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Development of Object Detection and Size Determination of Pineapple Fruit

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Abstract

Accurate measurement of pineapple size is crucial for farmers to determine fruit value. Existing challenges in size assessment, due to the irregular shape and the presence of crowns and stems, highlight the need for a precise measurement system. This research focuses on developing an object detection system tailored for accurately measuring and analysing pineapple sizes. The methodology integrates HC_SR04 and VL53L0X sensors with an Arduino MEGA 2560 for efficient data processing. The HC_SR04 assesses both height and diameter, while the VL53L0X specifically measures diameter, allowing for a comparative analysis of sensor accuracy. The collected data is transmitted to the Arduino MEGA 2560, which interprets and displays the readings on the Serial Monitor in centimetres. Experimental results affirm the success of this methodology in obtaining accurate diameter measurements. The HC_SR04 sensor emerges as the superior choice, offering precision and efficiency. The system's practicality lies in delivering readings in centimetres, enhancing ease of interpretation for users engaged in size measurement processes. In conclusion, the study establishes a reliable system for accurately measuring both height and diameter of pineapples. Future enhancements, such as incorporating LiDAR sensors known for superior accuracy, could further refine and expand the measurement system, paving the way for even higher precision in pineapple size assessment.

1. Introduction

From 2016 to 2020, Malaysia's pineapple exports, driven by native cultivars like MD2, N36, and Josapine, saw a significant rise. Only 5% of canned pineapple products are consumed locally, with 95% exported. Fresh pineapples dominate 70% of the local market and 30% of exports. To meet growing demand, this project develops a size measurement system using advanced technology [1]. Employing ultrasonic sensors on an Arduino MEGA 2560, the system focuses on detecting pineapple distances in two-dimensional space. The IR transmitter and receiver estimate pineapple sizes, and real-time data is displayed on the Serial Monitor. This technological improvement aims to enhance efficiency and accuracy in Malaysia's pineapple industry and advance agricultural practices. With

9.5% of the total fruit planting area dedicated to pineapples in 2020, this project contributes to meeting demand and optimizing resources. By leveraging cutting-edge technology for size measurement, Malaysia can strengthen its position in the global pineapple export market and boost the local economy [2].

2. Materials and Methods

2.1 Materials

The key components of the proposed to implement the upgrade system for the measurement of the dimensions and diameter of various objects, such as pineapples, included a microcontroller (Arduino Mega 2560), VL53L0X, and Ultrasonic sensor. This hardware implementation, which combined the Arduino Mega with VL53L0X and Ultrasonic sensor, demonstrated the advantages of incorporating advanced hardware components into measurement applications by providing an efficient and precise measurement system for measuring pineapples' size and diameter.

a) The Arduino Mega received the data and converted the analog signals to digital values. This digital data was then used by the Arduino to carry out calculations and measurements [3].

b) This ultrasonic sensor plays an important role in determining the height of pineapples by emitting ultrasonic waves. The ultrasonic waves bounce back after they hit the pineapple's surface, and the ultrasonic sensor measures the time it takes for them to bounce back [4].

c) The Time-of-Flight sensor (ToF) sensor measures the diameter of the pineapple by determining the distance from its side using reflected light.

2.2 Method

Based on Fig. 1, the pineapple measuring project design uses a systematic system of components to measure pineapple accurately. Four ultrasonic sensors are strategically placed to collect data from different angles, providing comprehensive coverage for precise measurements. The ultrasonic sensors are connected to the microcontroller Arduino MEGA 2560 which acts as the brains of the system. The stepper motor allows controlled the movement of the sensors, allowing them to move through the pineapple's surface systematically. To enhance measurement precision, a VL53L0X sensors, known for its accurate distance measuring capabilities, complements the ultrasonic sensors. The device operates by detecting the presence of a pineapple placed in its central area using an ultrasonic sensor. Once the pineapple is detected, the system triggers a stepper motor to initiate movement, enabling the sensors to begin measuring the size of the pineapple. Essentially, the device utilizes an ultrasonic sensor to identify the pineapple's presence, prompting the stepper motor to facilitate measurement by the sensors. The power supply is running at 12V and the overall dimensions of the project are carefully considered, with a height of 43 cm and a width of 33 cm, providing a compact and efficient from factor.

