The Design of the Divider Door for the Orange Grading Machine Based on the Diameter and Color Uses Image Processing

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Abstract. Post-harvest handling will affect the quality of agricultural commodities. One of the main post-harvest activities of orange fruit is grading. Grading is an activity to separate or classify orange fruit based on certain criteria such as size, weight, and color according to the applicable quality standard. This grading activity is important because it will determine the next handling process. Generally, orange grading activities are done manually, this was chosen because the process can be faster, but the manual grading has weakness e.g. less efficient and requires more man power. Using the man power in determining product quality are based on experience, guesswork and tend to be subjective because it is in accordance with the perceptions of human being. A grading system and machines that use controls were developed to obtain a more uniform product based on color and size is an alternative to overcome this problem. Nowadays, the grading process has been developed with an automation system using electronic and mechanical devices so that the results are more effective and accurate. The grading process of orange fruit with a divider door that uses image processing application and a microcontroller will have more precise and objective capability. It will be more profitable than manual grading in the future life. The aim of this research is to design a machine grading system based on the Arduino microcontroller. The grading machine uses an image processing application that reads the diameter value and skin color of the orange, Arduino microcontroller is used to separate oranges based on its quality class using a divider door connected to a stepper motor. The design of the orange grading machine has a size of 1.35 cm x 74 cm and has 4 grading classes, i.e class A, class B, class C and class D. The design of the divider door for the orange grading machine has 2 trapezoid-shaped doors, the length of the first door is 30 cm, the width of the top is 26 cm and the width of the bottom is 10 cm. The length of the second door is 30 cm, the width of the top is 22 cm and the width of the bottom is 10 cm. The percentage of suitability of the results of the grading machine with a dividing door compared to manual grading of oranges is 97%. Image processing error percentage is 14%. The capacity of the orange grading machine model with a dividing doors is 300 items / hour and the efficiency value of the orange grading machine model is 55.66%.

Keyword: Grading; Image Processing; Orange; Divider Door; Microcontroller

1. Introduction
Post-harvest handling will affect the quality of agricultural commodities. One of the main post-harvest activities of orange fruit is grading. Grading is an activity to separate or classify orange fruit based on certain criteria i.e size, weight, and color according to the applicable quality standards. This grading activity is important because it will determine the next handling process.
Generally, orange grading activities are done manually, this was chosen because the process can be faster, but the manual grading has weakness that is less efficient and requires more man power. Using the man power in determining product quality are based on experience, guesswork and tend to be subjective because it is in accordance with the perceptions of human being. An alternative to overcome this problem, a grading system and machines that use controls were developed to obtain a more uniform product based on color and size. Nowadays, the grading process has been developed with an automation system using electronic and mechanical devices so that the results are more effective and accurate.

Microcontroller-based monitoring and control systems have also been widely used in agricultural engineering [9]. In the post-harvest field, the microcontroller is used as the main component in automation system for sorting and grading fruit. Several studies have been carried out by applying image processing in the fresh fruit classification, including determining the quality of mangoes in real time [1], [3] regarding apple sorting tools; [10] regarding the rice coffee sorting tool; [8] regarding a fruit sorting tool by color.

According to [4] and [7] there are several methods that can be done to see the ripeness of the fruit, based on the intensity, color, shape or texture of the fruit. The design of a grading machine with a divider door uses an image processing application and a microcontroller based on Arduino Uno. Image processing will display an artificial visual system that uses a CCD camera (charge couple device) as an optical sensor. Image processing can display appearance based on color, size and shape visually on a computer screen. Several studies have been carried out by applying image processing in the classification of fresh fruit, including determining the quality of mangoes in real time by [1].

The grading process of orange fruit with a divider door using image processing applications and based on a microcontroller will have a more precise and objective ability. This design will be more profitable than manual grading in the future. The aim of this research is to design a machine grading system using image processing based on the Arduino microcontroller. The grading machine uses an image processing to read the diameter value and skin color of the orange, Arduino microcontroller is used to separate oranges based on its quality class using a divider door connected to a stepper motor.

