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IoT Based Smart Palm Oil Seed Segregator using RGB Color Sensor

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ABSTRACT

The manual seed grading process through human vision is tedious and time-consuming due to the tendency for errors and inconsistencies. Shell residues also failed to be properly segregated and required a huge amount of human energy as they were unable to be detected automatically once the waste container was full. The main objectives of this research are to develop an automated palm seed grading and sorting system to increase the seed's sorting quality. The system can segregate palm oil and shell residues automatically to ease kernel recycling in the future. In addition, the system can implement the waste bins' level detection, which can notify the user via the Blynk application, reducing the time and manpower required. To develop this system, sensor comparisons are done to determine the best-performing sensor to be used in the operation. The result shows that the RGB color sensor is the best color detecting sensor with an increment accuracy of 30.525%. As for the smart bin for shell residue, system response became 62.96% faster with the use of an ultrasonic sensor. The RGB sensor detects seed with readings <165 color concentration as freshly ripe and readings >165 color concentration as overripe. The janitor can be notified in real-time when the bins for oil and shell residues are full through the Blynk application using the WiFi module (ESP8266). The system has 100% accuracy, which was tested using the confusion matrix formula for both seed categories.

1. Introduction

Palm oil is one of Malaysia's main industries, accounting for the majority of the country's agricultural industry. According to the Malaysian Palm Oil Council, Malaysia accounted for 25.8 percent of global palm oil production and 34.3 percent of global palm oil exports in 2020. In producing good quality palm oil, the seed selection process should be emphasized as it ensures a supply of quality oil for domestic use as well as exports. Under-ripe, ripe, and over-ripe are the three main classifications of oil palm ripeness. As stated by Norasyikin *et al.,*[1], oil palm fruit color ranges from a very dark purple to an orange hue depending on its gene and level of ripeness. Currently, the

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method used to assess the seed's ripeness is to look for loose oil palm fruits on the ground nearby, where no loose fruits are underripe, a few loose fruits are ripe, and many loose fruits are overripe. This is time-wasting. The quality of agriculture and food products is typically the most crucial element. Producing high quality goods is essential for success in the current fiercely competitive market. In terms of agricultural use, the texture, shape, and color of produce, especially fruits, are frequently used to categorize its quality. When determining the ripeness and verifying the freshness of fruits and vegetables, color offers good data. The majority of agricultural products are typically split into various categories, and the majority of the time, these grades are determined manually through human observation. But this manually graded technique is unreliable. As a result, it is essential that a new grading method be created using sensor-based technology, such as color sensor. In producing good quality palm oil, the seed selection process should be emphasized because it is the beginning of the whole process. Indirectly, it maintains and ensures a supply of quality oil for use domestically as well as exported to foreign countries. Up to this day, oil palm FFB ripening prediction has been done by observing loose fruits on tall trees. However, due to the possibility that lost fruits could fall under a different tree, become stuck in the fronds, be carried away by strong rain, or be taken by animals in the area, this method may not be accurate. Solid waste, especially the kernels, is produced by oil palm mills other than the oils that are actually needed.

2. Background of Study

The number of loose fruit sockets on the bunch can also be counted as reported by researchers in their previous study [2]. In producing high grade palm oil, only the best palm seeds are selected and processed. Due to that, an accurate grading process is essential. Some researchers have developed a system that can detect the ripeness level of the palm oil fruit bunch including Sebastian *et al.,*[3] who created an oil palm FFB grading system. Researchers from previous study [4] determine the level of seed's maturity using a phototransistor that has proven its lack of accuracy and slow response time.

Presently, palm oil machines are facing difficulties in properly segregating wet and dry waste for recycling or other sectoral uses. As a result, the mixture of oil and seed residue will result in an imperfect end product in addition to complicating the process of recycling oil palm kernels in the future. The system by Azhaguramyaa *et al.,* [5] was developed using a faster R-CNN algorithm that provides high accuracy data for detecting waste categories but still lacks an automated segregating system to separate dry and wet waste materials. After palm seeds have been segregated and residues dumped into the waste bin, it still requires the worker to always check manually as it is unable to automatically detect whether the waste container is full or empty.

