Development of Cavendish Banana Maturity Detection and Sorting System Using Open Source Computer Vision and Loadcell Sensor

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***Abstract*— This research aims to develop a system of detecting the maturity and sorting of cavendish bananas using Open Source Computer Vision (OpenCV) and also assisted by a loadcell sensor. The problem experienced at this time is that fruit sorting is still manual which is less efficient and inaccurate in distinguishing banana maturity based on the color of the skin. This is because the human eye is sensitive to changes in lighting and fatigue. This designed system will use webcam for image processing and loadcell for fruit weight measurement, controlled by Arduino Uno microcontroller. While the algorithm used to determine the color of the ripeness of the banana fruit itself is HSV. The test results show an average weight error of 0.08% for ripe bananas, 0.71& for unripe bananas, while the color detection produces an accuracy of 47.34% on average in bright lighting conditions. In conclusion, this system is successful in improving sorting efficiency with adequate accuracy results, but further development is needed so that the accuracy level increases.**

***Index Terms*— Arduino; Banana Maturity Detector; Loadcell Sensor; OpenCV; Sortation.**

I. Introduction

Banana fruit is a very profitable commodity because it has variety and variety. The nutritional content contained in bananas is very much including sugar, vitamin A, B1, B2, B6, B12 and also vitamin C. Apart from being rich in nutrients, banana fruit can also be processed into various kinds of food, either eaten directly or processed into other products [1], [2].

In addition to having high food value, banana commodities also have high economic value. However, in Indonesia, the treatment of banana trees at the plantation level is less effective. Thus, in terms of banana production in Indonesia has not been able to compete in the international market due to relatively low quality [3].

This is because the detection and sorting tools of this fruit are mostly based on the color of the fruit skin, and the use of sensors used still use TCS3200 which still uses the intensity of light reflected on the object so that the sensor can be read. And the use of this sensor is less effective when the light intensity is less or the object is far from this sensor [4].

The human eye has an amazing ability to detect colors in various lighting conditions. However, adaptation to low light or dark conditions takes time and human vision can be affected by factors such as fatigue. Therefore, the use of OpenCV in performing color detection shows advantages in accuracy and consistency compared to human vision. Studies show that the color conversion from RGB to HSV in image processing is closer to human perception, thus improving the effectiveness of color detection. Under diverse lighting conditions, OpenCV can adapt better, overcoming the limitations faced by the human eye in assessing banana ripeness [5].

Thus, in an effort to increase the level of accuracy and efficiency in sorting bananas, the use of computer vision technology is one of the most promising solutions [6]. Advances in the use of computer vision show great potential for fruit ripeness detection. As in the previous study, which developed a deeo learning-based system with high accuracy that is relevant for other fruits, including bananas [7]. The thing that distinguishes the use of computer vision from previous research with the present is that the previous research used a variety of variables to determine the maturity of the fruit, while the method currently being developed is simpler because it does not require a large data set, so it is more resource efficient. In addition, the research conducted by the author was assisted by using a BLDC motor as a driver of the conveyor so as to improve the performance of the sorting tool [8]. With the help of machine learning algorithms the system can be trained in the form of adding data variations that will improve the performance of the sorting tool [9].

The use of image processing is very diverse not only for the classification of fruit maturity but also for classifying objects around. The use of Python-based OpenCV is also easier for programmers because for classifying the color of cavendish banana ripeness only requires the code of the dominant colors on the banana fruit. Whereas in other studies, classification using different methods still requires a lot of data and the tools made can only do color detection not sorting [10].

In addition to the importance of technology in sorting bananas, it is necessary to provide technical guidance and training to banana farmers who play a key role in the application of modern technology. Research conducted in Gowa and Takalar districts showed that through proper training, farmers can improve their skills in managing post-harvest bananas and adapt to more sophisticated technology, such as the application of technology like OpenCV [11].

OpenCV (Open Source Computer Vision) is one of the libraries on computers as real-time image processing. OpenCV can be applied using the C++, C, Python, and Java programming languages. An example of the application of OpenCV with Python is using a camera mounted on a banana sorting tool that is able to read the ripeness level of the banana fruit. In essence, OpenCV with Python can be utilized for image processing or video processing with the aim that images of bananas can be captured and then processed on a computer. The vision used in OpenCV is not limited to computer cameras, webcam cameras are one option as a substitute for computer cameras that have the same role as vision or as cameras [12], [13].

In addition to the use of the Python library, there are other components that support banana sorting, including the microcontroller used in this sorting tool is Arduino Uno which includes a program for sorting bananas using the C language to move the components in the tool [14], [15].

The driven components include a loadcell sensor this sensor functions in helping sort the banana fruit which if the weight of the ripe banana fruit meets it will be pushed or sorted using a servo motor into the conveyor [16]. Ensuring that the sorted fruit is ripe is assisted by a webcam that uses a Python program that is connected to the Arduino to detect the color level and also open the servo motor to enter the predetermined place [17].

Thus the innovation of this tool is expected to make it easier for farmers when sorting cavendish banana fruit, without checking and classifying the maturity level of cavendish banana fruit. Besides being able to detect the level of maturity, this tool can also sort automatically by using a servo motor as a sorter.

II. METHODS

The research method used in this study uses quantitative research methods that focus on the design and realization of the OpenCV Python-based cavendish banana ripeness detection and sorting system. This approach was chosen because of its ability to measure and analyze data objectively, so that it can produce valid and reliable information.