2. Materials and Methods
2.1. Materials and tools
Tools that have been used on this research are web camera, ultrasonic sensor, microcontroller, Arduino UNO, digital image software, image box, lamp, light sensor, Nema 123, NM and TB6600-4A-TB stepper motor, R Switching Power Supply 24 V 12.5 A, electric motor, limit switch, screwdriver, wrench, scissors, ruler and calipers. The orange that have been used on this research is the Gunung Omeh Siam with various sizes and colors (green, yellow and red).

2.2. Method
The grading process of orange fruit with a divider door using image processing application and a microcontroller (Arduino Uno) can classify orange fruit based on the diameter and skin color [5]. Orange fruits are classified based on quality i.e class A, B and C and D. The image of orange fruit is taken using a webcam on the image box which will be input to the program. The image processing program will produce orange class data. The grading process is continued by a grading machine that uses an electric motor and a conveyor belt. The classified oranges will go to the divider door. The divider door will move by the command of the stepper motor and the orange will move towards the basket. All commands on the grading machine are controlled using a microcontroller (Arduino Uno). This project consists of designing an image processing program and orange grading machine with divider door.

2.3. Image Processing Software Design
Design of image analysis program of orange grading uses Matlab 2010 software. The program is made with options on displays such as webcam, object capture, image processing program. The results of
image processing will produce quality classes of oranges in digital form, which will then be separated based on the classes. The flowchart of Image processing design can be seen in Figure 1.

Figure 1. Flowchart of Image Processing Design of Orange Fruit Grading Machine

Steps of image processing design of orange grading as follow:

- Orange Sampling
  The orange samples used were 110 oranges from Gunung Omeh field, Lima Puluh Kota Regency.

- Measuring the Diameter of Oranges
  The diameter of the oranges was measured by image processing program. The diameter measurement are stored as data used to find the relationship between the manually measured diameter and the image area using the program.

- Orange Image Capture
  The next step of the image processing algorithm is taking the orange image. Orange images are captured using a webcam. The distance between the orange and the camera is 19 cm.

- RGB color analysis (Red, Green and Blue).
  According to [2] color analysis using RGB color model is easy and simple, because the color information in the computer has been packed in the same model. The important thing is how we read the value of R, G and B in one pixel, show and interprete the color so that in accordance with what we expected.

Way to do the normalization as follow:

\[
    r = \frac{R}{R + G + B} \tag{1}
\]

\[
    g = \frac{G}{R + G + B} \tag{2}
\]

\[
    b = \frac{B}{R + G + B} \tag{3}
\]

Where, \( r \) is red color index, \( R \) is red, \( g \) is green color index, \( G \) is green, \( b \) is blue color index, and \( B \) is blue.
• Object Area Calculation

According to [6] measurement of the area and roundness is done by the way to change the color image become biner image with aim to differentiate object and background. Image area is analysed by calculating the pixel number of white color. Area of the object is calculated by calculating the object pixel of white color by equation below:

$$A = \sum_{i=1}^{m} \sum_{j=1}^{n} B[i,j]$$

(4)

Where, A is object area and B (i,j) is pixel object location at (i,j)

• Determine the limits of weight value and level of maturity according to the orange class

This stage forms a limitation for the diameter of the orange and the level of maturity that is adjusted to the orange class based on the Indonesian National Standard (SNI).

2.4. Orange Grading Machine Design with Divider Door

The frame of the orange grading machine is made of rectangular iron, the width is 135 cm and the height is 74 cm. At the bottom of the frame, there is an electric motor equipped with a belt and pulley. Belt Conveyor rotates when the electric motor is turned on. The conveyor belt used is covered with a white cloth as a background. White background aim to reduce light reflection from the lighting instrument and the colors captured by the camera are clearer.

