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Design and Construction of Duku Sorting System Based on Size Using a Microcontroller on Conveyor Work

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Abstract

Duku (*Lansuim Domesticum Corr*) fruit harvesting is generally done manually by farmers in Indonesia so that the quality of the duku fruit, especially the uniformity of size, is not considered. The impact of this harvesting is a decrease in fruit quality and a decrease in selling prices. It is necessary to develop a new sorting machine for duku so that the fruit size is accurate. This research aims to make a sorting system for duku fruit based on size using a microcontroller on conveyor work. The sorting system uses two sensors, VL53L0X and FC-51. The design has a servo actuator to separate the fruit classes. This study developed a correct sorting of duku fruit sizes up to 97.4%, counting accuracy up to 99.4%, system stability up to 96.65%, and transient response of 100 ms. The result of testing this tool is that the ability of the Duku fruit sorting system based on size has a stability value of 96.6%. The transient response obtained is 100ms. The accuracy of the perfect sorting results is 97.4%, and the calculation of the number of duku using the system is 99.4%. The conclusion is that the researchers can create a sorting system based on size using a microcontroller on conveyor work.

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INTRODUCTION

Duku (*Lansuim Domesticum Corr*) is a fruit plant that grows in tropical climates. There are several types of duku in Indonesia, such as the Komering duku, Condet duku, and Matesih duku. Duku fruit generally has a transverse diameter ranging from 1.5 cm to 3.5 cm. The longitudinal diameter of the duku is 2 cm to 4.5 cm [1]. Determination of high-quality duku fruit, namely thin, clean, yellowish skin, fruit without seeds, sweet taste, and uniform size. Determine the quality of duku, namely based on size, appearance, packaging, labeling, and hygiene. This quality is regulated in SNI 6151. SNI regulations also determine the division of duku fruit classes based on size. Duku fruit classes are divided into three, namely large sizes with a transverse diameter of more than 3 cm, medium sizes of 2.5 – 3 cm, and small sizes under 2.5 cm [2].

A sound control system must be the solution for this system to produce a reasonably accurate sorting [2]. Several studies were done about the fruit sorting system. Martinus et al. showed that sorting is essential in grouping duku. It can be categorized of the same age so that duku can be selected for mature local markets, duku for external needs that are immature and will mature in transit, and duku that are defective. The ability of the duku fruit sorting tool on this microcontroller-based conveyor system can separate duku fruit based on the color distance obtained by using the closest color distance

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equation to Super, A, and B classes [3]. The Arduino microcontroller-based semi-automatic fruit ripeness sorting tool has worked consistently to distinguish ripe and raw peppers with a success rate of 93.3% [4]. The organoleptic results carried out by five observers on each of the tomatoes and oranges had the same results as the readings on the fruit sorting device. So, we can conclude that the sorting tool has been successful with 100% accuracy. The R/G value on the sorting tool also has good integration with the servo motors [5].

The78rocesss of maintaining the quality of duku fruit must be done automatically. The process that is carried out automatically is developing the duku fruit sorting system. If the sorting process can be done automatically, it can prevent the fruit from being damaged due to the separation process.

Non-uniformity in size can determine the quality and price of duku fruit. The best quality duku fruit will be a high selling price. The different sizes of duku are due to the manual harvesting process. The sorting needs to be done to classify the quality of the fruit. The sorting process can be done in two ways, namely manually and using a machine. Manual sorting is the process of separating fruit by human resources. The drawback of the manual sorting process is that it takes a long time. Manual sorting can reduce the quality of duku before it is marketed. Duku fruit will experience discoloration of the skin and rot if stored for a long time. Duku fruit that has turned brown will experience a decrease in quality. The fruit will change color on the fruit skin for 4 to 5 days after the duku is harvested. The color can be detrimental if the duku fruit has not been marketed[6].