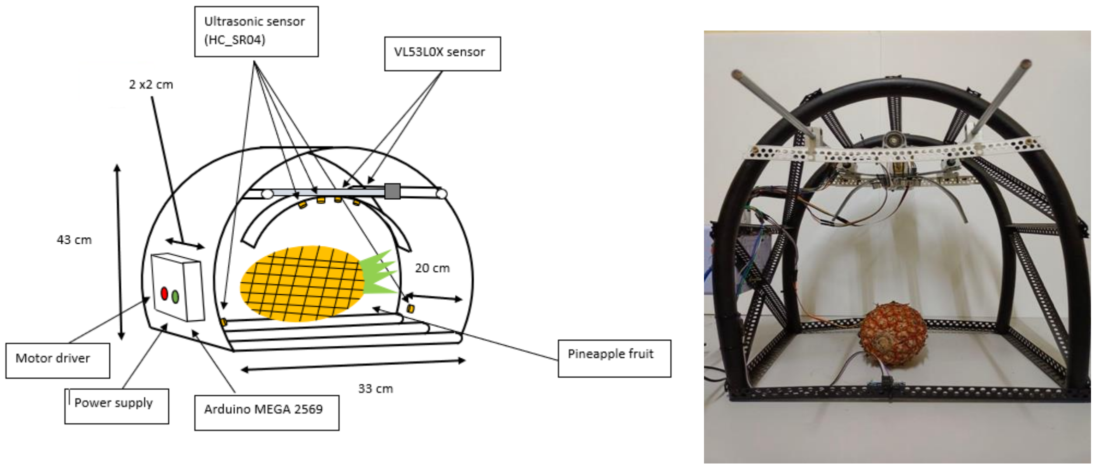

Fig. 1 *Project design*

2.3 Circuit Diagram

Based on Fig. 2, this flowchart outlines the basic programming logic for determining the diameter and height diameter of a pineapple with the aid of an ultrasonic sensor and an Arduino board. The actual implementation and code syntax may differ depending on the ultrasonic sensor and the board being used. The circuit diagram for this project is shown in Fig. 3. The Arduino MEGA 2560, Ultrasonic sensor (HC_SR04), Time-of-Flight sensor (VL53L0X), stepper motor, LED, and motor driver.