The image box was made from wood, the width is 40 cm and the height is 32 cm attached to the center. The top side of the image box is installed with a webcam and for the lighting instrument four PL lamps are installed. The inside of the image box is fitted with an ultrasonic sensor. The light sensor is useful when the oranges pass through the sensor, the oranges will stop and ready to be captured.

Two trapezoidal acrylics are attached to the ends of the conveyor belt, the first trapezoid as the fruit slide and the second trapezoid as the door for the orange fruit to the quality basket. The design of the divider door for the orange grading machine has 2 trapezoid-shaped doors, the length of the first door is 30 cm, the width of the top is 26 cm and the width of the bottom is 10 cm. The length of the second door is 30 cm, the width of the top is 22 cm and the width of the bottom is 10 cm. The second trapezoid is a door to direct the oranges into the basket according to its class.

A stepper motor is installed at the end of the grading machine to move the oranges divider door. On the left side of the stepper motor, a limit switch is also installed which serves as the initial limit for the divider door to start moving. The bottom of the frame is also installed with wheels to make it easier for this tool to be moved. The design of a grading machine with a divider door using image processing and microcontroller as shown in Figure 2.

Arduino uno has a very important role in moving the divider door. The controlled program builded in Arduino uno as follow:

• Control to move and stop the electric motor
• Control to read and send signals from the light sensor
• Control to drive the stepper motor
2.5. Orange Grading Machine Hardware Design with Divider Door

The system on the orange grading machine with divider door is constructed from several components. The electric motor used in the machine is 0.5 HP with type YC80B-4. The function of the motor is to drive the conveyor belt. A switching power supply is also installed on a grading machine to convert AC current into DC current and then convert it into power or energy needed by the components on the computer. The camera used is a webcam. The camera is used to take pictures of oranges for the grading process. The captured image will provide information to determine the grouping of orange fruits. The ultrasonic sensor is used to read the presence of oranges in the image box which is also connected to the Arduino Uno. The stepper motor connected to the Arduino will command the divider door to move according to the quality class of the orange that has been processed with the image. PC is used to process the read image from the Matlab program.

Inside of the image box is installed with an ultrasonic sensor to determine the class of oranges after entering the image box. When the electric motor is turned on, the conveyor belt will automatically rotate. When the orange fruit has passed the sensor, the motor will automatically shut down and the conveyor belt stops. oranges are ready to be captured and the quality is determined, the data will be saved automatically. Hardware design flowchart as shown in Figure 3.

Figure 3. The Design of Orange Grading Machine Hardware
Arduino Uno uses the C language. After the quality class is obtained from image processing process, Arduino Uno will order the orange divider door to move according to the quality class produced. The actuator in the grading machine uses a stepper motor to drive the divider door and has been installed at the end of the grading machine. The PC will send commands to Arduino Uno to drive the stepper motor and the divider door. Arduino Uno will map the input signal from the results of image processing into an output signal that will control the actuator in moving the divider door and directing oranges into its class. The basket consists of 4 classes i.e class A, class B, and class C and class D is outside of categories A, B and C.

2.6. Testing And Evaluation

The test aims to see the ability of the image processing program on an orange grading machine by using a divider that can direct the orange fruit to each class until it reaches the basket. In the evaluation stage, it includes calculating the percentage difference between image processing grading results with divider doors and manual grading results, calculating theoretical capacity, calculating actual capacity, and calculating engine efficiency.

Testing procedure:
- Machine checking e.g conveyors, lights, cameras and stepper motors.
- Turn on the computer.
- Hardware detection
- Run the software.
- Place the oranges on the conveyor belt.
- Conduct observations on the orange classification program.