The methods used include observation to identify the problems and needs of the tool, which is essential to ensure that the designed system can meet the expected functional criteria. In addition, conducting literature studies to support understanding in the concept of the tools created, including the use of OpenCV in image processing and color recognition, as has been proven in previous studies [4], [5].

Problem analysis is carried out by systematically testing the tool, which involves collecting data from the loadcell sensor and webcam. This process has the aim of solving problems that may arise during the operation of the tool. Furthermore, data collection and analysis are carried out so that significant conclusions can be drawn regarding the accuracy of the system in detecting fruit ripeness based on predetermined parameters. With this approach, it is expected to increase the efficiency and accuracy of the sorting system, as well as contribute to the development of technology in agriculture and agricultural processing, as in previous studies [1], [6].

A. *Block Diagram of System*

The main tools used in this research include the use of a webcam as a vision as well as a ripeness detector of banana fruit, assisted by loadcell in classifying the ripeness of the fruit, Arduino Uno as a microcontroller, servo motor for sorting fruit, and other supporting components. The system block diagram can be seen in Fig. 1.

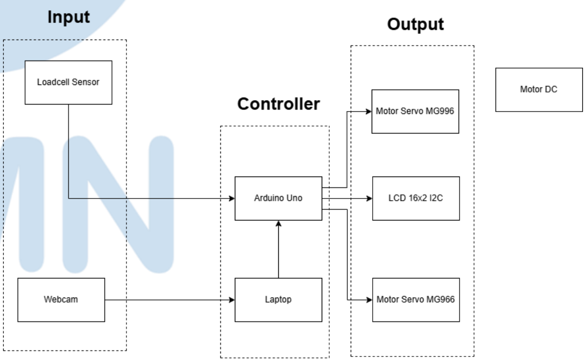


Fig. 1. Block Diagram of System

From Fig. 1 above, the working principle is that the loadcell sensor sends the weight reading data of the ripe or unripe cavendish banana fruit obtained to the Arduino Uno to be processed and displayed on the 16x2 I2C LCD [18]. After that, the first MG966 Servo Motor will move to push the banana into the conveyor and the DC Motor is turned on manually using PWM Motor Speed. The conveyor that turns on carrying bananas when through the vision of the Webcam will be detected the level of ripeness based on the color of the fruit, the data will be sent via a laptop that has a Python program for maturity classification using OpenCV [19]. Data that has been managed with the OpenCV program and algorithm will be sent via Arduino Uno with the output of opening the second MG966 Servo Motor contained in the conveyor [20].

B. *Design of Tools and Systems*

The prototype of this cavendish banana ripeness detection and sorting tool is made as concisely as possible using two Arduino Uno microcontrollers that have their respective uses as shown in Fig. 2. Is a hardware design design in the form of a sorting conveyor. Fig. 3. Is the result of the tool that has been designed.

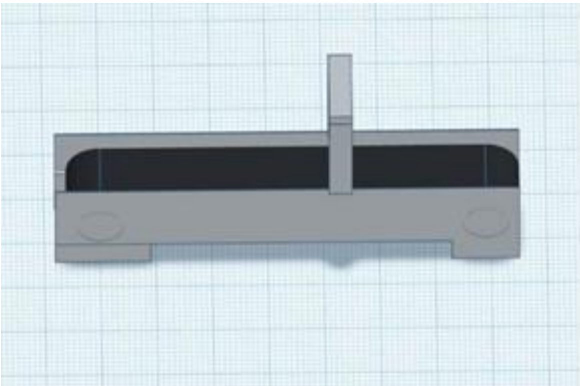
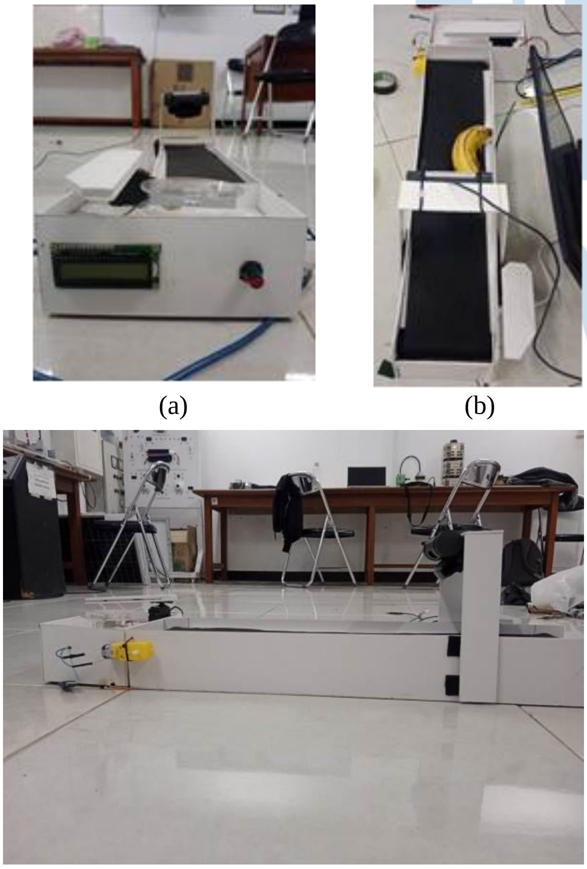


