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MATLAB-Based Coconut Maturity Classifier using Audio and Image Processing
Coconut Maturity Classifier

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Abstract

A key phase in the post-harvest process of a coconut is its classification according to age or stage of development. Currently, the manual tapping method, as well as using the coconut's exterior appearance as basis, is a customary practice among sellers to determine the fruit's age. However, both have drawbacks when it comes to accuracy, as retailers have noted losses in income because these methods do not guarantee correctly classified coconuts. To address this concern, a coconut maturity classifier that uses MATLAB for processing the fruit's thermal image and audio, produced by a mechanical tapper, was developed. After a series of tests, the proponents were able to develop a system that has an accuracy rate of 93.33% for audio and 60% for image. For the execution time, it takes an average of 75.37 seconds to complete the whole process. The user-friendly rating of the system is 4.62.

Index Terms: *Coconut Maturity Classifier, Audio Processing, Image Processing, Thermal Imaging, MATLAB, Fast Fourier Transform*

I. INTRODUCTION

The Philippines is one of the largest producers of coconut in the world. In fact, the country is second in the whole Asia. The coconut industry plays a vital role: it helps develop the national economy and is a key factor in the country's Gross National Product. There are about 3.26 million hectares of agricultural land planted with coconuts in the Philippines. This is about one-third of the country's healthy lands [1]. Currently, the production of coconut has increased by 3.3 percent from 3.69 million metric tons to 3.81 million metric tons during the same quarter of the previous year. The increase in production is due to the sufficient rains during the fruiting stage and applications of fertilizers, especially in CALABARZON, which is the top coconut-producing region for the quarter with contribution of 15.1 percent [2]. The said region depends so much on the coconut yield since it has become their main source of income.

Statement of the problem

A key phase in the post-harvest process of a coconut is the classification according to age or stage of development. Currently, the manual tapping method, as well as using the coconut's exterior appearance as basis, is a customary practice among sellers to determine a fruit's age. However, both have drawbacks when it comes to accuracy. According to retailers, these inaccuracies contribute to the failure in classifying coconuts, which eventually leads to loss in their income. Previous studies prove that the sound produced by the coconut can be suppressed, recorded, and processed using an acoustic property tester [3,4,5]. In addition, other studies explain that processing the image of a coconut allows us to determine the thickness of the kernel/endosperm,

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which can also aid in identifying the development stage without opening them [6,7].

Although these studies have been tested and proven, a similar device has yet to be implemented in the country. To address this, the proponents will develop an accurate, affordable, portable, fast, and user-friendly device that could be used by retailers, as well as the Philippine Coconut Authority, which is currently facing I.T. and Agricultural Engineering-oriented personnel deficiency. The device would quickly classify coconuts through water volume content and amount of kernel/endosperm.

Objectives

1. General

To develop a device that can be used to classify the coconuts depending on its stage of development

2. Specific

- The device should accurately determine the classification of the coconut.
- To construct a device which can be easily transported
- To construct a device that has a fast execution time
- To develop a device that is user-friendly.

Scope and Limitation

1. Scope

- The coconut variety named Laguna Tall will be used
- The device will be powered by a rechargeable battery
- There will be four classification of coconut:

  - Mucous Like (Malauhog)

  - Cooked Rice-Like (Malakanin)

  - Leatherlike (Malakatad)

  - Germination

2 Limitation

The device can only examine harvested coconuts. It cannot examine coconuts still attached on the trees.

The device doesn't have a sensor that would detect whether the fruit subjected to testing is coconut or not.