Tested Variable:
- Calculating The Proportion of Image Processing Results
  The percentage of errors is stated by comparing the results of the image processing program with the manual method
  
  The percentage of error can be calculated using the following equation:
  \[
  \text{Percentage of image processing results} = \frac{N-a}{N} \times 100\%
  \]

  Where, N is number of oranges (pcs) and a is number of oranges classified by grading machine (pcs).

- Calculating Theoretical Capacity

  \[
  \text{Theoretical capacity (fruit / hour)} = \frac{3600 \text{ sec}}{T_t}
  \]

  Where, \(T_t\) is Average processing time for 1 orange (seconds).

- Calculating The Actual Capacity

  \[
  \text{Actual capacity (fruit / hour)} = \frac{J_B}{W}
  \]

  Where, \(J_B\) is number of fruit processed and \(W\) is processing time (hours).

  \[
  \text{Efficiency} = \frac{\text{Actual Capacity}}{\text{Theoretical Capacity}} \times 100\%
  \]

3. Results and Discussion

3.1 Result of Divider Door Design for Orange Grading Machine

The results of the divider door design can be seen in Figure 4. Graded oranges will come out of the image box towards the divider door and will be moved by a stepper motor into the basket. All activities such as moving the divider door, reading sensors, and commands for moving the stepper motor are all set on the Arduino Uno. The orange container consists of 4 baskets i.e class A, class B,
class C and D which are made of round aluminum. This orange basket has dimensions of 35 cm in height and 28 cm in diameter. Activities on the grading machine start by connecting the program to the Arduino Uno. The first command in the program to Arduino Uno is to move the conveyor belt. Oranges are placed on the conveyor belt towards the image box. When the orange passes through the sensor, the electric motor will shut down for a few seconds and the oranges are ready to be captured. After the image captured, the program directly processes the image and the class of oranges is determined. The orange will stop in the image box for 4 seconds, then the Arduino Uno will order the stepper motor to move to the basket through the divider door according to the class obtained. Image of orange grading machine with divider door can be seen in Figure 5.

Arduino Uno consists of several controls that have been programmed as follow:

- **Electric motor drive**
  The program on the PC will instruct the Arduino uno to drive the electric motor so that the conveyor belt will rotates. The orange is placed on the conveyor belt and moves towards the image box.
- **Light sensor control**
The light sensor is needed to find out if there are oranges that have passed the sensor or not. An ultrasonic sensor is a sensor to convert physical quantities (sound) into electrical quantities and vice versa. This sensor works based on the principle of the reflection of a sound wave so that it can be used to interpret the existence (distance) of an object with a certain frequency. It is called an ultrasonic sensor because this sensor uses ultrasonic waves (ultrasonic sound).

- Stepper Motor Drive
  The program that has been made to drive the stepper motor consists of the direction of the stepper motor and position 0 is the starting position of the stepper motor.

3.2 Divider Door Control Program
From the test done, the output is a program display that can make it easier to regulate the movement of the divider door and adjust the movement of the stepper motor. The display of the program used can be seen in Figure 6.

![Figure 6. Display of The Divider Door Program](image)

The informations are as follows:
- Servo button is used to connect the stepper motor to Arduino Uno. The stepper motor will move according to each orange class that has been read from the image processing ordered by Arduino Uno, so that the stepper motor can determine where to move according to the intended class. The direction of the motor is used to adjust the direction of rotation of the stepper motor.
- The sensor button is used to determine the position of the orange in the image box.
- The CHIP button is the Integrated Circuit on the Arduino Uno.
- The Connect button is used to connect the three components above to Arduino Uno.