In recognizing fruit color and categorizing, citrus fruit sorting system with RGB color sensor was developed to recognize colors of oranges, as reported by this study [6]. Referring to research [7], Roseleena *et al.,* also developed a system to grade and classify oil palm fruit into its ripeness category. Moreover, research by Meftah Salem *et al.,* [8] has a similar concept to the system in this study [9] that was also designed based on the RGB color sensor to distinguish the categories based on the color intensity. These systems focused on categorize the seeds without a fully automated system, as the oil palm fruit needed to be held manually at the camera to be detected. Unlike Vishal and Mohit [10], they detect varying ripening stages of the fruit but still lack an automated segregator system as it only detects the fruit's ripeness without segregating between ripe and not.

In implementing a smart waste bin system, Sharanya *et al.,* [11] used an inductive proximity sensor, a soil moisture sensor and a laser LDR to sort waste into metallic, wet and dry categories. Smart Waste Bin [12], Automatic Waste Segregator and Monitoring System [13] and Development of

Automatic Waste Segregator and Monitoring System are also being developed with similar goals as stated from previous study [14]. Then, S.A. Mahajan *et al.,* [15] used a load cell in their system to monitor the level of garbage in the bins. However, the existing research lack an alert system to notify the janitor once the waste bin reaches the targeted load. Following that, Priya J and Sailusha [16] implemented a water level monitoring system, but they only used LED as the indicator with no IoT implementation as a notifier. Meanwhile, as mention by authors [17], the garbage monitoring system is designed to measure its level and alert the municipality whenever the bin is full using ThingSpeak without having any physical indicator such as LED or buzzer at the bin.

For all the projects stated above, there is still a lack of complete seed grading with an automatic sorting system that can notify the janitor without having to always check the bin's status.

2. Methodology

This section will go through the software and hardware components. It will also include block diagrams, a system flowchart, and a research prototype for this study.

2.1 Block Diagram

Figure 1 describes a block diagram of the system. The microcontroller for this system is an Arduino Mega 2560. It was chosen because it has more input and output ports that will be used to interconnect components. This board comes with 54 pins and 16 analog pins, plus more memory to store the code. All the input and output required are connected to this microcontroller. There are four inputs in this system, which are an infrared (IR) sensor, Red-Green-Blue (RGB) color sensor, a water level sensor, and an ultrasonic sensor, which result in output components that are a servo motor, a 12V DC motor, a light-emitting diode (LED), and a piezo buzzer. An IR sensor is placed at the beginning of the system to sense the presence of palm oil seeds. A programmable color light to frequency converter (TCS3200) color sensor was used as the color detector device. A conveyor system is also built to test the functionality of the prototype. The conveyor transporting the palm oil seeds is powered by the 12 DC geared motors produced by dry cells. The technique for determining the ripeness of the moving palm oil seeds' color follows. The sensor TCS3200, which is positioned vertically on the conveyer, will detect color and give the microcontroller a set of data in terms of RGB light intensity. Thus, the ripeness of the fruit will be determined using the Arduino Mega microcontroller. Also, both water level sensors and ultrasonic sensors are installed in the oil bin (bin 2) and waste bin (bin 3) to detect the level of oil produced and the level of shell residues, respectively. The conveyor will haul the ripe seed and push it into the compressor. In contrast, overripe seed will be carried away into bin 1. A servo motor is then used to move the plate to compress seeds once every ten seconds, ensuring more efficient operations. Continuously, after the compression process is done, a water level sensor is utilized to detect if the oil flowing into bin 2 is already full. Simultaneously, a servo motor tilts to transfer seed residues into the waste bin (bin 3). On these bins, a red LED and piezo buzzer will be used to indicate a warning and notify the janitor that the bin is now full. In implementing the IoT element, ESP8266 acts as a Wi-Fi module to communicate between the Arduino Mega and Blynk applications that have been installed on a smart phone. Finally, the Blynk application will be used to send push notifications every time each bin reaches its capacity limits, indicating that residue and oil bins are full.

