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Design and Implementation of Coconut Maturity Prediction System Based on Naïve Bayes Classification Algorithm Using Arduino and A Sound Sensor

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Abstract:- The level of coconut maturity may be measured not only by viewing the color of the shell, but also by using an acoustic recognition technique from pounding on the coconut shell. This knocking sound differentiates between Juicy, Semi - Juicy, Fleshy, Very Fleshy and mature coconut. Those with substantial knowledge and sound sensitivity to coconut knocking typically execute identifying the sound distinctive of banging on coconut. The design of a coconut maturity prediction system with acoustic frequency detection is devised to replace skilled workers. The coconut sound signal is captured using a stethoscope linked to a Max4466 Electret Microphone Amplifier. The signal is processed using an Arduino Due microcontroller. The signal processing procedure includes the following steps: converting an analog signal to a digital signal, screening the signal, and locating the signal. The signal processing procedure includes the following steps: converting an analog signal to a digital signal, screening the signal, and determining the average value of the sound signal frequency spectrum. The signal screening employs a bandpass digital filter of the type IIR (Infinite Impulse Response) with an elliptic order of 6-7. This filter is used to ensure that the signal being processed is not noise but the signal of a banging sound on a coconut. The Nave Bayes Machine Learning Classification Algorithm is used to calculate the average value of the sound signal frequency spectrum. The Naive Bayes classification approach is used for maturity prediction. The input is three average values of knocking sound frequency and coconut size, and the output is coconut maturity categorization shown on an LED screen.

Keywords:- *Acoustic, Distinctive, Spectrum ,Machine Learning, Elliptic Order*

I. INTRODUCTION

Ghana's coconut industry is a major economic crop due to its Ghana is exporting more fruits and vegetables, especially coconuts. The coconut (Cocos nucifera) is a significant economic crop in Ghana. Due to the multiple byproducts it produces, coconuts are seen as a cash crop with numerous advantages for Ghana. Coconuts are a very adaptable fruit because its milk, flesh, water, and oil can all be used in a wide range of products for the culinary, beauty, and energy industries. Due to these by-products, coconuts are a highly lucrative investment for farmers. According to the Ghana Export Promotion Authority (GEPA), the coconut industry would bring in 2.8 billion USD by 2021[1].The coconut tree is regarded as the "tree of life" because any part of it, including the roots, trunk, palm, and fruit, may be beneficial. The coconut fruit's growth into various phases or age levels determines whether it is used as a meal or a beverage. The main coconut product, coconut oil (CO), has received a lot of attention from the media and the general public in recent years, particularly in Europe and North America. Celebrities, social media influencers, and even physicians have advocated for the use of this oil as a cooking medium in place of standard vegetable oils, as well as a supplement to coffee and vitamin smoothies.CO intake is advertised in blogs, online videos, and publications as having a number of health advantages.Among these, include cholesterol-lowering effects, a lower risk of Cardiovascular Disease (CVD), weight loss, increased cognitive capacities, antimicrobial activity, and other benefits [2]. Coconut flesh and mature coconut water may provide protein and antioxidants. Post-harvest management and the use of appropriate technology will increase the economic value of coconut. It is vital to build systems that can categorize the amount of ripeness depending on customer demands in order to improve the selling value and consumption of coconut. Fruit ripeness categorization has shown to be a challenging topic that will require more research [3]. Fruit ripeness categorization is challenging because fruit characteristics are difficult to distinguish and display variable patterns within one classification class. Unfortunately, no non-invasive determining application has been created that can reliably evaluate the maturity stage of coconuts [4].The degree of maturity of the coconut has a direct influence on various internal coconut metrics, including the amount of coconut water, thickness of coconut flesh, and wet weight of coconut flesh [5]. Farmers and coconut traders have historically judged coconut maturity by carefully listening to the sound made when hammering on the coconut shell. The acoustic frequency generated by knocking on a coconut shell is changed by the maturity stage of the coconut, according to[6].This is because both the coconut meat and the coconut shell will be thicker and more difficult to chew as the coconut ages. In addition to the aforementioned fact, the amount of coconut water will decrease, which will reduce the weight of the coconut and increase the frequency of knocking noises on the coconut.Nave Bayes (NB) is one of the most well-known data mining techniques for categorization [7]. Based on the premise that all traits are independent of one another, it determines the likelihood that a fresh sample belongs to a specific class [8]. This presumption is driven by the requirement to estimate multivariate probabilities from training data. In reality, the training data only adequately or entirely represents the majority of attribute value combinations. As a result, direct calculation of each pertinent multi-variate probability will be unreliable. This issue is resolved by the conditional independence presumption in Nave Bayes. Despite this stringent independence requirement, nave Bayes is a very good classifier in a variety of real-world circumstances [9]. Despite the fact that naive Bayes has previously shown amazing classification accuracy, the conditional independence assumption is rarely true in practice.As a result, reducing the conditional independence assumption is a logical way to enhance nave Bayes. Attribute weighting, attribute selection, structure extension, and other methods are used to accomplish this. According to previous studies [10], picking only part of the criteria may improve classification accuracy. After analyzing all conceivable additions or removals of one attribute in one pass through the training data, the traditional greedy search approach [11] adds (or removes) an attribute to (or from) a previous model. Multiple runs over the training data are necessary to create the final model since only one characteristic is added or deleted after one pass, resulting in significant computational overhead. Selective Nave Bayes(SNB) is an efficient attribute selection technique proposed in this study (SNB). It builds selective naive Bayes models using only part of the features. Because various models in SNB imply varying numbers of characteristics that will be utilized when categorizing an example, attribute selection is done through model selection.