3.3 Testing and Validation

3.3.1 Divider Door Testing
This is a test of the divider door of the orange grading machine model. Merging programs is done using Matlab software. This test aim to see the manual grading result compared with the grading of the image processing results using a divider that leads the oranges to the basket.

| Orange Quality | Direction of Door Dividers (Stepper Motor) | Number of Oranges | Grading results oranges based on the image processing result | Results of manual grading |
|----------------|-------------------------------------------|-------------------|-------------------------------------------------------------|--------------------------|
| A              | A                                         | 30                | 30                                                          | 30                       |
| B              | B                                         | 40                | 38                                                          | 40                       |
From the test done, the accuracy of the grading process using an image processing program with divider doors and manual grading is 97.09%. The percentage is 97%, with a difference of 3%, it means that the grading machine for image processing programs with dividers can replace the manual grading process. Image processing results are more accurate and precise, especially in terms of orange fruit color. The display of the image processing program during the grading process is as shown in Figure 7.

![Figure 7. Display of Orange Grading Program with Image Processing with Divider Doors and Microcontroller Based (Arduino Uno)](image)

This project has the weakness. When image processing testing is being processed, the captured image of orange is not in the good position so that the processed oranges would be classified into classes that are not compatible with manual grading processing. The error in taking the image of oranges was 15 oranges or the error was 14%. This error occurs due to several things including:

- The tested oranges have varied and non-uniform shapes. Another problem is how to put oranges on the conveyor, on the process of entering oranges into the machine it is still manual by hand, when the round oranges are placed on the conveyor, the oranges do not directly stick to the conveyor but roll slightly to the right or to the left so that when shooting the oranges they are not in the desired position.
- The human fatigue factor, the process of entering oranges is still manual by hand. In the classification process is very likely that people tend to experience fatigue so that the position of the oranges is not consistent and correct.

Based on observations result, the distance between placing the oranges on the conveyor belt before entering the image processing box is quite influential and can reduce errors. The time needed for placing the orange to the entrance of the image processing house is 3 seconds, so that when it reaches the sensor, the orange is not perfectly located, which can cause the wrong position of the orange in the image box. From the observations and tests done, it is best if the distance is slightly extended. So even when placing the oranges on the conveyor and the oranges rolling slightly to the right or left, the oranges still have enough time to adjust their position to the moving conveyor before reaching the light sensor.

3.3.2 Machine Capacity
The time needed for one orange from orange placing to entering the container is an average of 12 seconds. Then the theoretical capacity of this grading machine model is:
Theoretical Capacity = \frac{3600}{12} = 300 \text{ fruit/hour} \hspace{1cm} (9)

Testing on 107 oranges, the processing time was 38.52 minutes. Testing on 107 oranges, the processing time was 38.52 minutes. Then the actual capacity is:

\text{Actual Capacity} = \frac{107}{38.52} \times 60 = 167 \text{ fruit/hour} \hspace{1cm} (10)

From the calculation of the theoretical capacity and actual capacity, the efficiency will be:

\text{Machine efficiency} = \frac{\text{actual classification capacity}}{\text{theoretical classification capacity}} \times 100\% = \frac{167}{300} \times 100\% = 55.66\% \hspace{1cm} (11)

From the test done, the engine efficiency value is 55.66%, which means that there are still many shortcomings in this machine and there is still a lot of time wasted during processing. This happens because several things, the orange places into the conveyor belt manually by hand, as a result the time to put oranges into the conveyor is not consistent. When testing, there are still orange that classified are not in accordance with manual grading so that it needs to be retested several times. In terms of diameter and color using images the results are more accurate than manual process, because human color will judge subjectively and the opinion of each person.

4. Conclusion

From the research, the following conclusions are the design of the divider door for the orange grading machine was made of acrylic material with a trapezoidal shape. The design of the divider door for the orange grading machine has 2 trapezoid-shaped doors, the length of the first door is 30 cm, the width of the top is 26 cm and the width of the bottom is 10 cm. The length of the second door is 30 cm, the width of the top is 22 cm and the width of the bottom is 10 cm. The percentage of suitability of the results of the grading machine with a dividing door compared to manual grading of orange is 97.07%. Image processing error percentage is 14%. The capacity of the orange grading machine model based on the design is 300 items / hour. The efficiency value of the orange grading machine model is 55.66%.

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