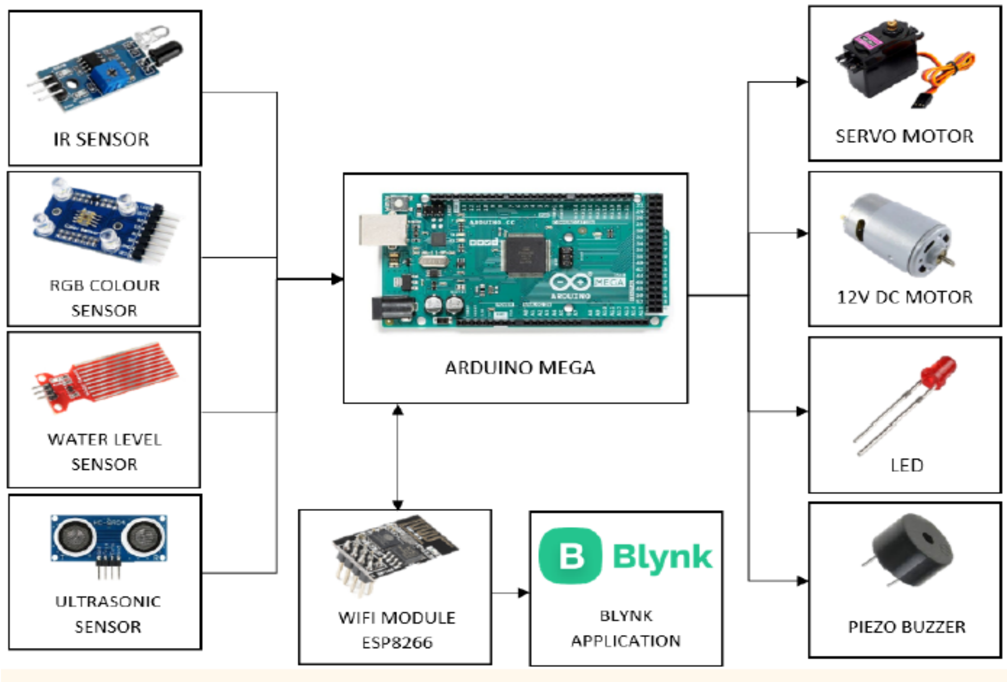

Fig. 1. Block Diagram of The Proposed System

2.2 System Flowchart

Figure 2 shows the flowchart for the research. Firstly, the IR sensor will sense any object in its surroundings by emitting light. In this case, it will sense if any palm seed is placed on the conveyor that is powered by a DC motor to indicate the process has begun. Then, an RGB color sensor is activated to identify palm seed color and categorize it according to its ripeness level. RGB reading between 90 and 165 ($90<x<165$) color concentration indicates seeds are ripe perfectly, as referred to [18]. Thus, it will continue with the whole process. However, readings over 165 ($>>165$) will be categorized as overripe. Servo motor 1 will rotate 45° to carry that seed into waste bin 1. The perfect ripe seed will continue to the next process, compression. Once it falls onto the strainer, servo motor 2 then rotates to move the plate to compress the seeds. Two forms of outcomes will be formed, namely palm oil and shell residues. The oils produced will flow into bin 2, which is placed under the compressor. Continuously, servo motor 3 will tilt moving the seed residues into bin 3. A water level sensor inside bin 2 will always be ready to check whether or not the oil level in the bin has exceeded the full limit. If it is full, red LED 1 will light up. At the same time, a push notification will be sent into the Blynk Apps that is controlled by the janitor, stating, "Noty: Essence is Full!" while buzzer connected will also sound to notify users around. Simultaneously, after servo 2 has compressed the seeds inserted, it will then activate the third servo motor, servo 3, which will continue to rotate the compressor, tilting 180°, and transfer shell residues into bin 3. An ultrasonic sensor is also placed in this bin. It measures the distance to the shell residues using ultrasonic waves and senses the target distance of the shell residue in the bin. In this research, 4 cm is set to suit the hardware built. It indicates the bin's depth. The sensor will trigger as the range decreases. Just like the process in bin 2, once the shell residues exceed the target limit, red LED 2 lights up and a buzzer will sound to inform the janitor. Finally, a push notification will also be sent into the Blynk Apps stating, "Noty: Residue is Full!".