Conceptual Framework

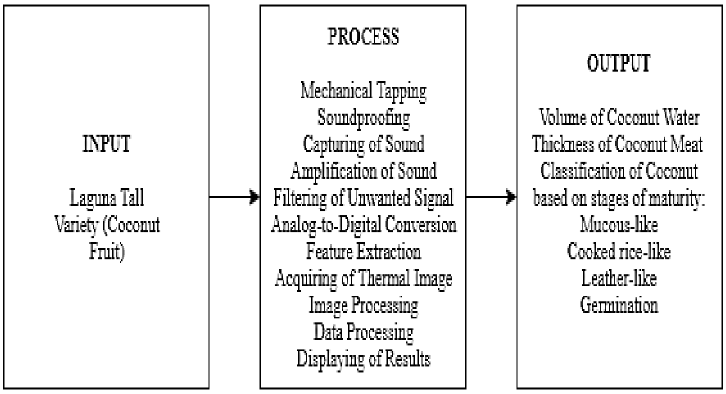

Figure 1: Conceptual Framework of the Design Project

The input of the classifying device is the coconut itself. The main process of the system has two parts: the audio processing and image processing. For the audio processing, the sound produced once the coconut is mechanically tapped will be captured, amplified and will undergo filtration process. Take note that while the sound is being captured, the interference from the outside source is not allowed to pass through using soundproofing techniques. This signal which is in analog form will be processed by converting it into digital form and extracting the features from it. For the image processing, it will start once the fruit has already been captured thermally. The expected output will be the volume of the coconut water, thickness of the coconut meat, and the maturity stage of the coconut (Mucous-like, Cooked Rice-like, Leatherlike, and Germination).

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II. METHODS AND PROCEDURES

Functional Design

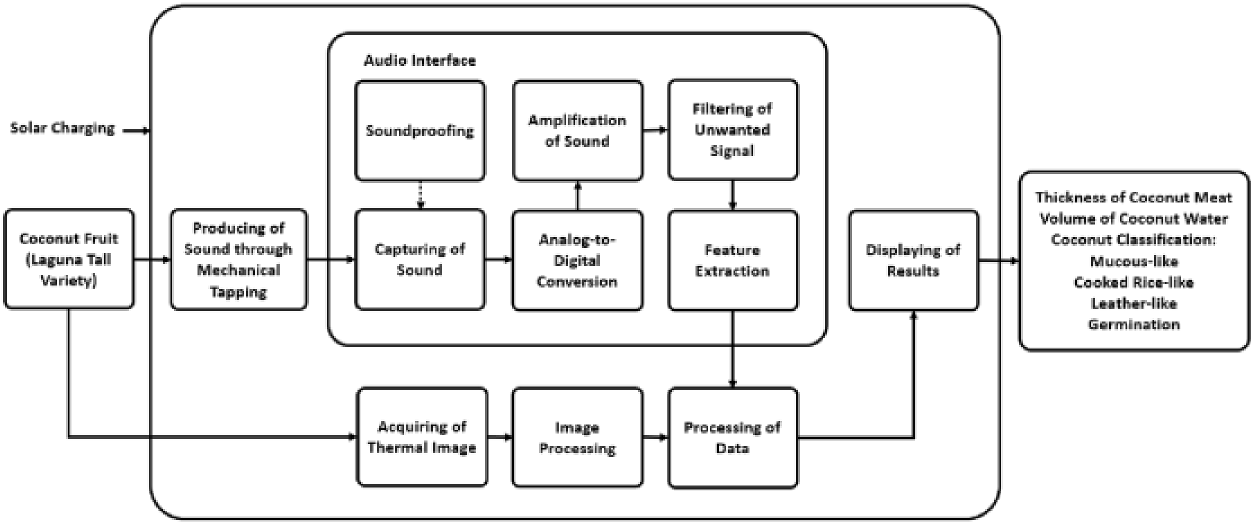

Figure 2: Glass Box

Figure 2 shows the block diagram of the design project. A 12 volts battery will be used to power up the system, this battery along with a solar charger will serve as the power source of the system. Moreover, the coconut will serve as the main input whereas its classification will serve as the output of the system. It will undergo two processes which are the audio processing and the image processing. For the audio processing part, mechanical tapping will be done to produce the sound to be captured by the microphone of the device which at the same time soundproofing will occur with the help of the acoustical foams inside the device. For easier manipulation and processing of signal, the system will convert the captured signal into its digital form. The digital signal will then be amplified by the system to three times of its original amplitude or by 10 dB (decibels). This amplified signal will then undergo filtration using a Bessel filter with cut-off frequency of 2kHz where frequencies beyond the cut-off frequency will be remove. Values from 0 to 2 kHz are the only ones allowed for further processing. The filtered signal will undergo feature extraction using Fast Fourier Transform in order to determine its characteristics as well as for fundamental frequency be extracted. This frequency will be the determining factor for the classification of the coconut based on audio. As for the image processing, the thermal content of the coconut will be captured using the AMG8833 thermal camera. This thermal image will process by the system using MATLAB Simulink in order to convert it to its corresponding values. Through data processing, the system will determine the heat content (in Celsius) of the coconut and classify it accordingly. The coconut’s classification base on audio and image will be display by the system along with its expected volume of coconut water, thickness of coconut meat, and overall classification.