Fig. 2. Design of Sorting Conveyor

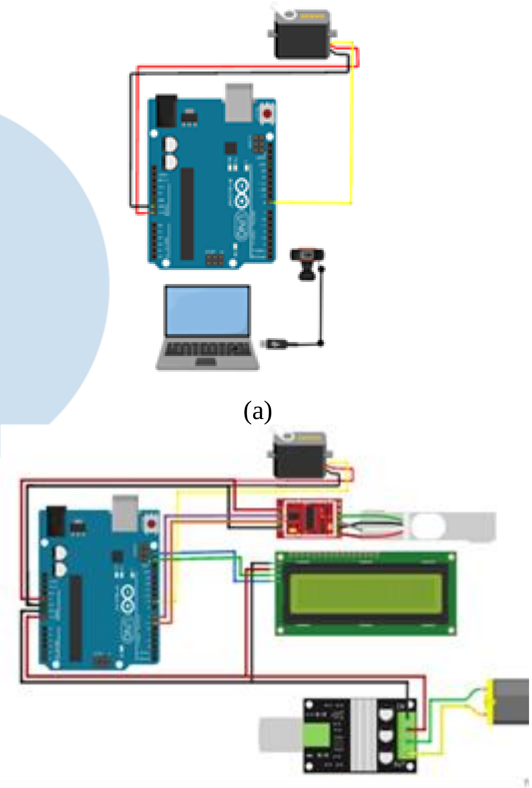


(a) (b)

(c)

Fig. 3. Front View of Tools (a) Top View of Tools (b) and Side View of Tools (c)

In Fig. 2 above shows the design of the hardware while in Fig. 3 is the result of the tool that has been designed where the workings of this tool are as a place to walk the fruit to be sorted using a dc motor as a driver of the conveyor and equipped with a webcam camera that will process the maturity level of the banana fruit but before the fruit enters the conveyor the fruit will be weighed first with a loadcell. The system design of this tool is able to classify the maturity of banana fruit and sorting using machine learning using the OpenCV algorithm. The data used requires a comparison of ripe fruit and unripe fruit by looking at the difference in the color of ripe and unripe fruit. This tool is intended for cavendish banana farmers who have difficulty sorting ripe and unripe bananas. So that in data collection researchers use two comparisons of ripe and unripe fruit.



(a)

(b)

Fig. 4. (a) Maturity Detection and Sorting Circuit Schematic Using *OpenCV* (b) Cavendish Banana Fruit Detection Circuit Schematic Using Loadcell

Fig. 4 shows the circuit schematics of each detection device shown in Fig. 4 (a) is a scheme of the circuit that will be filled by the program to detect the level of maturity of the banana fruit that has been obtained the color range. The data is entered into the Python program with the OpenCV library which will be sent to Arduino Uno to activate the servo motor when it detects the ripeness of the banana fruit captured by the webcam camera, and will open the servo on the conveyor for sorting. As for Fig. 4 (b) is a circuit scheme for detecting the level of maturity of banana fruit through changes in weight and texture of banana fruit when the weight has met the criteria for ripe fruit, the servo motor will push the banana fruit that has been weighed using a loadcell sensor into the conveyor.

C. Flowchart

The flowchart depicted in Fig. 5. In the flowchart there are two checking conditions, the first check is the texture or weight of the banana fruit to be sorted because the weight of the unripe banana fruit with the ripe one has a difference, if the predetermined weight is met then the servo contained in the weighing process will actively push the banana fruit into the conveyor, if the weight does not meet then the servo will not move. After the fruit that has entered the conveyor is continued by activating the conveyor by rotating the dc motor pwm, the fruit that is on the conveyor will continue to run until the webcam detects the presence of the fruit and checks the level of maturity with the Python OpenCV program on the computer if the fruit is detected the level of maturity then the servo motor at the end of the conveyor will open for the fruit that passes the sorting.

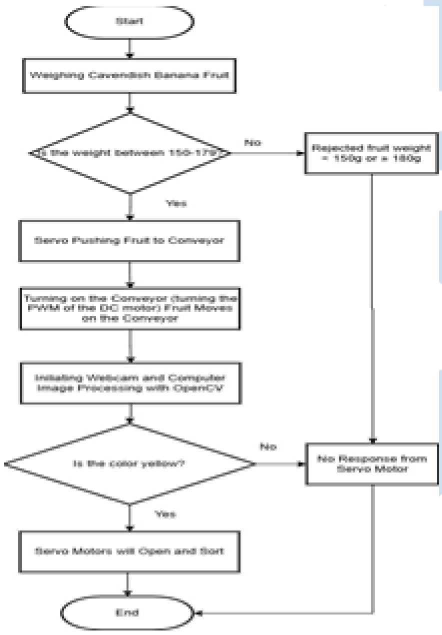


Fig. 5. Flowchart

III. RESULTS AND DISCUSSION

The OpenCV method using HSV color space, which is closer to the perception of the human eye, shows advantages in accuracy as well as flexibility over other methods based on light sensors such as TCS3200, especially in diverse lighting conditions. Compared to using decision trees, the HSV algorithm is simpler and more efficient, although machine learning such as Naïve Bayes can be used to improve the accuracy of more complex datasets.

