture, image analysis, and DC motor control. Communication between loop producers and consumers uses queues that carry data into a "queue" so that no data is lost.

2.3.1 Producer Loop

Producer loop there is an LDR sensor reading program where the resistance value of the sensor will control the course of the program. If the resistor in the sensor reads 59-70kOhm, the DC motor will be active and run the conveyor. Meanwhile, if the resistance in the sensor reads 50-58kOhm, the DC motor will stop and the component sorting process will occur. This value is obtained from experimental results. In addition to the sensor reading, there are queues for the stop button that will stop the DC motor and the whole program directly. The results of readings from the sensor will be the case selector to determine the conditions that occur in the tool. Because the case selector of the case structure has the numeric format I32, the sensor readings must be converted from DBL to I32. If the sensor resistance value shows a range of 59-70kOhm, the program will enter the case containing the enum constant with the state "Motor on". Meanwhile, if the sensor resistance value shows a range of 50-58kOhm, it will enter the case containing the enum constant with the state "Motor off". This enum constant will be sent to the consumer loop via the enqueue element.
2.3.2 Consumer Loop
Consumer loop consists of several programs. Data sent from the queue in the producer loop is received by the consumer loop, then the data sent out of the dequeue element function will then be the case selector of the case structure contained in the consumer loop. There are 2 cases in this program, according to the contents of the defined enum. In the case of "Motor off" there are DC motor control programs, image acquisition, image processing, DC motor settings with timers, and servo motor programs. While in the "Motor on" case there is a DC motor control program. The stop program itself is in different loops with different queues to avoid dependencies between loops. The function of this loop is to stop all processes that occur when the program runs and also stop the DC motor.

2.4 Testing
Characterization of the components has been carried out as well as testing on the whole sorting machine. Characterization of LDR sensors, servo motors, DC motors, and camera configurations were performed. In addition to component characterization, testing is also carried out on the whole sorting machine. In the overall test, five tests were conducted, namely testing with PCB images, testing with the same PCB as the template, testing with reject PCB, testing with random PCB, and testing the variation of PCB positions.

3. Result and Discussion
3.1 Component Characterization Results
3.1.1 Sensor Characterization
Sensor characterization has been done to see the sensor response to the position of the components placed differently. From the test results, the test results obtained in Table 1 are obtained.

| Components Position (cm) | Sensor Output (kOhm) |
|-------------------------|----------------------|
| 4                       | 39                   |
| 5                       | 41                   |
| 6                       | 42                   |
| 7                       | 45                   |
| 8                       | 44                   |
| 9                       | 47                   |
| 9,8                     | 46                   |

If there are no components in the sorting chamber, the LDR sensor will give a resistance value between 50-60 kOhm. Meanwhile, if a component is detected in the sorting chamber, the sensor will show a resistance value between 37-47kOhm.

3.1.2 Servo Motor Characterization
Servo motor characterization has been done using a servo motor control program based on the given position. From the results of the characterization, obtained results in Table 2.

| Position Input | Angle (°) | Distance of Separator Block to Object (cm) | Result                             |
|----------------|-----------|------------------------------------------|------------------------------------|
| 50             | 67,5      | 3,2                                      | Separator blocks do not push objects. |
| 100            | 135       | 2,7                                      | Separator blocks do not push objects. |
| 120            | 144       | 2                                       | Separator blocks do not push objects. |
| 140            | 153       | 1,5                                      | Separator blocks do not push objects. |
| 160            | 162       | 0                                       | Object touched, not pushed.         |
| 180            | 171       | 0                                       | Object partially pushed.            |
| 200            | 180       | 0                                       | Object fully pushed.                |

From the characterization results, it is found that the component can be pushed until it falls to the side of the conveyor with an input position on the motor of 200.
3.1.3 DC Motor Characterization
Characterization of DC motors to determine whether DC motors can be controlled with the driver used. The DC motor must be driven so that the component approaches and enters the sorting chamber. From the test results, the results are contained in Table 3.

**Table 3. DC Motor Characterization Result**

| Input Logic AO11 AO13 | Output Voltage (V) | Result                                      |
|-----------------------|--------------------|---------------------------------------------|
| T F                   | 3,3                | Components away from the sorting chamber.   |
| F T                   | 3,3                | The component approaches the sorting chamber.|
| F F                   | 3,3                | Motor DC stopped.                           |

3.1.4 Camera Configuration
The camera configuration using NI-MAX software is performed with the results set out in Table 4.

**Table 4. Camera Configuration Result**

| Attribute Kamera      | Hasil                     |
|-----------------------|---------------------------|
| Brightness            | Manual mode, 141.         |
| Contrast              | Manual mode, 32.          |
| Saturation            | Manual mode, 32.          |
| Sharpness             | Manual mode, 22.          |
| Backlight compensation| Manual mode, 1.           |
| Gain                  | Manual mode, 43.          |
| Power line frequency  | 60Hz                      |
| Exposure              | Manual mode, 551.         |
| White balance         | Manual mode, 6266.        |
| Focus                 | Manual mode, 55.          |
| Zoom                  | Manual mode, 1.           |

3.2 Hardware Result
A component sorting machine hardware has been made with dimensions of length 100 x 10 x 24 cm. The material used to make conveyors and their sorting chambers is transparent acrylic with a thickness of 5mm acrylic. In the sorting room itself there are LEDs that are above the room, where the LED's intensity is reduced by black plastic, then right below it there is an LDR sensor that has been assembled with a resistor to detect components that will pass in front of it. The camera is directly above the sorter room and has been fixed there. The results of the manufacturing tools are shown in Fig.8 and Fig.9.