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System Flowchart

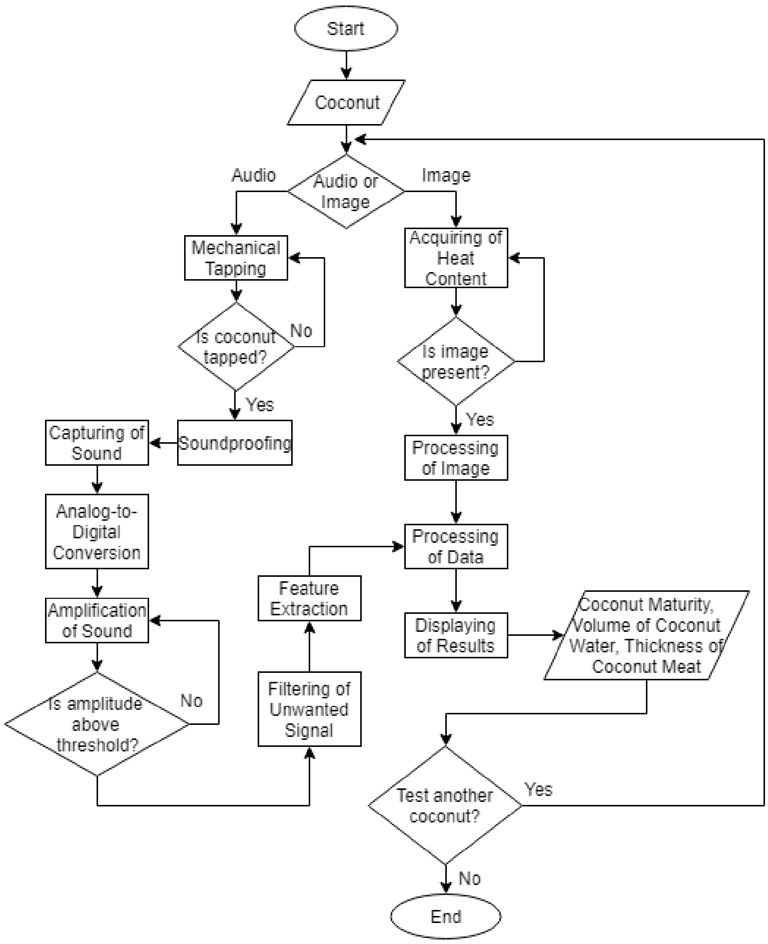

Figure 3: Program Flow of the system

As the coconut is placed inside the box, the user will then be allowed to choose from either audio or image processing from the graphical user interface of the system. Whenever the user chooses audio processing, the push button must be pressed to activate the motor and tap the coconut inside the box. Due to the attached acoustic foams inside the box, sounds from the outside will be lessened, allowing the microphone to capture a much clearer signal. The captured sound will then be automatically converted into discrete form due to the language of the PC and the hard-coded conversion in the MATLAB. Sound converted will then be amplified through the system which should be above the threshold level of 10dB. The amplified signal will then be filtered through the coded Butterworth response using Fast Fourier Transform in the MATLAB code. This will filter out all frequencies above 2 kHz which is the cut-off frequency of the filter. After all the processes are done, feature extraction will take place to determine the fundamental frequency of the captured sound which will determine the classification of the coconut subjected into testing. As for the other part, whenever the user chooses image processing, with the use of the AMG8833, the device will capture the average heat of the coconut. It will then undergo processes using certain algorithms to produce the needed output of the user. Both areas will then be processed through the platform used to allow control of the output devices. All desired outputs such as coconut maturity, volume of coconut water, and thickness of coconut meat will then be displayed in the GUI. The system will then restart whenever another coconut is subjected to testing, otherwise, it will stop.