Sorting machines usually use a mesh screen and require gravitational force. Sorting by mesh screen resulted in some of the duku being damaged. The fruit sorting process caused the damage [7]. The damage is due to collisions and duku fruit being squeezed during sorting. Therefore, it is necessary to develop a duku fruit sorting tool that does not damage the fruit in the sorting process. These various problems require a strategy to determine duku class to determine the quality and reduce losses in the market. Good post-harvest technology is needed to control the quality of duku fruit [8].

This system is used to sort the uniformity of duku fruit size. The system is mounted on the conveyor belt [9], [10]. Installation on the conveyor belt is intended so that the duku fruit is not damaged and makes it easier to detect fruit quality. The Belt Conveyor is designed to be lightweight for easy portability by farmers. The technology is expected that farmers can sell duku fruit at prices according to quality. The technology is also likely to reduce consumer losses in buying duku fruit. Many industrial processes shift from manual systems to automation systems. Automated systems are easier to control by human roles[11], [12]. However, the difference between this research and previous researchs is that this research has the purpose of making a sorting system for duku fruit based on size using a microcontroller on conveyor work.

METHOD

Tools and Materials

This research was conducted at the Mechatronics Center, Department of Mechanical Engineering, University of Lampung. The tools and materials used in this study are the VL53L0X sensors, FC-51 sensor, SG90 servo motor, power supply 24V, Arduino mega, TCA9548A module, LCD I2C, power supply 5V, PWM, calipers, 24 V DC motor, belt, UNP iron, UCP bearing, 3-inch pipe, multitester, and fruit duku. The VL53L0X sensor is calibrated using a caliper with an accuracy of 0.05 mm.

Research Implementation

The research was carried out in several stages, namely: the planning stage, the assembly stage, the programming stage, the tool calibration stage, the design result testing phase, and the data analysis stage. The planning stage is carried out by analyzing the sorting system to determine the location of the part of the control system as well as the design of the sensor layout, control devices, and the mechanism of the duku fruit sorting system. The method of the sorting system divides several parts of the control system, namely the data processing and sorting actuators. The components of the sorting system can be seen in Figure 1.

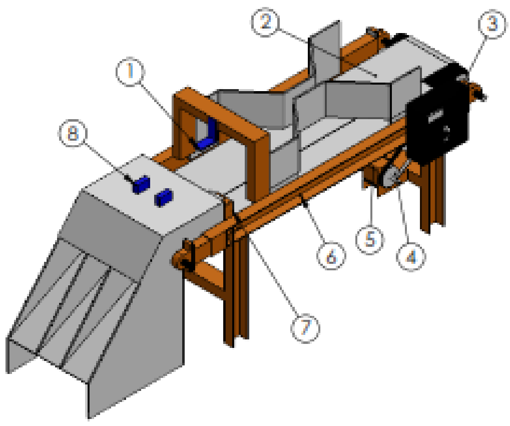

Figure 1. Sorting System Design

Description:
1. VL53L0X sensor
2. Belt conveyor
3. Box controller
4. Transmission
5. DC Motor
6. Frame conveyor
7. FC-51 sensor
8. SG90 servo

The manufacturing stage is divided into several stages: making the conveyor belt, making programs, and assembling hardware. Making the conveyor belt is carried out following the design of the sorting system—the stages of making a program under the desired work. Hardware manufacturing is done by assembling electronic paper devices on a conveyor belt. An automatic definition is a tool or machine that can move and work independently. Automation replaces human labor with machine power that automatically performs and regulates work to no longer require human supervision [13].

The program was created using software Arduino IDE version 1.8.10. The program that has been made is installed on the microcontroller—programs created according to designed work orders. The programming flow includes orders to take the fruit dimensions by the VL53L0X sensor reading, and it accepted the condition of the duku fruit by the FC-51 sensor—data processing by a microcontroller. Then, display the reading results on the LCD. The microcontroller also functions as decision-making and passes it on to the servo.