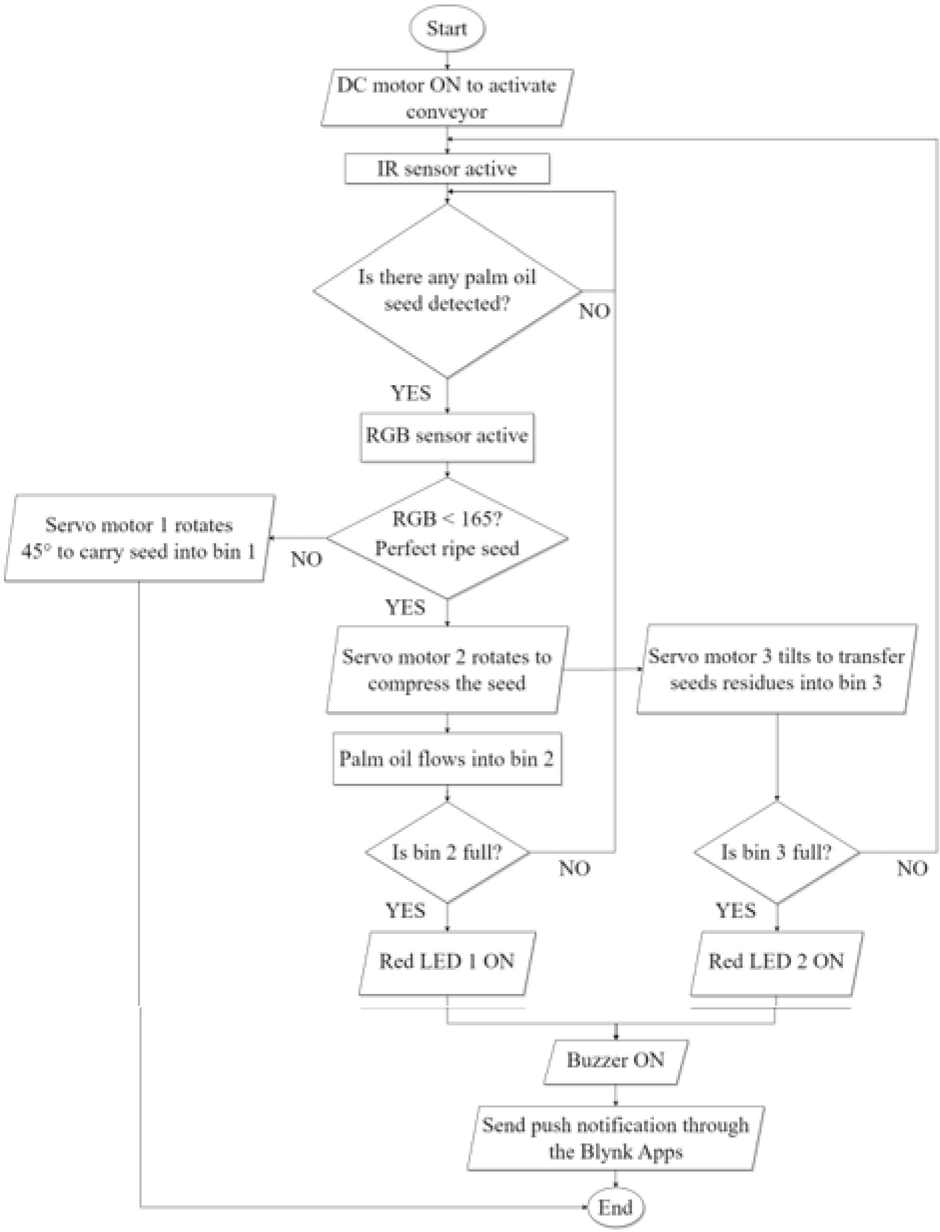

Fig. 2. System Flowchart

2.3 System Software

The main controller for this system is an Arduino Mega 2560, which is used in developing the system software. It is a user interface that allows users to design programmes to manage and maintain their systems. In a precise line of code, each input and output component are defined. In this work, C++-based Arduino integrated development environment (IDE) software is used to construct the code. A complete prototype of this work is shown in Figure 3. The palm oil seeds are positioned at the conveyor's beginning point and pass through a section that consists of IR sensor and a color sensor as they go along the conveyor. In order to give the color sensor adequate time to identify the color of the palm oil seed placed, the conveyor will halt for three seconds. Once the seed's ripeness is determined, the servo motor will either move to a position of 0° or 45° to shove the ripe seed into the next process, which are compressing.

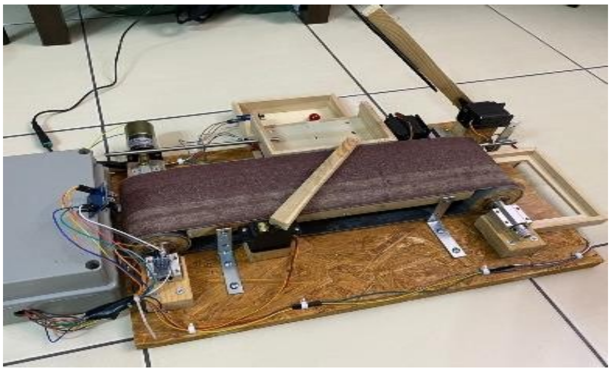

Fig. 3. Research Prototype

An IoT part has been developed in the system to notify the user once the residue or oil bin is full. The system connected using the board NodeMCU ESP8266 as the WiFi interface between the system and smartphone. The smart bin system concept is used for both bins to ensure efficient working principles. Once a signal is received at the microcontroller, the system will process it and send a push notification to the user, as shown in Figure 4.