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C. Wiring Diagram

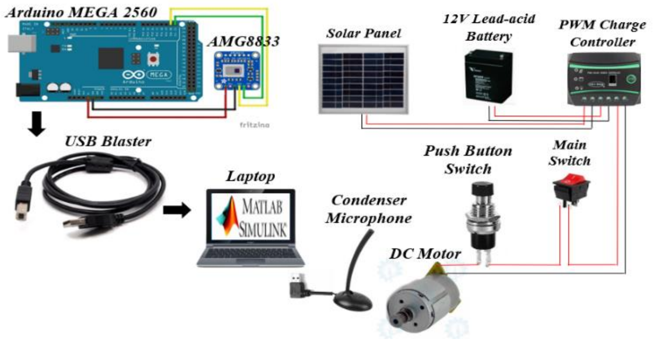

Figure 4: Overall Wiring Diagram of the Design Project

Figure 4 shows the overall wiring diagram of the project. It includes The Arduino Mega 2560, AMG8833, USB blaster, laptop, microphone, DC motor, push button switch, main switch, PWM charge controller, 12V lead-acid battery, and solar panel.

D. Determining of Heat Content

The instrument used for determining the heat content of the coconut is an 8x8 thermal camera which contains a total of 64 pixels. Each pixel detects different values of temperature whenever the thermal image is being captured. Therefore, the average of all the pixels should be computed to determine the total heat content of the coconut. It is computed using the equation 1 where P_n represents each pixel of the camera with different equivalent values of temperature.

$$T = \frac{P_1 + P_2 + P_3 + \ldots + P_{64}}{64} \qquad (1)$$

E. Determining of Fundamental Frequency

The sound produced by tapping the coconut serves as the input of the system. The fundamental frequency of the sound is computed using equation 2.

$$X = (log_{10}(fft(Y)) + 10dB) \qquad (2)$$

$$f_{fundamental} = \max\left(abs\left(butterworth(X)\right)\right) \qquad (3)$$

The fft() function performs the Fast Fourier Transform of the signal ‘Y’. Its signal level is increased by 10dB resulting to ‘X’. This amplified signal undergoes filtering using the butterworth() function. The max() function determines the frequency with the highest signal level which represents the fundamental frequency of the processed audio.

F. Processing of Audio Signal

In this phase, the sound produced from tapping is captured and serves as the input of the system.

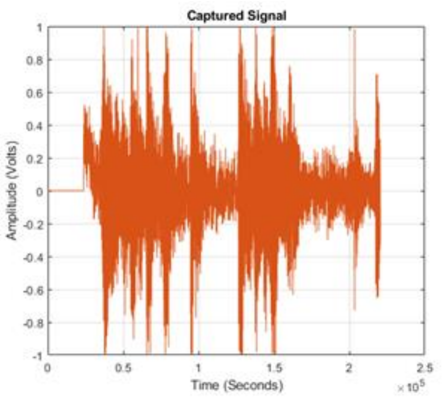

Figure 5: Captured Signal

Since the captured signal is analog, the system converts the signal into its digital form for easy processing and feature extraction.

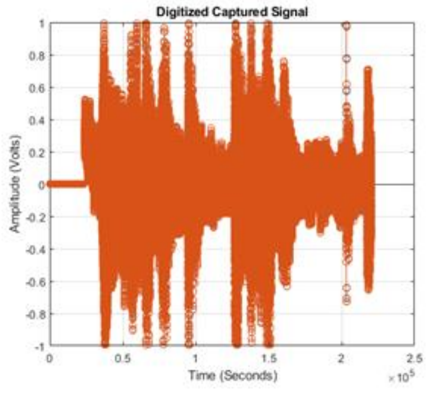

Figure 6: Digitized Signal

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In order to avoid loss or distortion of the important parts of the signal, amplification by 10 decibels was done.

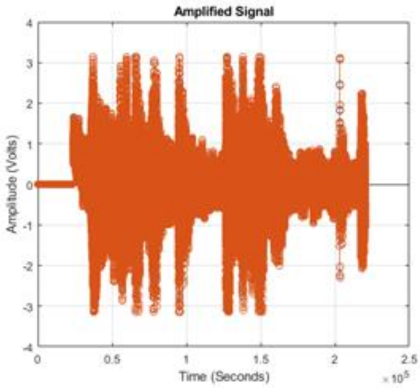

Figure 7: Amplified Signal

Since the frequency of the coconut ranges only from 270 to 1330 Hz, filtering was done with a cut-off frequency of 2 kHz.