The sensor calibration stage is used to equalize the output value of the measuring instrument in general from the equation obtained [8]. Sensor calibration is done by testing the control device to read the height of the sensor position. Sensor calibration is also done with the part of the fruit duku when it is on top of the conveyor belt working. Testing is done by comparing the reading results of the system with the calibrator. The calibrator used to calibrate the VL53L0X sensor is a caliper. Data from the VL53L0X sensor calibration were analyzed using a linear regression method. The sensor positions' height variations are 55 mm, 60 mm, 65 mm, 70 mm, 75 mm, and 80 mm. The regression analysis results of the VL53L0X sensor calibration obtained the equation. The equation is entered into the program as a sensor measurement correction factor. Instruments with high validity reflect that a measure of the measurement results is under the actual situation of what the device has made [14].

The control system was tested using duku fruit samples from various size classes. Determination of duku fruit class based on the size specified in SNI. Class A duku fruit size> 3 cm, class B 2.5 cm – 3 cm and class C <2.5 cm. The first test is the effect of the rotation speed conveyor belt on the success of the sorting results. Rotation speed Conveyor belt by regulating the drive motor tension. The voltages are 16V, 18V, 20V, 22V, and 24V. The number of duku fruit samples used was 60 from each class totaling 20 pieces.

Furthermore, the test carried out is transient response testing. Short response testing is done to see the time it takes the VL53L0X sensor to detect fruit size. This test is done by making a cube-shaped reading sample. The cubes are made to the maximum size of the duku fruit. The next test is testing the accuracy of the system's success. This test Is conducted to determine the accuracy of the system. This test tests 100 duku of various size classes. Trying the system's accuracy compares the sorting results with the actual results. The last test is testing the stability of the system. This test aims to determine the tool's strength for sorting the same duku.

RESULTS AND DISCUSSION

Results of Control System Design

The main result of the duku fruit sorting system design based on size classes is a control device (Figure 2). The control device consists of a microcontroller (Arduino Mega 2560 with a flash memory capacity of 256 Kb), VL53L0X proximity sensor, FC-51 sensor, LCD, TCA9548A module, and SG90 servo motor. The microcontroller is the control center's brain that controls all the components that have been made. Microcontrollers generally work at a voltage of 5 -12 volts. In this study, the voltage source used in the microcontroller comes from a power supply of 5-volt DC.

This study uses a VL53L0X sensor that is placed on the conveyor belt. The VL53L0X sensor functions to measure the diameter of the duku fruit. The VL53L0X sensor works using a laser beam reflected by the emitter to the transmitter. The reflection of the laser light will form an angle which is then translated into a quantity of distance[15]. The results of the measurement of the duku fruit are then used to select the servo that will move. In the series, the VL53L0X sensor is connected to the TCA9548A module and then to the Arduino Mega. The TCA9548A is used to combine several I2C used in control systems.

The FC-51 sensor is used to detect the presence or absence of fruit. This sensor can detect the presence of objects around it without physical contact with the object [16], [17]. The FC-51 sensor functions to detect the presence of duku that will be seen. Then the FC-51 sensor sends a signal to tell the servo time to run. The FC-51 sensor also functions to count the number of duku fruits. The FC-51 sensor will detect objects passing in front of the FC-51 sensor.

The TCA9548A module is used to connect several components that use I2C. The TCA9548A module used can connect 7 I2C pieces. Liquid Crystal Display (LCD) is an alphanumeric type LCD in this study. The LCD used has a size of 20 x 4—the LCDs data on the size of duku and the number of duku fruit. The data displayed by the LCD is the maximum size data read by the VL510X sensor. The LCD also shows the number of fruits detected by the FC-51 sensor. There are two servo motors used in this study. Servo motors open and close the path (gate) duku fruit separator. This servo works separately, according to the criteria for the size class of duku fruit.