Data collection was carried out using 30 ripe bananas and 30 unripe bananas. There are 2 kinds of data taken, the first is taking data on the weight of each cavendish banana, and the second is testing the color on the webcam with different light intensities in the room. The tools used to collect this data include digital scales from Idealife and the webcam used from Brio500. From taking these two data, it can be seen as follows:

A. Banana Weight Data Collection

From the data in Table 1 shows the data obtained from measuring the weight of ripe banana fruit, the measurement is carried out once with a total of 30 fruits each so that measurement data is obtained using loadcell scales with kitchen scales. The purpose of this measurement is to know the difference when using kitchen scales and scales made by researchers. Another goal is to know the accuracy of the loadcell scales that have been made by researchers.

TABLE I. WEIGHT MEASUREMENT RESULT OF RIPE BANANA FRUIT

Measurement to	Weight Measurement Result			
	Actual Weight (gram)	Loacell Reading (gram)	Error (gram)	Percent Error (%)
1	157	156.89	0.11	0.07
2	151	150.68	0.32	0.21
3	160	159.92	0.08	0.05
4	161	160.96	0.04	0.02
5	170	169.81	0.19	0.11
6	165	164.95	0.05	0.03
7	162	161.88	0.12	0.07
8	158	157.94	0.06	0.04
9	164	163.98	0.02	0.01
10	171	170.89	0.11	0.06
11	163	162.92	0.08	0.05
12	168	167.87	0.13	0.08
13	160	159.91	0.09	0.06
14	165	164.93	0.07	0.04
15	175	174.61	0.39	0.22
16	170	169.94	0.06	0.04
17	174	173.95	0.05	0.03
18	166	165.92	0.08	0.05
19	159	158.88	0.12	0.08
20	167	166.94	0.06	0.04
21	172	171.89	0.11	0.06
22	169	168.69	0.31	0.18
23	161	160.91	0.09	0.06
24	162	161.89	0.11	0.07
25	164	163.95	0.05	0.03
26	168	167.91	0.09	0.05
27	171	170.88	0.12	0.07
28	160	159.92	0.08	0.05
29	174	174.94	0.94	0.54
30	166	165.91	0.09	0.05
Average			0.14	0.08

The average error obtained is quite small, namely 0.08%, this shows the accuracy of the loadcell scales is not much different from the kitchen scales used during weighing. After testing as many as 30 pieces, the average error reached 0.14. The data in Table 2 measure the weight of banana fruit in raw conditions carried out in the same way using kitchen scales and loadcell scales.

TABLE II. WEIGHT MEASUREMENT RESULT OF RAW BANANA FRUIT

Measurement to	Weight Measurement Result			
	Actual Weight (gram)	Loacell Reading (gram)	Error (gram)	Percent Error (%)
1	205	204.73	0.27	0.13
2	191	189.43	1.57	0.83
3	194	192.16	1.84	0.96
4	184	182.86	1.14	0.62
5	200	200.63	0.63	0.31
6	215	215.66	0.66	0.31
7	200	198.89	1.11	0.55
8	184	185.44	1.44	0.78
9	209	208.45	0.55	0.26
10	230	230.21	0.21	0.09
11	203	202.47	0.53	0.26
12	217	219	2	0.91
13	185	185.32	0.32	0.17
14	180	180.02	0.02	0.01
15	211	212.56	1.56	0.73
16	180	180.77	0.77	0.43
17	184	184.65	0.65	0.35
18	224	223.78	0.22	0.1
19	193	192.28	0.72	0.37
20	208	207.14	0.86	0.42
21	194	193.66	0.34	0.18
22	233	231.78	1.22	0.53
23	190	190.08	0.08	0.04
24	188	187.77	0.23	0.12
25	191	190.64	0.36	0.19
26	201	200.93	0.07	0.05
27	200	199.78	0.22	0.11
28	235	235.68	0.68	0.29
29	197	197.33	0.33	0.17
30	186	185.25	0.75	0.41
Average			0.71	0.36

The error value obtained by unripe fruit is quite large at an average of 0.71%, this is because unripe banana fruit has a denser texture than ripe banana fruit, the measurement results between Table 1 and Table 2 are different because the size of the banana fruit used has a very slight difference. Researchers took measurements again for raw fruit that had turned into ripe fruit and obtained measurement results as in Table 3.

TABLE III. WEIGHT MEASUREMENT RESULT OF RIPE RAW FRUIT

Measurement to	Weight Measurement Result			
	Actual Weight (gram)	Loacell Reading (gram)	Error (gram)	Percent Error (%)
1	201	200.73	0.27	0.13
2	187	186.43	0.57	0.31
3	190	191.16	1.16	0.61
4	181	180.86	0.14	0.08
5	196	195.63	0.37	0.19
6	212	212.66	0.66	0.31
7	196	195.78	0.22	0.11
8	180	181.77	1.77	0.97
9	206	205.44	0.56	0.27
10	226	225.58	0.42	0.19
11	199	198.23	0.77	0.39
12	213	213.01	0.01	0.005
13	181	180.56	0.44	0.24
14	176	175.88	0.12	0.07
15	208	208.37	0.37	0.18
16	178	177.51	0.49	0.28
17	180	180.76	0.76	0.42
18	221	222.54	1.54	0.69
19	189	188.20	0.8	0.43
20	205	204.98	0.02	0.01
21	191	190.08	0.92	0.48
22	229	228.11	0.89	0.391
23	187	187.13	0.13	0.07
24	185	185.41	0.41	0.22
25	187	187.16	0.16	0.09
26	196	196.53	0.53	0.27
27	197	196.61	0.39	0.2
28	230	229.83	0.17	0.07
29	194	194.27	0.27	0.14
30	182	180.78	1.22	0.68
Average			0.47	0.24