In a single pass through the training data, the suggested technique assesses all potential additions of one attribute, two attributes, and an attribute, respectively, from an empty attribute set, where an is the number of attributes. As a result, instead of numerous runs over the training data, all of the models may be evaluated in a one pass. It is efficient because, in comparison to ordinary nave Bayes, numerous selective nave Bayes models that have been developed in such a way that one is merely a simple extension of another may be assessed using incremental leave-one-out cross validation in a single extra trip over the training data. As a result, it necessitates two runs over the training data.

II. LITERATURE REVIEW

A. Signal Processing & LTI System

Signal processing is the manipulation of signals to extract information or modify its characteristics [7]. It is a critical area in various fields, including telecommunications, audio processing, image processing, and biomedical engineering [8]. In the present research, signal processing is used to analyze the sound signals generated by coconuts to classify them into different maturity levels.

One of the significant challenges in signal processing is extracting meaningful features from the raw signal [9]. In the coconut maturity prediction system, an efficient feature extraction algorithm will be developed to extract essential features from the sound signals generated by coconuts. This algorithm will use signal processing techniques such as filtering, feature selection, and dimensionality reduction to extract the most relevant features that can be used to classify coconuts into their maturity levels.

The Naïve Bayes classification algorithm will be used to classify the maturity levels of coconuts based on the extracted features. This algorithm is a popular data mining technique that can predict the probability of a new sample belonging to a particular class based on the training data [10]. Naïve Bayes is widely used in various applications such as spam filtering, sentiment analysis, and medical diagnosis.

B. Fourier in Image Processing

Image The Fourier Transform is not only useful in signal processing, but also in image processing. In fact, Fourier transform plays a crucial role in the analysis, filtering, reconstruction, and compression of images [11]. The Fourier Transform decomposes the image into its frequency components, which makes it easier to analyze and manipulate the image. The use of Fourier Transform in image processing is particularly relevant in areas such as computer vision, remote sensing, and medical imaging, where images are analyzed and processed in order to extract useful information [12].One of the most important applications of Fourier Transform in image processing is image filtering. Filtering involves modifying the frequency content of an image in order to enhance or suppress certain features. Filtering is used extensively in image enhancement, noise reduction, and edge detection [13]. In addition to filtering, the Fourier Transform is also used in image reconstruction. Image reconstruction involves recovering the original image from its frequency components [14]. This process is particularly useful in cases where an image is distorted or incomplete.

C. Fourier Transform

Fourier Transform (FT) is an important mathematical tool used in signal processing to analyze and manipulate signals. It allows signals to be represented in the frequency domain rather than the time domain, enabling better understanding of signal characteristics and facilitating processing techniques such as filtering, compression, and modulation [15].

In the context of the coconut maturity prediction system, the FT is essential in the analysis of the sound signals generated by coconuts at different maturity levels. By analyzing the frequency components of the sound signals using the FT, relevant features can be extracted and used in the Naïve Bayes classification algorithm to determine the maturity level of the coconut.

The efficiency and accuracy of the Fourier Transform in signal processing have been well documented in literature. It has been used in various applications, such as in image processing, speech recognition, and biomedical signal analysis [16]. In particular, the use of FT in the analysis of sound signals has been extensively studied in the field of acoustics and audio engineering .

The implementation of the Fourier Transform in signal processing applications has also been made easier with the development of software packages and libraries, such as MATLAB and NumPy, which provide pre-built functions for performing the transform. This has allowed researchers and engineers to focus on the application of the FT rather than the mathematical intricacies of the transform itself [18]

D. Review of Related Literature

Coconut is an important crop for many tropical countries, and the maturity stage is a significant component in determining the fruit's quality and productivity. Visual inspection and physical tapping are both time-consuming and subjective techniques of detecting coconut ripeness. As a result, a precise and efficient method of predicting coconut maturity is required.