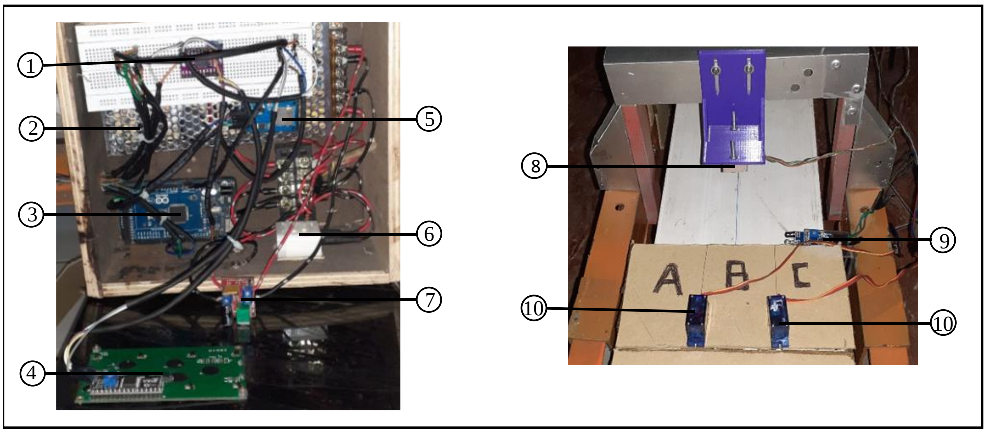

Figure 2. Sorting Control Tool

Information:

1. TCA9548A Module
2. Power supply 24V
3. Arduino Mega
4. LCD
5. Data logger
6. Power supply 5 V
7. PWM
8. VL53L0X Sensor
9. FC-51 Sensor
10. SG90 Servo

Results of Calibration and Validation of Control Tools

Calibration is carried out for primary verification in the measurement process by the sensor. Calibration is done by comparing the measurement of the VL53L0X sensor with the calibrator. The calibrator used is a caliper. The calibration process is carried out by comparing the height reading of the sensor position. The sensor position's height is measured using a system and a caliper. The Lidar VL53L0X sensor can read the measurement distance between 20 mm to 1300 mm[18]. The heights used are 55 mm, 60 mm, 65 mm, 70 mm, 75 mm, and 80 mm.

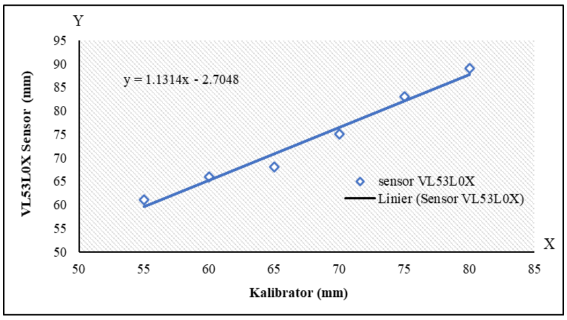

Figure 3. Calibration of the VL53L0X Sensor at The Position of Sensor

The data from the sensor height measurement results are analyzed. The analysis carried out is linear regression. The results obtained from comparing the VL53L0X sensor and the calibrator are equations. The equation is $y = 1.1314x - 2.7048$. From these equations made in programming function as a sensor reading correction factor. The value of x is the sensor reading before calibration, and y is the sensor's measurement after the calibration process. After the calibration process, validation was carried out to prove a mechanism. The results obtained from comparing the sensor and the calibrator are the correlation coefficient (R)[19] from the sensor correlation coefficient value of 0.977 or 97%.

Control System Performance Test Result

The first performance test is to test the effect of the rotation speed conveyor belt on the success of the sorting results. In this test, 60 samples of duku were used from each size class. The test was carried out using variations in the working voltage of the drive motor and conveyor, namely 16V, 18V, 20V, 22V, and 24V.

Table 1. Effect of Belt Conveyor Rotation Speed in the Success of Duku Fruit Sorting.

	Motor Voltage	16V	18V	20V	22V	24V
Class I	Perfectly sorted	18	17	18	15	16
	Mixed	0	0	0	0	0
Class II	Perfectly sorted	20	20	2	15	13
	Mixed	2	3	20	5	4
Class III	Perfectly sorted	20	20	2	20	20
	Mixed	0	0		5	7

The speed effect is very influential when the VL53L0X sensor reads the diameter of the duku fruit. Significant sensor reading error when the rotation of is conveyor belt gets higher. At a motor voltage of 24 V, 11 slips were mixed. At the same time, the lowest slip occurs at a 16V motor voltage of 3 mixed pieces. It can be concluded that the lower the motor rotation, the lower the error value is generated.[20].