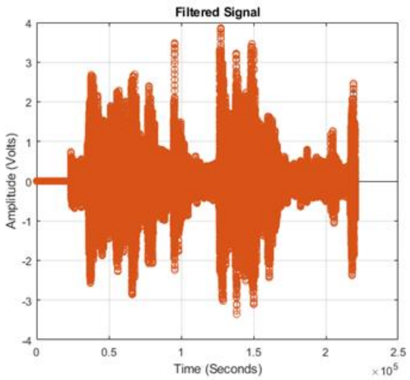

Figure 8: Filtered Signal

After filtration, FFT will be done of the signal in order to extract its fundamental frequency which has the highest amplitude in its waveform.

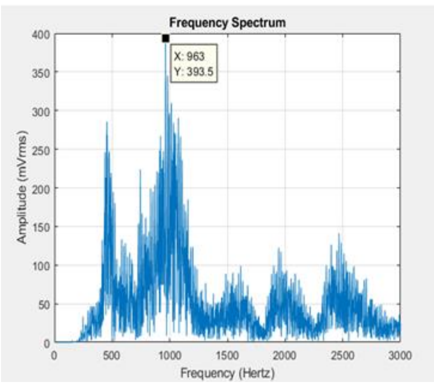

Figure 9: Processed Signal

Instruments and Techniques Used

MATLAB was used as the software platform in creating the project. The MATLAB Simulink, along with the needed add ons and libraries, was used in creating the program for extracting and concatenation of the captured temperatures of each pixel in the 8x8 AMG8833 thermal camera. The hardware platform used was the ATMEGA 2560 which is responsible for receiving the captured image of the thermal camera to be sent to the software. Also, MATLAB was used for the designed graphical user interface of the system.

III. RESULTS AND DISCUSSION

In measuring the accuracy, the proponents compared the results of their system with the actual classification of the coconuts. For the portability, the actual volume of the testing box was calculated. On the other hand, the speed was measured from the start of the system until it produces its output. Moreover, the user-friendliness of the device was evaluated from surveys conducted.

A. Accuracy

In testing the accuracy, the final classification displayed by the system based on the frequency and heat content of the fruit and the correct classification of coconut must be the same with the expected output. For thorough testing, the accuracy of each classification of coconut based on audio and image processing was independently determined. Accuracy of the system was computed using equation 3.

$$\%Accuracy \ \frac{Total\ number\ of\ coconuts\ correctly\ classified}{Total\ number\ of\ coconuts\ subjected\ to\ testing}\ x\ 100 \quad (4)$$

Table 1: Overall Results for Accuracy

Classification	Accuracy through Audio	Accuracy through Image
Mucous-like	86.67%	60.00%
Cooked Rice-like	100.00%	66.67%
Leatherlike	93.33%	53.33%
Germination	93.33%	60.00%
Overall Accuracy	**93.33%**	**60.00%**

Table 1 shows the summary of accuracy per classification. For audio processing, Cooked Rice-like classification has the highest accuracy rating with 100.00% and Mucous-like has the lowest

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accuracy with 86.67%. For the image processing, Cooked Rice-like classification has the highest accuracy rating with 66.67% and Leatherlike has the lowest accuracy with 53.33%. The overall accuracy was determined by calculating the average of the values for each coconut classification which is 93.33% for the audio processing and 60.00% for the image processing.

B. Portability

The testing box has a dimension of 18 x 15.5 x 15.5 inches. In measuring the portability, the proponents used the formula for computing the volume of a rectangular parallelepiped as shown in equation 5 where L is the length of the testing box, W is the width, and H is its height. Through computation, the actual hardware design's volume has a value of 4,324.50 in3.

$$V = L \, x \, W \, x \, H \quad (5)$$

Figure 10: Isometric View of Hardware Design

Figure 11: Top View of Hardware Design

C.Speed

In testing the system speed, a stopwatch was used for measuring the system's speed. The timer for the audio processing will start once the system begins capturing the tapped sound from the coconut, and will stop once the frequency, volume of coconut water, and coconut classification based on audio are displayed by the system. On the other hand, the timer for the image processing will start once the camera begins capturing the thermal image of the coconut and will stop once the heat content, thickness of coconut meat, and coconut classification based on thermal image are displayed by the system.