Fig. 4. Push Notification via Blynk Application

3. Results

This section will elaborate more on the outcomes of the research including performance analysis for sensors, seed readings and accuracy of the sorting system.

3.1 Phototransistor vs Color Sensor
3.1.1 Phototransistor

The difference in reflecting light reading determines level of ripeness of the palm oil seed. Sebastian *et al.,* determined the level of maturity of oil palm FFB using a phototransistor [3]. However, the process is quite complicated as they analyzed it by measuring the reflectance data of the oil palm FFB. The chlorophyll content is selected and utilized by using the four-band sensor, a system of four wavelength-varying reflectance sensing elements and narrow-band light sources. One in the red-edge region (750 nm), two in the visible zone (at 570 and 670 nm), and one in the near infrared region (870 nm), in order to classify the maturity.

3.1.2 RGB color sensor

Detects RGB values by receiving ambient light using a photodiode and identifying the intensity of the received red, green, and blue (RGB) light, respectively. In measuring the wavelengths of the RGB colors, the sensor then activates three filters with three different wavelength sensitivities, allowing for the identification of ripe and overripe seeds by their color.

3.1.3 Performance Analysis

The graphs shown in Figure 5 show the characteristic curves of both sensors and current outputs at light intensity. The sensors are examined at the same ambient temperature (28 °C) and voltage (+5V) under changing light intensity, and a sensitivity analysis has been carried out. Referring to Figure 5, it can be observed that for each of these devices, the current outputs increased with increasing light intensity. Both current outputs showed linearity, but the RGB color sensor current output has greater linearity and uniformity in response to variable illumination than the phototransistor. The sensitivity of the sensors was taken from the current standard deviation value of each sensor [19]. It is observed that both sensors respond exponentially to light, but while the value of the standard deviation of the RGB color sensor is 20.26, the phototransistor is 30.52. The sensor improvement percentage is then calculated using the average value for both sensors. The color detecting accuracy is 30.525% higher when using RGB color sensor compared to a phototransistor. It can be said that the electrical responses of the color sensor with respect to illumination show a better variation profile in terms of sensitivity and accuracy. In systems, the consistency of the generated electrical values with respect to lighting fluctuations is essential. It can also be seen that using RGB color sensor to detect the palm oil seed's color will give more consistent readings.

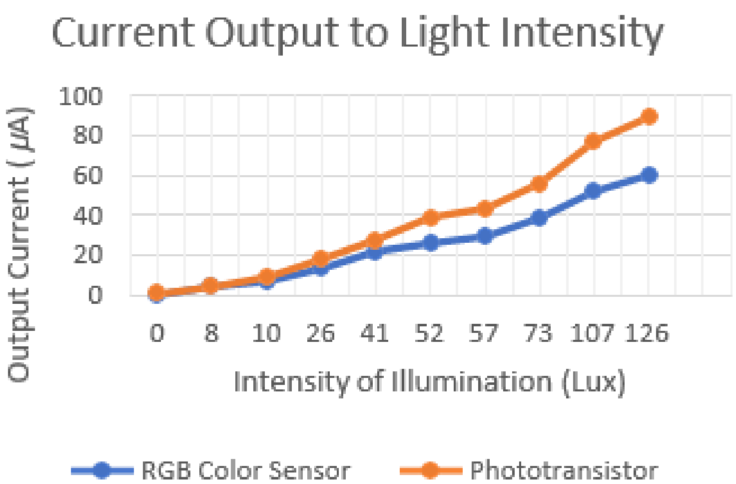

Fig. 5. Characteristics Curves of Sensor's Current Output to Light Intensity

3.2 Infrared (IR) Sensor vs Ultrasonic Sensor
3.2.1 Infrared (IR) Sensor

This sensor uses light reflectance to find things based on its motion. It detects motion or objects every time within its detection range, thus triggering the red LED and buzzer. This situation is not the desired working principle of the system. The IR sensor is more usable and recommended for knowing the existence of an object due to its reliability and performance in detecting an obstacle. [20].

3.2.2 Ultrasonic Sensor

This sensor uses sound waves to calculate the distance to an object or detect obstacles. For presence detection, ultrasonic sensors detect objects regardless of the color, surface, or material, unless the material is very soft, like wool, as it would absorb sound. However, it is not a problem, as shell residue is an opaque and hard object. In actuality, it will gauge the separation from the implanted shell fragments. The target distance for the sensor to be triggered can be set. Thus, the red LED and buzzer would not be activated every time a motion was detected. Additionally, it is not easily influenced by light sources like sunshine.