In the data in Table 3, no ripe fruit was detected in the tool that the researcher designed this is because the data is new data that has not been entered into the researcher's program. In general, machine learning when new data is inputted, the tool can adapt when experiencing changes as well as what researchers do in this data collection. If you look at the difference from Table 2 and Table 3, the data obtained there is a change in the weight and texture of the banana fruit by 3 - 4 grams. When viewed in Table 1, researchers directly use ripe fruit, it can be assumed that when the fruit is still raw it is also heavier by 3 - 4 grams.

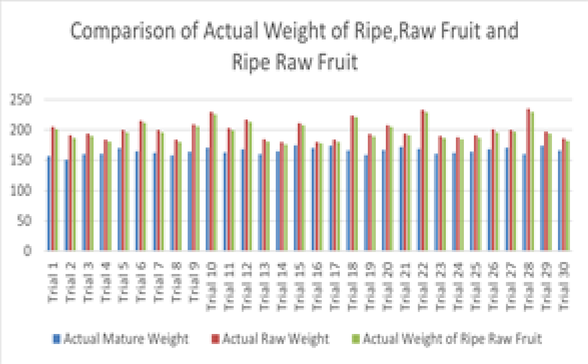


Fig. 6. Comparison of Actual Weight of Ripe, Raw and Ripe Raw Fruit

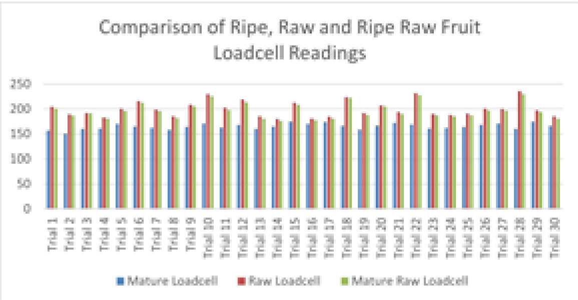


Fig. 7. Comparison of Ripe, Raw and Ripe Raw Fruit Loadcell Readings

When viewed from Fig. 6 and Fig. 7, it shows the difference in actual weight and the difference in loadcell readings from each ripe, unripe and ripe banana fruit. The data in Fig. 6 which is a combination of reading results using digital scales / kitchen scales, while in Fig. 7 is the result of reading from the loadcell scales obtained showing the picture as above.

B. *Data Collection of Banana Fruit Maturity Color*

Data collection for the level of ripeness of banana fruit based on the color of the peel, carried out using a webcam camera connected directly to a computer that has a Python OpenCV program, the detection results will appear on the computer used so that the data can be sent to the Arduino Uno for the sorting process as in Fig. 8. Is the detection of ripe fruit in bright lighting conditions, Fig. 9 is the detection of fruit maturity in dim lighting conditions and Fig. 10 is the detection of fruit maturity in dark conditions.

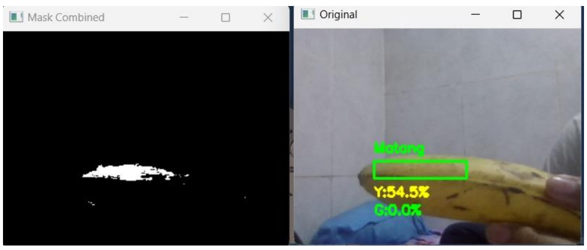


Fig. 8. Data Collection on the Maturity Level of Ripe Banana Fruit in Bright Condition

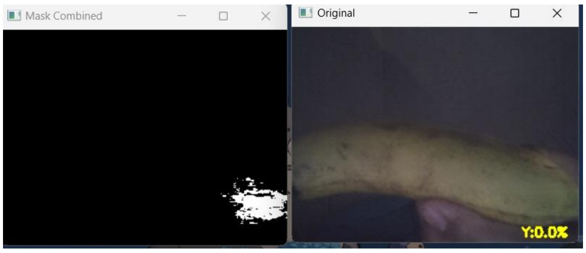


Fig. 9. Data Collection of Ripeness Level of Ripe Banana Fruit in Dim Condition

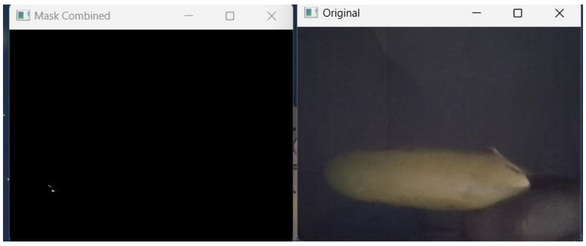


Fig. 10. Data Collection on the Maturity Level of Ripe Banana Fruit in Dark Condition

In the data collection presented in Fig. 8, 9, and 10, it can be seen the difference from the lighting conditions when detecting the color of the banana fruit where the color pixels of the ripe fruit or yellow color are very little detected by the webcam camera. In addition, data collection for the level of ripeness of banana fruit researchers can be seen in Table 4 below how the response of the servo when detected yellow or ripe fruit and the percentage obtained.