Table 2: Results of System Speed

Classification	Speed through Audio Processing (seconds)	Speed through Image Processing (seconds)	Total (seconds)
Mucous-like	5.65	63.96	69.61
Cooked Rice-like	5.10	79.02	84.12
Leatherlike	5.16	74.26	79.42
Germination	6.04	62.28	68.32
Average Speed	**5.49**	**69.88**	**75.37**

Table 2 shows the summary of the result for the system's speed, where the values stated are the average speed per coconut classification. Moreover, the average speed of the system in terms of audio processing is 5.49 seconds, while 69.88 seconds for image processing. With the testing, the average total speed of the system considering both audio and image processing is 75.37 seconds.

D. User-Friendliness

This objective refers to the user's ability to understand the operation of the system. The rating would range from "1", being the most difficult to understand, to the rating of "5", which is the easiest to understand. This will be done by taking the average of the rating done by the 50 respondents to determine the rating of the system's complexity.

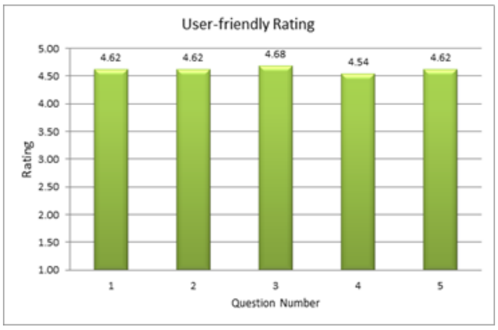

Figure 12: User-Friendly Rating

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There are five questions asked during each survey. The first question checks whether the prototype is properly labeled or not. The second question refers to the readability of the GUI's font. The third question is about the proper positioning of buttons, images, and the results obtained on the GUI. The fourth question discusses the system's performance and if any errors occurred, while the last question rates how easy it is to use the project. The average rating of the 50 respondents was shown at figure 12. By getting the arithmetic mean of the ratings, the overall user-friendly rating of the project is 4.62.

IV. SUMMARY OF FINDINGS, CONCLUSION, AND RECOMMENDATION

A. Summary of Findings

Table 3 shows the summary of findings after a series of testing. It shows the objectives, and the actual values gathered for each. For the accuracy testing, 15 samples per coconut classification is used amounting to a total of 60 samples. The results for the accurate identification for audio processing have a minimum value of 86.67% and a maximum value of 100% with an average of 93.33%. For the accurate identification in image processing, the minimum and maximum values are 53.33% and 66.67% respectively, with an average value of 60.00%. For the portability of the device, the volume is calculated at 4,324.50 inches3. For the speed in classifying, the extreme values are 108.22 seconds and 54.62 seconds, resulting to the average duration of the system at 75.37 second. Lastly, the user-friendly objective of the project was rated 4.54 at minimum and 4.68 at maximum with an average of 4.62.

Table 3: Summary of Findings

Objectives	Actual Values		
	Minimum	Maximum	Average
Accurate Identification through Audio (%)	86.67	100.00	93.33
Accurate Identification through Image (%)	53.33	66.67	60.00
Affordability of Device (Php)		95,488.21	
Portability of Device (in^3)		4,324.50	
Speed in Classifying (seconds)	108.22	54.62	75.37
User-friendliness of Device	4.54	4.68	4.62

B. Conclusion

The proponents conclude the following based on the results of the data gathered:

The accuracy of the device in terms of audio processing 93.33%. This value has exceeded the target accuracy of the group that is 87.63%.

Since the system uses thermal imaging, a new method in classifying coconuts, the accuracy of the device in terms of image processing is only 60%.

The device's portability has a measurement of 18” x 15.5” x 15.5” and a total volume of 4,324.5 in3, smaller than the device created by previous researchers.

Considering the processes done by MATLAB, it takes 75.37 seconds to classify the coconut. This is greatly affected by the time it takes for the system to process the thermal image. However, it only takes an average of 5.48 seconds for the audio processing alone.

The user-friendliness of the system has an average rating of 4.57 based on the survey conducted.

C. Recommendations

During the development stage, the researchers were able to see some aspects that the project might improve on. The following items below are some of the things that the proponents took note of:

Use a very high sensitive thermal camera for fast and more accurate results.

Use a microphone with higher sensitivity to easily allow capture of low frequency sound.

Portability would be best improved using other acoustical materials as a replacement or alternative for acoustical foam.

Consider using a laptop or desktop computer with higher specifications to help increase the speed of the image processing.

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Provide a means of verifying whether the expected values for the contents of the coconut is the same with its actual value.

On a bigger scale, future work may engage into automating the system.

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