3.2.3 Performance Analysis

From the data tabulated in Table 1, the average error value for both sensors are calculated for all seven data sets to determine which sensor detects distance the best. Based on the results, the IR sensor has a higher average error in measuring the distance compared to the ultrasonic sensor, which is 29.86 and 4.26, respectively. It is always significant to use an accurate sensor when determining the distance between the sensor and the desired object, as this will establish the level of relativity between the bin depth used in prototype development and the distance detected by the sensor, as well as assisting the researcher in the process of implementing code in the Arduino software. Not only that, the standard deviation for each sensor is also calculated to determine which sensor is the best to use. The ultrasonic sensor has a lower standard deviation with a value of 2.95, and the IR sensor has a value of 22.93, which is higher. The difference between these two sensors is also large in value, approximately 19.98. Thus, it can be clearly said that ultrasonic sensors perform better than IR sensors, which indicates that they are more reliable [20].

Table 1
Distance Measurement in (cm) for Both Sensors

Sensor	Actual	Measured	Error	Sensor	Actual	Measured	Error
IR Sensor	0	80	80	Ultrasonic Sensor	0	0	0
	20	39	19		20	15	5
	30	19	11		30	22	8
	40	20	20		40	38	2
	50	23	27		50	43.2	6.8
	60	38	22		60	58	2
	70	40	30		70	64	6
Average Error	29.86			Average Error	4.26		
Standard Deviation	22.93			Standard Deviation	2.95		

The statistical analysis of the sensor data against palm oil seed is also shown in Table 1. The correlation coefficient (r) was estimated between measured and actual distance values as well as infrared and ultrasonic sensor readings for the analysis. The standard deviation parameter (for an individual sensor data set) is also considered to check the consistency of the sensor measurement for a specific type of obstacle. The benchmark set for the readings was 0.9 and above—very high correlation; 0.7–0.9—high correlation; 0.5–0.7—medium correlation; and 0.3–0.5—low correlation [21]. Correlation means that the obstacle material and sensor have a strong relationship with each other, while a weak or low correlation means that the variables are hardly related. A high correlation between the seed and the sensor is needed in the system because it indicates that as the distance between the seed and sensor decreased, the sensor range results fluctuated significantly, resulting in a shorter response time. In other words, it is the level of sensitivity of a sensor.

As palm oil seed has a rough surface and reflects a good quantity of sound energy, Figure 6 illustrates a constant reading for ultrasonic. The infrared (IR) sensor exhibits a significant offset and decreased range deviation. This is due to the sensor reflection being carried over a considerable distance at lower ranges. Lack of a flat surface for light reflection causes reading errors. Thus, the ideal sensor for such an obstacle, shell residue, is an ultrasonic sensor.

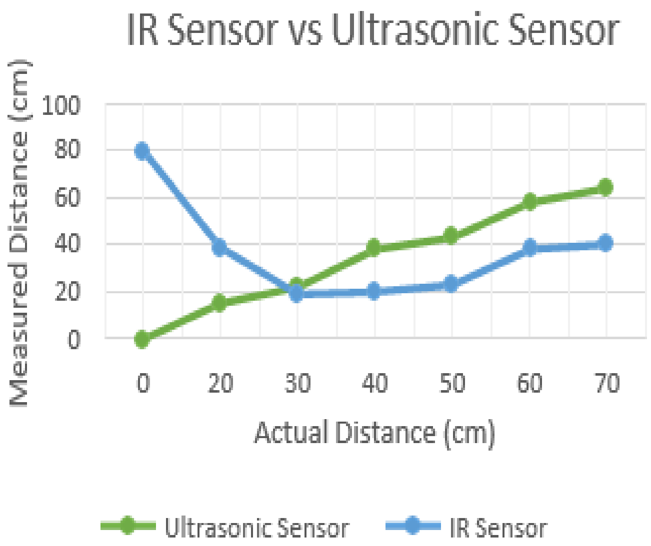

Fig. 6. Measured vs Actual Distance of Sensors

3.3 Response Time for Smartphone Notifications

Based on Table 2, it is clearly shown that the ultrasonic sensor has a shorter response time compared to the IR sensor, which is 1 second. This value is good enough, as it will send a notification as soon as the sensor detects the bin is full without any delay. It is important to have a reliable sensor on the smart bin to give a real-time notification to the user once bins are full. IR sensor response is averaged at 2.7s, while ultrasonic sensor response is faster at 1s for all the sets. When using an ultrasonic sensor, it shows a 62.96% response time compared to an IR sensor. It means that the system responds faster with the use of an ultrasonic sensor. The accuracy and reliability of these sensors are some of the important differentiators. Thus, ultrasonic sensors are the best choice of components to be used in developing this system. Since this research requires a precise, numerical representation of distance, ultrasonic sensors will almost always deliver more accurate and dependable data than IR sensors.