TABLE IV. RIPENESS DETECTION TEST RESULT DATA ON RIPE BANANA FRUIT IN BRIGHT LIGHT CONDITION

Measurement to	Accuracy Sensor		
	Servo Response	Detectede Color	Color Percentage
1	Open	Yellow	54.5
2	Open	Yellow	54.5
3	Open	Yellow	49.3
4	Open	Yellow	24.3
5	Open	Yellow	33.6
6	Open	Yellow	50.8
7	Open	Yellow	25.4
8	Open	Yellow	51.4
9	Open	Yellow	62.7
10	Open	Yellow	68.5
11	Open	Yellow	67.5
12	Open	Yellow	50.6
13	Open	Yellow	47.2
14	Open	Yellow	44.8
15	Open	Yellow	40.5
16	Open	Yellow	39.7
17	Open	Yellow	45
18	Open	Yellow	49
19	Open	Yellow	46.3
20	Open	Yellow	44.8

21	Open	Yellow	48.8
22	Open	Yellow	50.8
23	Open	Yellow	50.1
24	Open	Yellow	68.2
25	Open	Yellow	52.4
26	Open	Yellow	55.9
27	Open	Yellow	44.5
28	Open	Yellow	25.7
29	Open	Yellow	22.4
30	Open	Yellow	51.1
Average			47.34

The results of the data obtained when detecting the maturity level of a ripe banana fruit, the average percentage of the color captured is 47.34%. The detected color pixels are affected by other colors besides yellow, therefore when detecting the fruit has a small average value. However, the camera easily captures the color accurately enough for the sorting to run properly.

TABLE V. RIPENESS DETECTION TEST RESULT DATA ON RIPE BANANA FRUIT IN DIM LIGHTING CONDITION

Measurement to	**Accuracy Sensor**		
	Servo Response	**Detectede Color**	**Color Percentage**
1	Close	Color Not Detected	0
2	Close	Color Not Detected	0
3	Close	Color Not Detected	0
4	Close	Color Not Detected	0
5	Close	Color Not Detected	0
6	Close	Color Not Detected	0
7	Close	Color Not Detected	0
8	Close	Color Not Detected	0
9	Close	Color Not Detected	0
10	Close	Color Not Detected	0
11	Close	Color Not Detected	0
12	Close	Color Not Detected	0
13	Close	Color Not Detected	0
14	Close	Color Not Detected	0
15	Close	Color Not Detected	0
16	Open	Yellow	20.3
17	Open	Yellow	19.1
18	Open	Yellow	22.8
19	Open	Yellow	18.7
20	Open	Yellow	16.4
21	Open	Yellow	15.2
22	Open	Yellow	23.5
23	Open	Yellow	21.8
24	Open	Yellow	19.9
25	Open	Yellow	17.6
26	Open	Yellow	16.2
27	Open	Yellow	20.1
28	Open	Yellow	21
29	Open	Yellow	25
30	Open	Yellow	28.3
Average			10.20

The results obtained when taking data in different lighting conditions get results as in Table 5, where the ripe banana fruit is yellow when in dim lighting conditions the color pixels on the fruit are not detected because the fruit undergoes a color change transition so that the detected yellow color is less. So that the average percentage of color is 10.20% and in this lighting condition the system considers the detected fruit as a ripe fruit because there are few color pixels detected.

TABLE VI. RIPENESS DETECTION TEST RESULT DATA ON RIPE BANANA FRUIT IN DARK LIGHTING CONDITION

Measurement to	**Accuracy Sensor**		
	Servo Response	**Detectede Color**	**Color Percentage**
1	Close	Color Not Detected	0
2	Close	Color Not Detected	0
3	Close	Color Not Detected	0
4	Close	Color Not Detected	0
5	Close	Color Not Detected	0
6	Close	Color Not Detected	0
7	Close	Color Not Detected	0
8	Close	Color Not Detected	0
9	Close	Color Not Detected	0
10	Close	Color Not Detected	0
11	Close	Color Not Detected	0
12	Close	Color Not Detected	0
13	Close	Color Not Detected	0
14	Close	Color Not Detected	0
15	Close	Color Not Detected	0

16	Close	Color Not Detected	0
17	Close	Color Not Detected	0
18	Close	Color Not Detected	0
19	Close	Color Not Detected	0
20	Close	Color Not Detected	0
21	Close	Color Not Detected	0
22	Close	Color Not Detected	0
23	Close	Color Not Detected	0
24	Close	Color Not Detected	0
25	Close	Color Not Detected	0
26	Close	Color Not Detected	0
27	Close	Color Not Detected	0
28	Close	Color Not Detected	0
29	Close	Color Not Detected	0
30	Close	Color Not Detected	0
Average			0

The data results in Table 6 are not much different from the results in Table 5. The difference between these two data is the lighting conditions of the data collection on the fruit. It shows that the yellow color pixel of the fruit is not detected on the camera so that the average percentage of the color is 0% which makes the servo not open. In this condition color detection is almost impossible for the camera to identify the color.

The data taken for banana fruit in unripe condition with the same lighting conditions as in Fig. 11 for ripeness detection on unripe fruit in bright conditions, Fig. 12 for ripeness detection in dim lighting conditions, and Fig. 13 for ripeness detection in dark light conditions.