![Figure 8. Hardware Result](image-url)
3.3 Software Result
A sorting machine program has been created where the program is created in LabVIEW 2018 software with the appearance shown in Fig. 10.

![Figure 10. Software Result](image)

3.4 Testing
3.4.1 Testing with PCB images
The first test is to use a PCB image that has been printed on a piece of paper, then affixed onto a styrofoam so that it can be detected by an LDR sensor. The printed image has several variations. The image of the PCB used as the template itself is shown in Fig. 11.

![Figure 11. PCB Object](image)

With variations on these objects the results obtained as set out in Table 5.

| Input Images          | Result                  |
|----------------------|-------------------------|
| Original size image  | PCB detected normal.    |
| Image enlarged 30%   | PCB detected reject.    |
| Image reduced 30%    | PCB detected reject.    |
| Image darkened 10%   | PCB detected normal.    |
| Image lightened 10%  | PCB detected normal.    |
From the test it was found that the color pattern matching algorithm can detect the PCB as an object at its original size, as well as the slightly altered lighting conditions. The program cannot detect an enlarged and reduced PCB because the patterns on the PCB are considered to be different and the program cannot adapt to these changes.

3.4.2 Testing with the same PCB template
The second test is passed PCB which contains resistors with certain patterns and angles that vary 10 times. PCB that is passed is PCB with the same pattern as the template in the program. The results of this second test are shown in Table 6.

| PCB- | Result          |
|------|-----------------|
| 1    | Detected Normal.|
| 2    | Detected Normal.|
| 3    | Detected Normal.|
| 4    | Detected Normal.|
| 5    | Detected Normal.|
| 6    | Detected Normal.|
| 7    | Detected Normal.|
| 8    | Detected Normal.|
| 9    | Detected Normal.|
| 10   | Detected Normal.|

From the results of the second test, the program can adapt to the angle changes made to the input. The results of this test will go into the calculation of accuracy and precision to see the performance of the tool.

3.4.3 Testing with reject PCB
The third test is the passing of the PCB with an attached resistor made different from the template embedded in the program. In this test will see whether the program can detect the PCB "reject" or not. From the test results, the results obtained as set out in Table 7.

| PCB Condition          | Result                        |
|------------------------|-------------------------------|
| One R4KΩ is removed    | PCB is detected as reject item.|
| One R22Ω is removed    | PCB is detected as normal item.|
| One R10KΩ is removed   | PCB is detected as reject item.|
| One R330Ω is removed   | PCB is detected as reject item.|
| One R680Ω is removed   | PCB is detected as reject item.|
| 2 Resistor are blackened | PCB is detected as reject item.|

From the third test results obtained that the sorting machine can detect correctly that the PCB entering the sorting room is a reject PCB, when a condition occurs one of the resistor components is removed, or blackened. This is because the value of sample compatibility with the template has a much lower number so that the PCB is considered to be a reject component.

3.4.4 Testing with random PCB
The fourth test is a test where the normal component is rejected by the reject component to see how the program responds if the incoming sample is of different type. The results of this fourth test are set out in Table 8.
From the test results obtained that there are two failures. But compared to the success of the program in sorting samples, program failure only occurred 2 times out of 18 trials.

3.4.5 PCB placement variation testing
In the fifth test, variations in the conditions of placement of components were passed to the conveyor. From this experiment the results obtained as in Table 9.

| Condition of the first and second PCB                                      | Result                                      |
|---------------------------------------------------------------------------|---------------------------------------------|
| 0cm distance                                                              | Detected two pallets, program interrupted.  |
| 1cm distance                                                              | Detected two pallets, program interrupted.  |
| 5cm distance                                                              | Detected two pallets, program interrupted.  |
| 10cm distance                                                             | Detected two pallets, program interrupted.  |
| The second palette enters after the first palette leaves sorting room     | The program in the flat sequence is still running, the data from the detection of the second program will be deleted. |
| The second palette enters when the first palette will be pushed by separator block | The program in the flat sequence is still running, the data from the detection of the second program will be deleted. |
| The second component enters after the first component is pushed by separator block | One palette detected, the program runs well. |

3.5 Performance

3.5.1 Accuracy
From the results of calculations based on data in the second, third, and fourth tests, the following accuracy is obtained.

\[ tp = 26 \]
\[ fp = 2 \]
\[ tn = 5 \]
\[ fn = 1 \]

\[ \text{Accuracy} = \frac{tp + tn}{tp + fp + tn + fn} \times 100\% \]
\[ \text{Accuracy} = \frac{26 + 5}{26 + 2 + 5 + 1} \times 100\% = 91\% \]

3.5.2 Precision
From the calculation results obtained the following precision values.

\[ tp = 26 \]
\[ fp = 2 \]

\[ \text{Precision} = \frac{tp}{tp + fp} \times 100\% \]
\[ \text{Precision} = \frac{26}{26 + 2} \times 100\% = 93\% \]
4. Conclusion
A myRIO-based component sorting machine has been designed and made with a camera instead of an eye sensor. Used a PCB with a resistor circuit as an object to sort by also displaying the number of resistors detected in the program. The sorting machine has an accuracy value of 91% and a precision value of 93% from 34 test data.

5. References
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