Table 2
Response Time for Smartphone Notifications

Distance (cm)	Response Time (s)	
	IR Sensor	Ultrasonic Sensor
2	2	1
4	2.2	1
6	3	1
8	3	1
10	3	1
12	3	1
Average Response Time	2.7	1

3.4 Seed Readings Results

The sample size of each seed category, ripe and overripe, is 10 seeds. Thus, in total, 20 seed samples were tested. For each seed, four measurements were taken and recorded, and the average value of these three measurements is calculated. The accuracy of this study is then measured using a confusion matrix classification algorithm. Based on the outputs, this system uses a binary classification method where data is entered and then grouped in one of two classes. In this method, the performance measurement is broken down into four terms that represent the results of the testing process, namely True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN). The test accuracy value can be obtained from four plots. Below is the precision formula used in the binary classification method [22]:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} * 100 \quad (1)$$

where TP (True Positive) is the amount of positive data that the system correctly classifies, TN (True Negative) is the amount of negative data that the system correctly classifies, FP (False Positive) is the amount of positive data misclassified by the system and FN (False Negative) is the amount of negative data misclassified by the system.

3.4.1 Ripe Fruit

Applying a collection of samples of seeds that have been classified as ripe and overripe, this system's functioning and accuracy are assessed. According to previous research [18], mature palm oil seeds have changed from green to yellow and dark red tips and bases of each fruit. The average voltage readings for the ripe category are less than those for overripe, where most of the values are less than 2V [3]. This is proven when the values of the voltages are lower than the overripe category. To put it differently, some of the light that is projected is absorbed by the oil palm, and the light that is reflected is weaker and only allows a moderate amount of voltage to flow through the sensor. As shown in Table 3, the created system has successfully identified and classified them as ripe fruits with RGB range values between 90 and 165 color concentrations suggesting a strong signal of freshly ripen. Each of the 10 samples has been run four times through these trials to assure the perfect accuracy of the system as well as for statistical purposes. Referring to Table 3**,** researchers [18] reported that RGB reading between 90 and 165 ($90<x<165$) color concentration indicates seeds are ripe perfectly. In this case, only the green color category is observed to set the limit to ease the coding process. Ripe palm seed's color is combined from equal parts yellow and red with a slight blue, resulting in a red-ish orange in color with dark purple tips. That is why RGB values for green color concentration are the highest among the three. A higher number indicates that there are more lights. The lighter the colour, the higher the RGB values.

Table 3
RGB Intensity for Ripe Seeds

Sample	Test	R	G	B	Output	Sample	Test	R	G	B	Output
1	1	120	133	110	Ripe	6	1	100	115	97	Ripe
	2	115	130	116	Ripe		2	104	115	96	Ripe
	3	122	136	108	Ripe		3	110	119	96	Ripe
	4	115	129	109	Ripe		4	100	114	95	Ripe
2	1	133	149	127	Ripe	7	1	111	122	103	Ripe
	2	125	146	125	Ripe		2	120	130	105	Ripe
	3	133	155	131	Ripe		3	116	128	105	Ripe
	4	129	145	123	Ripe		4	118	129	108	Ripe
3	1	119	142	118	Ripe	8	1	119	133	107	Ripe
	2	99	120	105	Ripe		2	102	117	96	Ripe
	3	109	125	100	Ripe		3	113	119	101	Ripe
	4	118	143	123	Ripe		4	103	116	97	Ripe
4	1	117	134	115	Ripe	9	1	117	130	107	Ripe
	2	113	125	100	Ripe		2	101	113	94	Ripe
	3	120	135	113	Ripe		3	107	120	98	Ripe
	4	130	153	132	Ripe		4	100	116	97	Ripe
5	1	138	155	127	Ripe	10	1	105	115	94	Ripe
	2	115	137	117	Ripe		2	100	112	93	Ripe
	3	130	157	134	Ripe		3	99	113	94	Ripe
	4	100	112	100	Ripe		4	150	161	141	Ripe