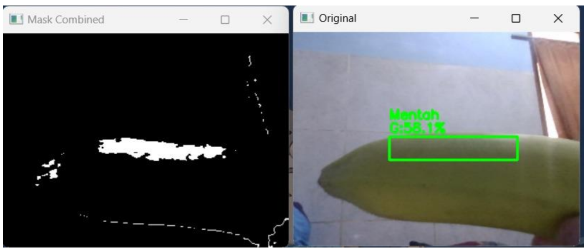


Fig. 11. Data Collection of Maturity Level of Raw Banana Fruit in Bright Condition

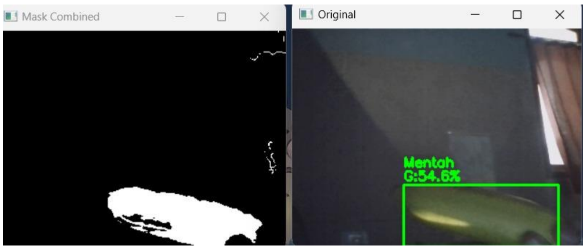


Fig. 12. Data Collection of Maturity Level of Banana Fruit in Dim Condition

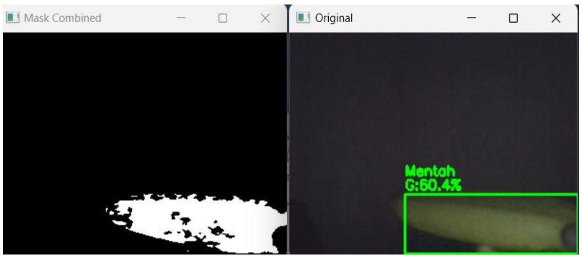


Fig. 13. Data Collection on the Maturity Level of Raw Banana Fruit in Dark Condition

At the time of data collection, bright light conditions were detected to be ripe because there was a yellow color and also the banana fruit itself was greenish yellow but the weight of this banana fruit did not meet the requirements and did not want to enter the conveyor as shown in Fig. 11, 12 and 13 of the fruit detected by the webcam. However, from the data collection, the servo motor also experienced a response when the fruit was detected to be greenish yellow as shown in Table 7.

TABLE VII. Ripeness Detection Test Result Data on Raw Banana Fruit in Bright Lighting Condition

Measurement to	Accuracy Sensor		
	Servo Response	**Detectede Color**	**Color Percentage**
1	Close	Green	54.4
2	Close	Green	58.1
3	Close	Green	58.5
4	Close	Green	56.4
5	Close	Green	55.9
6	Close	Green	54.7
7	Close	Green	57.3
8	Close	Green	51.1
9	Close	Green	55.4
10	Close	Green	58.8
11	Close	Green	57.3
12	Close	Green	59.1
13	Close	Green	56.2
14	Close	Green	58.7
15	Close	Green	60
16	Close	Green	55.5
17	Close	Green	57.8
18	Close	Green	54.9
19	Close	Green	59.3

20	Close	Green	58.4
21	Close	Green	56.7
22	Close	Green	58.2
23	Close	Green	55.6
24	Close	Green	54.7
25	Close	Green	57.9
26	Close	Green	57.2
27	Close	Green	60.4
28	Close	Green	43.3
29	Close	Green	54.8
30	Close	Green	56.7
Average			56.44

The results obtained in Table 7 after testing the color detection of banana fruit in bright lighting conditions the detected color is green with an average color detected depending on the color pixel is 56.44% and detected that the fruit is still unripe. As shown in Fig. 11, the detected fruit is dominantly green which causes the percentage of detected colors to be quite large.

TABLE VIII. RIPENESS DETECTION TEST RESULT DATA ON RAW BANANA FRUIT IN DIM LIGHTING CONDITION

Measurement to	**Accuracy Sensor**		
	Servo Response	**Detectede Color**	**Color Percentage**
1	Close	Green	59.8
2	Close	Green	52.2
3	Close	Green	51.4
4	Close	Green	55.5
5	Close	Green	54.6
6	Close	Green	51.1
7	Close	Green	45.8
8	Close	Green	30.9
9	Close	Greenish Yellow	59.7
10	Close	Green	60.4
11	Close	Green	36.6
12	Close	Green	58.2
13	Close	Green	47.3
14	Close	Green	59.2
15	Close	Green	52.2
16	Close	Green	51.4
17	Close	Green	55.5
18	Close	Green	54.6
19	Close	Green	53.7
20	Close	Green	56.3
21	Close	Green	57.8
22	Close	Green	52.1
23	Close	Green	55.9
24	Close	Green	56.5
25	Close	Green	54.0
26	Close	Green	53.2
27	Close	Green	57.4
28	Close	Green	54.4
29	Close	Green	52.2
30	Close	Green	51.4
Average			52.94

In Table 8 data, it has been tested to detect the maturity of banana fruit in low light conditions, it is found that the webcam camera detects the green color on the banana fruit, the green color pixels detected in the fruit test get an average value of 52.94%, this is because the dominant color detected is still visible as in dim lighting. As in Fig. 12 each fruit has a fairly high percentage because the color pixels that are read are quite a lot.