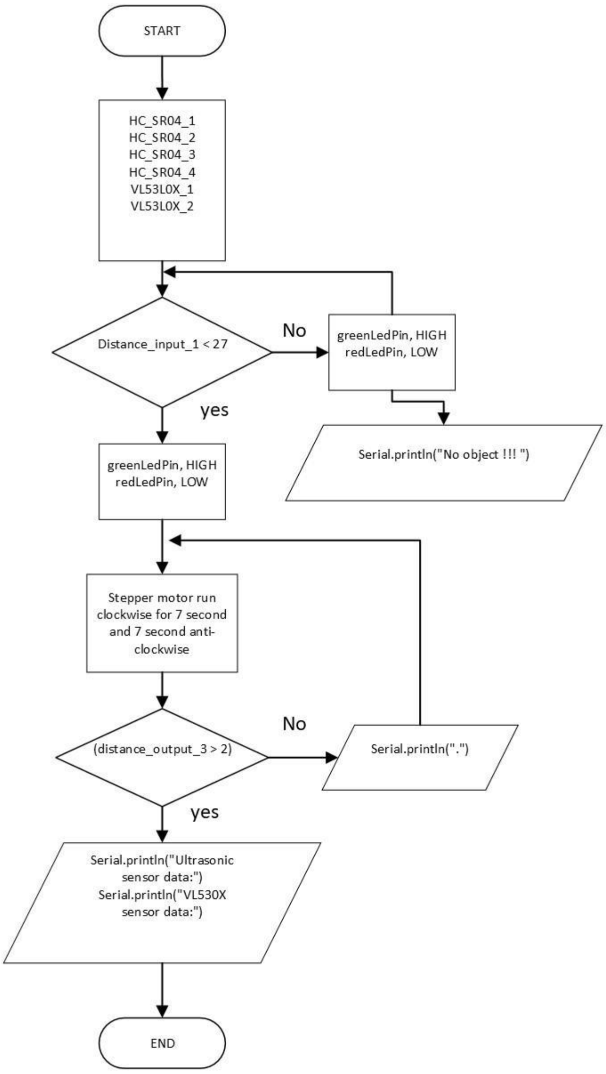

Fig. 2 *Flowchart programming*

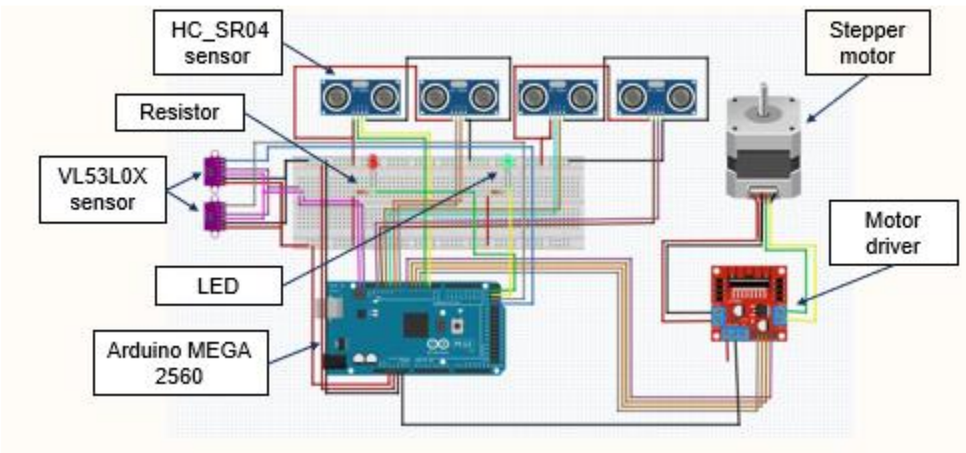

Fig. 3 *Circuit connection*

3. Results and Discussion

3.1 Classification of Pineapple Fruit

Based on Table 1 to assist in the development of machines or equipment related to pineapple fruit processing, a study was conducted to assess and document the physical characteristics of pineapple fruits. The researchers focused on measuring various physical attributes and classified them based on the chosen market-grade. The study found that there is a correlation between the size of the pineapple fruit and its weight. Generally, larger pineapple fruits tend to be heavier compared to smaller ones. This indicates that weight can be used as an indicator of fruit size. Additionally, the study observed that larger pineapple fruits also tend to have greater lengths and diameters. This suggests that the size of the fruit in terms of length and diameter increases as the fruit grade improves. Furthermore, the study noted that larger pineapple fruits exhibit higher maximum circumferences and stem diameters. This indicates that as the fruit size increases, both the circumference (the distance around the widest part of the fruit) and the stem diameter (the thickness of the stem) also tend to increase.

Table 1 *Data analysis pineapple fruit [5]*

Grade	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (kg)
Small(S)	14.13 ± 2.05	10.06 ± 0.91	0.89 ± 0.13
Medium (M)	16.59 ± 0.11	11.07 ± 1.36	1.34 ± 0.11

Based on Table 2 and Table 3, ten picture samples of pineapple fruits, equally divided between the category medium and grade small classifications, with five samples for each category, make up the dataset. Pineapples of grade B are generally of good quality with respect to size, weight, and colour, although they may have a few minor flaws. On the other hand, pineapples of grade small are smaller, lighter, and have more noticeable imperfections, which may make them less fit for human eating. A thorough assessment of the image processing system's capacity to correctly categorise pineapples according to their individual grades is made possible by this balanced distribution, which guarantees a thorough portrayal of pineapple variability. The wide range of samples helps to fully analyse the system's performance and provide insightful information on how well it can discriminate between fruits graded medium and small.

Table 2 *Grade B pineapple*

Grade medium pineapple				
Sample 1	Sample 2	Sample 3	Sample 4	Sample 5

Table 3 ***Grade C pineapple***

Grade small pineapple				
Sample 1	Sample 2	Sample 3	Sample 4	Sample 5

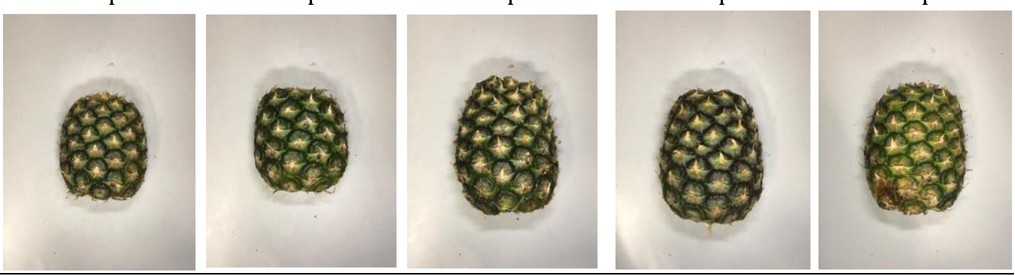

Table 4 classifies the examined pineapple fruits as Grade medium, indicating their generally favourable attributes in terms of size, weight, and colour. While Grade medium fruits may exhibit slight imperfections or texture variations, they are considered suitable for consumption. In contrast, Table 2 categorizes the specific pineapples under Class C, signifying smaller size, lighter weight, and more pronounced blemishes in terms of hue, texture, and overall quality. Class C fruits may be less ideal for consumption compared to higher-class counterparts. Table 3 collectively aim to assess the error between manual and system measurements. This evaluation seeks to quantify the discrepancies between the two measurement techniques, allowing for a comparison of the accuracy and reliability of system measurements against manual ones. The outcome provides valuable insights into the quality and integrity of the measurement methodology employed.