3.4.2 Overripe Fruit

Overripe palm oil seeds were correctly detected as such by the system and were then transferred to the proper container. As shown in Table 4, the RGB range values show that the overmature palm oil seeds have physical deep dark orange in color with the most outer fruits gone, as reported by Norasyikin *et al.,* [1]**,** resulting in a higher detection value with a majority of more than 165 points even after being repeated four times to reveal a consistent result, proving the system's dependability. Referring to Sebastian *et. al.* [3], the overripe category produces a voltage value of most in the range of 2 V to 2.7 V, and the value of the standard deviation has been calculated. The amount of chlorophyll in palm oil should theoretically decrease as it ripens. This implies that the overripe category has the lowest amount. As a result, the FFB of overripe seed will absorb the least light compared to ripe fruit due to their black-ish colors. Referring to Table 4, an RGB reading that exceeds 165 (>165) color concentration indicates seeds are overripe, as referred to this researchers [18]. However, only the green color category is observed once again to set the limit in the coding process. Overripe palm seed’s color is a black-ish purple that is combined with red and blue. That is resulting in the RGB values for green color concentration being the highest among the three for all samples. The lower the RGB's, the darker the color of an object, as mentioned by Bakker [21].

Table 4
RGB Intensity for Overripe Seeds

Sample	Test	R	G	B	Output	Sample	Test	R	G	B	Output
	1	171	190	166	Overripe	6	1	170	183	150	Overripe
1	2	185	215	191	Overripe		2	146	153	128	Overripe
	3	168	185	157	Overripe		3	154	173	152	Overripe
	4	169	181	152	Overripe		4	140	150	129	Overripe
	1	198	231	193	Overripe	7	1	150	166	145	Overripe
2	2	190	205	164	Overripe		2	170	190	154	Overripe
	3	180	199	181	Overripe		3	160	165	141	Overripe
	4	204	223	187	Overripe		4	170	183	149	Overripe
	1	206	221	177	Overripe	8	1	158	188	150	Overripe
3	2	180	205	187	Overripe		2	166	185	153	Overripe
	3	179	186	156	Overripe		3	174	188	146	Overripe
	4	174	177	154	Overripe		4	162	185	164	Overripe
	1	199	217	172	Overripe	9	1	159	180	151	Overripe
4	2	143	155	132	Overripe		2	138	159	138	Overripe
	3	150	163	137	Overripe		3	160	183	144	Overripe
	4	169	183	143	Overripe		4	145	155	129	Overripe
	1	159	169	141	Overripe	10	1	161	166	141	Overripe
5	2	146	162	140	Overripe		2	149	166	145	Overripe
	3	159	163	140	Overripe		3	150	165	141	Overripe
	4	159	181	159	Overripe		4	156	166	136	Overripe

3.4.3 Analysis of Accuracy and Test Results for The Sorting System

The classification system's accuracy is calculated according to the outcomes acquired after performing binary classification ten times. The classification tool's accuracy is then verified by entering it into the confusion matrix formula [23]. The confusion matrix is a predictive analysis tool. It is a table designed to define and evaluate the performance of a classification-based machine learning model [24]. Table 5 shows the overall test results for both the ripe and overripe categories.

Table 5
Accuracy Test Result for Ripe and Overripe Palm Seed

Test	True Positive (TP)	True Negative (TN)	False Positive (FP)	False Negative (FN)	Accuracy
1	10	0	0	0	100%
2	10	0	0	0	100%
3	10	0	0	0	100%
4	10	0	0	0	100%
5	10	0	0	0	100%
6	10	0	0	0	100%
7	10	0	0	0	100%
8	10	0	0	0	100%
9	10	0	0	0	100%
10	10	0	0	0	100%

4. Conclusions

In conclusion, a smart palm oil seed segregator system using RGB color sensor has been successfully developed and has achieved all the research objectives to overcome the problems stated. The system can successfully categorize seeds and notify the janitor through Blynk Apps every time each bin is full. It is equipped with the finest components to assure high reliability. RGB color sensor is better than a phototransistor with an increment of 30.525% and 62.96% accuracy improvement in response time when using an ultrasonic sensor. The overripe palm oil seed displayed a value greater than 165, while the ripe seed displayed a value less than 165 in colour concentration for all data sets. In the future, it is suggested to apply image processing techniques using a set of sensors to detect the ripeness of a bunch of oil palm seeds at the beginning of the system. This will hasten the process of segmentation and make it easier to respond to the industry.

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