TABLE IX. RIPENESS DETECTION TEST RESULT DATA ON RAW BANANA FRUIT IN DARK LIGHTING CONDITION

Measurement to	**Accuracy Sensor**		
	Servo Response	**Detectede Color**	**Color Percentage**
1	Close	Green	57.2
2	Close	Greenish Yellow	54.4
3	Close	Green	55.9
4	Close	Green	60.4
5	Close	Color Not Detected	0
6	Close	Green	36.2
7	Close	Green	58.4
8	Close	Green	30.2
9	Close	Green	28.1
10	Close	Green	25.5
11	Close	Green	29.8
12	Close	Green	45.2
13	Close	Green	35.8
14	Close	Green	47.1
15	Close	Green	44.5
16	Close	Green	21.9
17	Close	Green	57.2
18	Close	Green	55.9
19	Close	Green	50.3
20	Close	Green	40.6
21	Close	Color Not Detected	0
22	Close	Green	27.3
23	Close	Green	31.1
24	Close	Green	59.1
25	Close	Green	30.3
26	Close	Color Not Detected	0
27	Close	Green	46.8
28	Close	Green	48.4
29	Close	Green	58.4
30	Close	Color Not Detected	0

Average	37.87

The data in Table 9 is almost the same as the previous raw fruit data, the difference is that when taking data in dark light conditions there are yellow-green color readings and some are not detected by the camera from the webcam. Pixel color from yellow is 24.4% and green is 30% so that the average color is obtained by 37.87% when totaled as a whole percentage of the data taken. The average of the fruit detected in this dark condition is the green color pixel which is more dominant than the yellow color pixel on the fruit. The difference can be seen in Fig. 13 above is a portion of the color captured with a relatively small percentage of color due to lighting that affects the ability of the webcam camera to detect color.

After taking data for the accuracy of the sensor with the response of the servo motor can be displayed in the form of a graph for the average value obtained from testing in bright, dim, and dark lighting conditions for ripe fruit and unripe fruit with the same lighting conditions can be seen through the graph presented below:

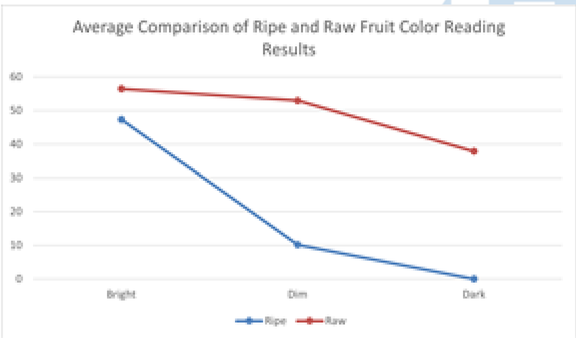


Fig. 14. Graph of Average Sensor Readings

The difference obtained through this detection shows that light conditions play a significant role in the accuracy of the system. To further understand the advantages and disadvantages of the various methods that can be used in fruit ripeness detection systems, please refer to the table presented below:

TABLE X. COMPARISON OF THE ADVANTAGES AND DISADVANTAGES OF THE MENTIONED METHODS

Methods	Advantage	Shortage
TCS3200	Simple	Less effective in low light conditions
Decision Tree	Fast for small datasets	Unsuitable for complex datasets
OpenCV	Accurate and flexible	Performance degrades in dark lighting
Naive Bayes	Adaptive for diverse data	Requires large datasets

A conclusion can be drawn for the use of the methods mentioned, that using the OpenCV method was chosen by the author due to its advantages in flexibility and accuracy in color detection, which is relevant to the needs of the developed tool. However, combining it with other methods such as Decision Tree or Naïve Bayes can improve the performance of the tool if the dataset is larger or with additions such as reading the texture of the fruit.

C. *Limitation and Future Work*

The system developed in this study has several limitations that need to be considered. One of the main limitations of this research is the sensitivity to lighting conditions, the accuracy of color detection decreases due to low or dark lighting, as shown in table 4, the results are 47.34% in bright conditions, but in dim conditions 10.2% and 0% in dark conditions. To improve performance in the future, it can be done by adding datasets with more variations and implementing adaptive algorithms on HSV parameters to increase accuracy in various lighting conditions.

D. *Comparison with Similar Systems*

The system proposed by the authors uses OpenCV to perform banana ripeness detection based on skin color, which is more flexible and efficient than using TCS3200 and Decision Tree. OpenCV offers higher accuracy in various lighting conditions by utilizing HSV color space, while the use of TCS3200 sensor is more sensitive to light changes. While Decision Tree is fast on small datasets, it is less adaptive to complex data variations. Another study using a different method, Naïve Bayes, showed superiority on large datasets, but required more resources. The results of this test show an accuracy of 47.34% in bright conidia which can still be improved with algorithm adjustments. This system provides a simple and efficient solution compared to more complex machine learning-based methods, with potential for further development.

IV. CONCLUSION

This banana ripeness detection and sorting tool has been successfully realized, the tool succeeds in recognizing changes in texture and weight of ripe and unripe cavendish bananas. OpenCV which works as a maturity level detector can also classify the maturity of banana fruit based on the color of the fruit. From the test results that have been carried out this tool has an average error for reading the weight of the fruit of 0.09%, 0.57%, and 0.26% respectively.

The test results of this tool that have been realized show that the level of accuracy is fairly sufficient, but this tool needs to be developed by adding training data so that this tool can function better in the hope of increasing the accuracy of this tool in classifying either from color or from the weight or texture of the fruit.

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