Table 4 *Classification of Pineapple fruit*

Number of samples	Grade medium pineapple fruit				Grade small pineapple fruit			
	Exact measurement		Manual measurement		Exact measurement		Manual measurement	
	Height	Diameter	Height	Diameter	Height	Diameter	Height	Diameter
Sample 1	14.09 cm	10.31 cm	16 cm	10 cm	8.87 cm	7.61 cm	10 cm	9 cm
Sample 2	15 cm	10.07 cm	14 cm	9 cm	10.14 cm	8.63 cm	10 cm	9 cm
Sample 3	15.58 cm	10.98 cm	16 cm	11 cm	12.18 cm	9.23 cm	12 cm	9 cm
Sample 4	12.05 cm	11.33 cm	12 cm	10 cm	12.36 cm	9.90 cm	10 cm	9 cm
Sample 5	13.68 cm	10.67 cm	13 cm	10 cm	10.28 cm	8.99 cm	11 cm	9.90 cm

Table 5 provides a comprehensive overview of the height and diameter measurements of the different pineapple samples. The height and diameter values represent key physical dimensions of the pineapples, offering insights into their size and shape variation. Looking at the data, the heights range from 7 cm to 12 cm, showcasing considerable diversity in pineapple sizes within the sampled group. Sample 10 stands out as the tallest with a height of 12 cm, while samples 3, 6, 12, and 13 share the smallest height measurement at 7.5 cm. this variance suggests that pineapples can exhibit a range of heights, possibly influenced by factors such as species, growing conditions, or maturation stages. Similarly, when look at the diameter column, the diameter ranges from 7cm to 11cm. The largest diameter is found in samples 11 and 12 at 11cm, while several other samples 3, 6, 13 and 14 have the smallest diameter of 7.5cm. Diameter values give us more information about the overall size and filling of pineapples. Larger diameters indicate a wider and possibly more mature fruit.

Table 5 *Manual Measurement Height and Diameter*

Number of samples	Height	Diameter
Sample 1	11 cm	9 cm
Sample 2	10 cm	9 cm
Sample 3	8 cm	8 cm
Sample 4	9 cm	8.5 cm
Sample 5	8 cm	8 cm
Sample 6	8 cm	7 cm
Sample 7	8.5 cm	8 cm
Sample 8	8.5 cm	8.5 cm
Sample 9	7.5 cm	8 cm
Sample 10	12 cm	10 cm
Sample 11	11 cm	11 cm
Sample 12	7.5 cm	7.5 cm
Sample 13	7 cm	7.5 cm
Sample 14	8 cm	8 cm
Sample 15	8 cm	8 cm

3.2 Exact Measurement by using Ultrasonic Sensor HC_SR04 and Time-of-Flight sensor

The aim of using these advanced sensors was to provide precise and reliable measurements for the set of 15 pineapples. The ultrasonic sensor HC_SR04 measured the height and diameter and the time-of-flight sensor (VL53L0X) measured the diameter. The ultrasonic sensor (HC_SR04) measures the height and diameter. This sensor works by sending ultrasonic pulses and counting how long it takes for those pulses to return. Therefore, it measures the distance with high accuracy. The time-of-Flight (ToF) sensor measures the diameter. It works by measuring the distance a laser beam travels to its target and back.

Table 6 presents detailed results from two experiments conducted to measure the height and diameter of pineapples using different sensors. In the first experiment, the Time-of-Flight Sensor VL53L0X and the Ultrasonic Sensor HC_SR04 were employed. For the first experiment, the Ultrasonic Sensor precisely measured the height of each pineapple by utilizing sound waves to estimate the distance to the top surface of the fruit. Simultaneously, the Time-of-Flight Sensor, employing laser technology, precisely measured the diameter of the pineapples. The integration of these two sensors allowed for a comprehensive evaluation of both diameter and height measurements for each sample.

The second experiment, detailed in the same Table 6, involved a replication of the first experiment with a focus on maintaining consistent instrumentation. In this case, the Ultrasonic Sensor HC_SR04 was again used to measure both the height and diameter of the pineapple samples. Additionally, the Time-of-Flight Sensor VL53L0X was employed specifically for diameter measurements. The use of multiple sensors in both experiments facilitated cross-validation of the collected data, thereby enhancing the reliability and precision of the obtained outcomes.