The next test is to determine the response system transients. This test is done by taking a sample of a cube shape with a size of 3.5 cm on each side. This size is included in the size of the duku class A. When the sensor reads more than 3.5 cm, the reading is one so that when it reads below 3.5 cm, it is considered 0. The time from 0 to 1 is the system's transient response. The Response transient measures the time the system is used until it reaches the maximum object size. The Response transient requiring a sensor is a time average of 100 ms. The results of the system response test show that the VL53L0X sensor can detect objects very quickly. The VL53L0X sensor can see it soon because it uses a laser beam.

Testing a tool's accuracy level is needed to determine the accuracy value of the tool's performance [21]. Accuracy is the accuracy in reading or controlling the object to match the value set point or is at the real value [22]. This test is carried out using duku fruit samples from various classes. Then do the sorting and counting of the duku fruit.

Table 2. Testing the Accuracy of the System's Success

Repetition	Number of Samples (pieces)	Sorting (pieces)		Amount in System Reading (pieces)
		Perfect	Mixed	
1	100	99	1	100
2	100	93	7	98
3	100	97	3	99
4	100	99	1	100
5	100	99	1	100

This test was carried out using 100 samples of duku fruit from various classes. The belt conveyor is set at a motor voltage of 16 V. From data table 2, the average accuracy rate of the sorting system is 97.4%. The accuracy rate of the counting system for the number of fruits is 99.4% on average. So, it can be concluded that the sorting results depend on reading the VL53L0X sensor diameter and detecting the presence of duku by the FC-51 sensor. The VL53L0X sensor has a rate error measurement of ±3 mm. So, when seeing duku fruit with a diameter close to ± 3 mm with a class diameter limit, it can fail to detect fruit class groups. The FC-51 sensor can fail to detect the presence of duku fruit. When the VL53L0X sensor has detected the duku fruit group, the FC-51 sensor does not see the presence of duku fruit. Then it can result in the servo motor not working and cause errors in the sorting process.

Stability testing is carried out to determine whether the performance of a system is constant over time. Stability determines whether the tool can produce the correct performance over a long period [23]. Testing the duku fruit sorting system based on fruit size used a sample of 100 pieces from all classes. Two tests for stability were carried out, namely, the strength of the sorting results and the stability of the calculation of duku.

An unstable system is a system in which certain conditions cause the controlled variable to constantly shift at a specified value or change to an increasingly enlarged oscillation process[25]. The system created has a high stability level because each experiment produces a detection deviation level that is not much different[24]. The stability test results of the success of the sorting results show relatively stable results with an average deviation of 3,4. In the stability test, the calculation results of duku fruit, the most significant variation is three duku. The error of this calculation results in the success of the outcome of the sorting of duku fruit.

Several factors affect the success of sorting using this system, including:

1. If the dimensions of the duku are ± 3 mm from the class size limit, it will incorrectly detect the group because the VL53L0X sensor has an error rate of ± 3 mm.
2. Suppose the duku that will pass through the FC-51 sensor is too crowded; the FC-51 could not detect the presence of the next duku fruit. This resulted in the FC-51 sensor being unable to send a signal to the servo to work according to the size class of the duku. In addition, it can result in an error counting the number of sorted duku.
3. There will be a vibration when the belt conveyor works, especially in the belt. This vibration resulted in an error in the process of detecting fruit size. Besides, it could result in the FC-51 sensor detecting the presence of duku.

CONCLUSION

The testing results are, first, the ability of the duku fruit class sorting system based on size has a stability value of 96.6%. Second, the transient response obtained is 100ms. Third, the accuracy of the perfect sorting results is 97.4%, and the counting of the number of duku fruits using the system is 99.4%.

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