Table 6 *Exact Measurement by using HC_SR04 and VL53L0X*

No of samples	First Experiment			Second Experiment		
	HC_SR04		VL53L0X	HC_SR04		VL53L0X
	Height	Diameter	Diameter	Height	Diameter	Diameter
Sample 1	10.73 cm	6.64 cm	111 mm	9.51 cm	7.84 cm	104 mm
Sample 2	7.92 cm	8.37 cm	95 mm	6.57 cm	7.64 cm	80 mm
Sample 3	6.25 cm	5.22 cm	61 mm	5.42 cm	4.70 cm	79 mm
Sample 4	7.56 cm	8.30 cm	87 mm	7.03 cm	6.28 cm	67 mm
Sample 5	5.12 cm	4.56 cm	81 mm	6.37 cm	6.86 cm	55 mm
Sample 6	6.81 cm	6.47 cm	52 mm	7.01 cm	6.18 cm	66 mm
Sample 7	6.73 cm	6.33 cm	64 mm	6.97 cm	6.43 cm	65 mm
Sample 8	8.09 cm	6.16 cm	75 mm	7.40 cm	4.79 cm	68 mm
Sample 9	6.07 cm	6.86 cm	50 mm	5.29 cm	7.41 cm	56 mm
Sample 10	8.89 cm	7.00 cm	85 mm	9.14 cm	8.12 cm	82 mm
Sample 11	9.12 cm	7.02 cm	101 mm	8.17 cm	8.12 cm	101 mm
Sample 12	6.90 cm	6.52 cm	63 mm	5.80 cm	7.21 cm	59 mm
Sample 13	5.29 cm	5.59 cm	63 mm	6.01 cm	6.28 cm	58 mm
Sample 14	5.77 cm	6.16 cm	61 mm	6.08 cm	6.50 cm	67 mm
Sample 15	6.19 cm	5.54 cm	67 mm	5.29 cm	5.46 cm	52 mm

3.3 Standard Deviation

Based on Table 7, a comparative study of the data from both experimental trials showed that, in comparison to the Time-of-Flight sensor (VL53L0X), the HC_SR04 sensor consistently generated somewhat lower mean values for both pineapple height and diameter. Furthermore, the HC_SR04 sensor's variance and standard deviation readings were consistently lower than the Time-of-Flight sensor's, suggesting a lower level of measurement variability. The lower mean values from the HC_SR04 sensor suggest a systematic difference in measurements between the two sensors, with the HC_SR04 consistently providing measurements on the lower side. The reduced variance and standard deviation further imply that the HC_SR04 sensor's measurements exhibited less variability around the mean compared to the Time-of-Flight sensor. This reduced variability indicates a higher degree of precision and consistency in the measurements obtained using the HC_SR04 sensor.

Furthermore, it's critical to take the standard deviation into account when evaluating the sensor's accuracy in detecting pineapple diameter. A smaller standard deviation denotes a closer-knit clustering of the data around the mean, which is indicative of greater precision. When compared to the Time-of-Flight sensor, the HC_SR04 sensor provides more consistent and precise measurements of pineapple fruit diameter, as seen by its consistently lower standard deviation results.

Table 7 *Standard Deviation*

	Manual measurement		First experiment			Second experiment		
			HC_SR04		VL53L0X	HC-SR04		VL53L0X
	Height (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Diameter (cm)	Height (cm)	Diameter (cm)	Diameter (cm)
Max	12.00	11.00	10.73	8.37	11.10	9.14	8.12	10.40
Min	7.00	7.00	5.12	4.56	5.00	5.29	5.46	5.50
Mean (μ)	8.77	8.4	7.16	6.45	7.44	6.80	6.65	7.06
Variance (σ^2)	2.28	1.04	2.44	1.06	3.33	1.72	1.21	2.51
Standard deviation ($\sqrt{\sigma}$)	1.51	1.02	1.56	1.03	1.83	1.31	1.10	1.58

4. Conclusion

The system's development and design were informed by the project's utilization of insights gleaned from previous investigations and literature reviews. In the early phases, calculations were made to set parameters and specifications and make sure the components that were chosen fulfilled performance standards. The development of an image processing system for precise height and diameter measurements followed, setting up a camera for high-resolution picture acquisition. To improve precision, it was proposed that future studies include the use of a LiDAR (light detection and ranging) sensor. By monitoring the amount of time, it took for laser beams to return after striking the surface of the pineapple, this laser-based sensor produced precise data. Accuracy was increased by the LiDAR sensor's smooth integration into the current framework, which allowed it to function regardless of ambient lighting. This strategic addition demonstrated the project's commitment to continuous improvement, utilizing cutting-edge technology to set a new standard for pineapple size assessment, benefiting farmers and stakeholders in the agricultural sector.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The author attests to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

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