Several approaches for forecasting coconut maturity have been proposed, including the use of acoustic signals, image analysis, and machine learning algorithms. Acoustic signals, for example, have been found to be a viable tool for predicting coconut maturity since they can give non-invasive and real-time measures of coconut maturity[14] proposed using sound cues and machine learning techniques to forecast the maturity of immature coconuts. The study used a Support Vector Machine (SVM) algorithm and attained an accuracy of 90% in predicting the maturity stage of immature coconuts. However, the study only looked at young coconuts, and more research is needed to determine the efficiency of acoustic signals in forecasting the maturity of adult coconuts.

Another study in [15] proposed using acoustic cues and image processing to estimate coconut ripeness. The study used a Convolutional Neural Network (CNN) algorithm to predict the maturity stage of coconuts and attained an accuracy of 97%. However, in addition to acoustic signals, image processing was used in the study, which may not be practicable for real-time and non-invasive assessments.

A study by Zhou et al used a Naïve Bayes algorithm to classify the maturity level of kiwifruit based on their acoustic features.

Another study by Cao et al used a Naïve Bayes algorithm to predict the maturity level of peaches based on their acoustic characteristics.

Arduino microcontrollers have also been used in various applications related to agriculture, including fruit maturity prediction. A study by Singh et al. used an Arduino-based system to predict the maturity level of mangoes based on their color and firmness.

Another study by Song et al. [19] used an Arduino-based system to predict the maturity level of strawberries based on their color and shape.

"Determining Philippine coconut maturity level using machine learning algorithms based on acoustic signal."

In[15] June 2020, Anne Caladcada, Shiela Cabahugb, Mary Rose Catamco, and colleagues conducted research on the topic [17] proposed an Arduino-based Sound Acquisition System for Coconut Maturity Classification Using Fast Fourier Transform Algorithm.The system consists of an Arduino board, a microphone sensor, and an LCD display to display the results. The system's primary goal is to detect the maturity degree of fruits based on their sound frequency characteristics. The authors explain that the sound generated by a fruit changes as it matures due to physiological changes that occur during the ripening process. The FFT technique, which decomposes the sound wave into its frequency components, is used to study the sound frequency properties of the fruit. The authors also discuss the development of the Nave Bayes classification method for categorizing fruit maturity level based on frequency components.

"*An Intelligent Non-Invasive Sensing Method in Identifying Coconut (Coco nucifera var. Ebunea) Ripeness Using Computer Vision and Artificial Neural Network."*

eccentricity, metric, contrast, correlation, energy, and homogeneity were created using MATLAB 2015a.

According to G. Manogaran et al. [24], the perimeter is the number of pixels designating the border or portion of an item, whereas the number of pixels in an object area represent the area. In order to characterize agricultural products like grain surface area, Wang et al. [25] employed perimeter and area. Eccentricity was utilized by Feng Li to measure the separation between small and large elliptical foci. The eccentricity of a thing can range from 0 to 1. Spherical or circular objects have a value that is close to zero, whereas long or nearly straight objects have a value of one. Numerous studies have been done.

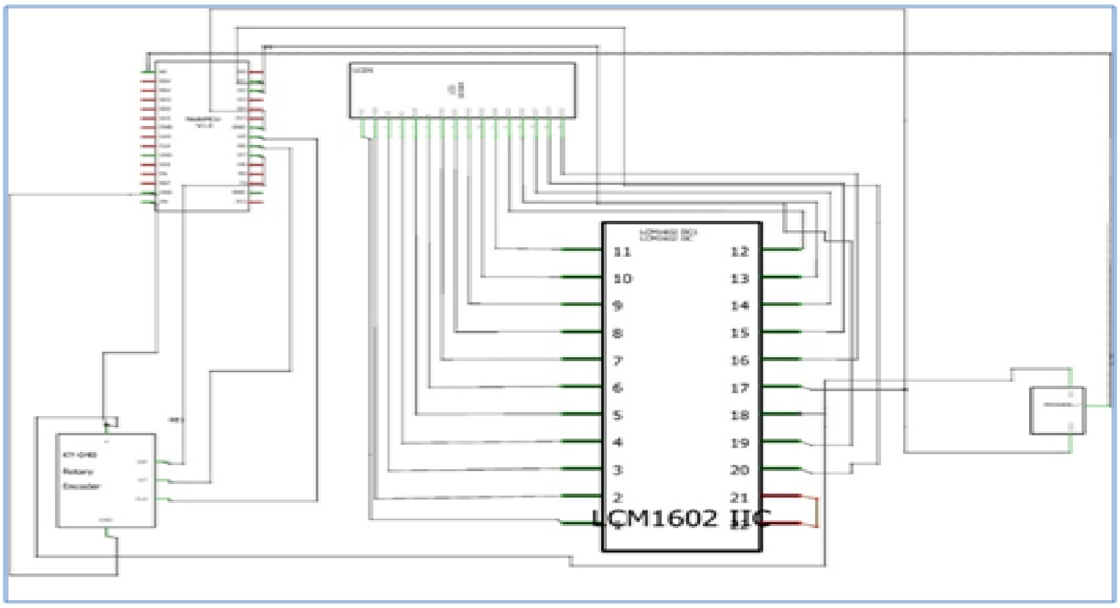

Fig. 1: System Schematic

using the eccentricity measure to identify and examine the appearance characteristics of fruits and foods. The eccentricity equation is as follows:

$$eccentricity(e) = \sqrt{1 - \frac{a^2}{b^2}} \quad [1]$$

From which he represents eccentricity, a the length of the main axis, and b the length of the minor axis. Metric is a unit of measurement that represents an object's roundness . The metric values range from 0 to 1. The metric value approaches one as the thing becomes more rounded. Using image analysis and metric measurements, Cohen et al [correctly described biological entities. The metric value can be calculated using the following equation:

$$\text{metric} = \frac{4\pi \text{ x area}}{\text{perimeter}^2} \quad [2]$$

III. SYSTEM MODEL

The purpose of this research is to create a coconut maturity prediction system based on Fast Fourier Transform and Nave Bayes classification algorithms utilizing an ESP32 microcontroller, a max4466 sound sensor, and a stethoscope as a sound resonator. The goal of this project is to create a coconut maturity prediction that determines the status of the coconut. This reduces the need to destroy immature, unripe coconut fruits before realizing their states. This is meant to function on sound / frequency sensing from the coconut fruit and will increase the efficiency of farmers' projections or merely guesses. Along with a 16x2 LCD module, which will provide the user with system visual predictions.

The approach for constructing this project is based on the System Development Life Cycle (SDLC), which consists of three key steps: planning, implementing, and analyzing.

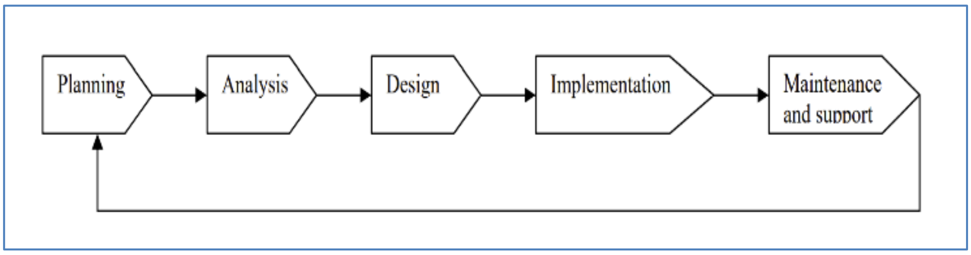

Fig. 2: Phase for SDLC

A. *Software*

We choose Proteus for circuit simulation, Arduino Integrated Development Environment (IDE) and C++ to program the microcontroller. Arduino IDE is characterized as a software package for simulation that can be run on a computer. As well as Proteus is a simulation software for programmable circuit boards for practical applications. Using Proteus and the C++ programming language, a software program is created to simulate the desired application and attributes. The Proteus is used to execute operation on both the software simulator and the practical development board as a prototype. It may connect to a computer through USB port or via an adapter that must be purchased separately.

Below is the software component and materials to accomplish the project.

- Arduino IDE
- C++

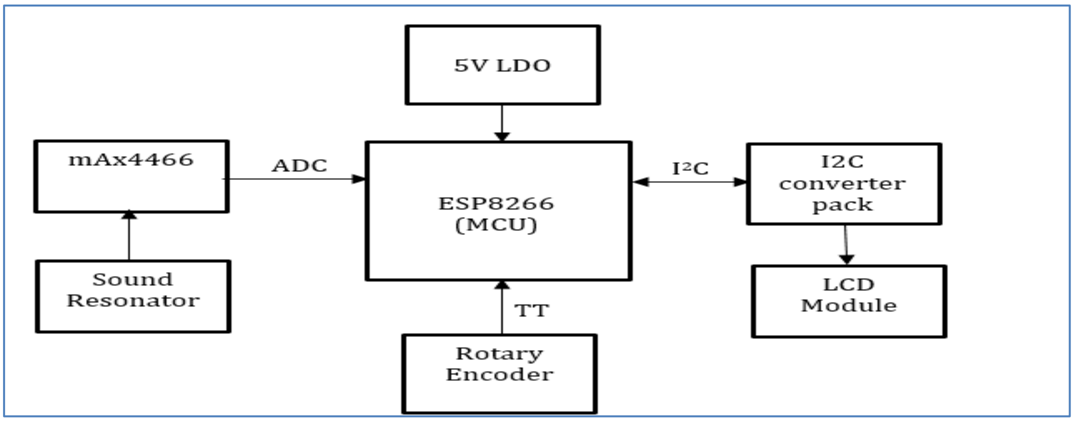

Fig. 3: Basic System Model

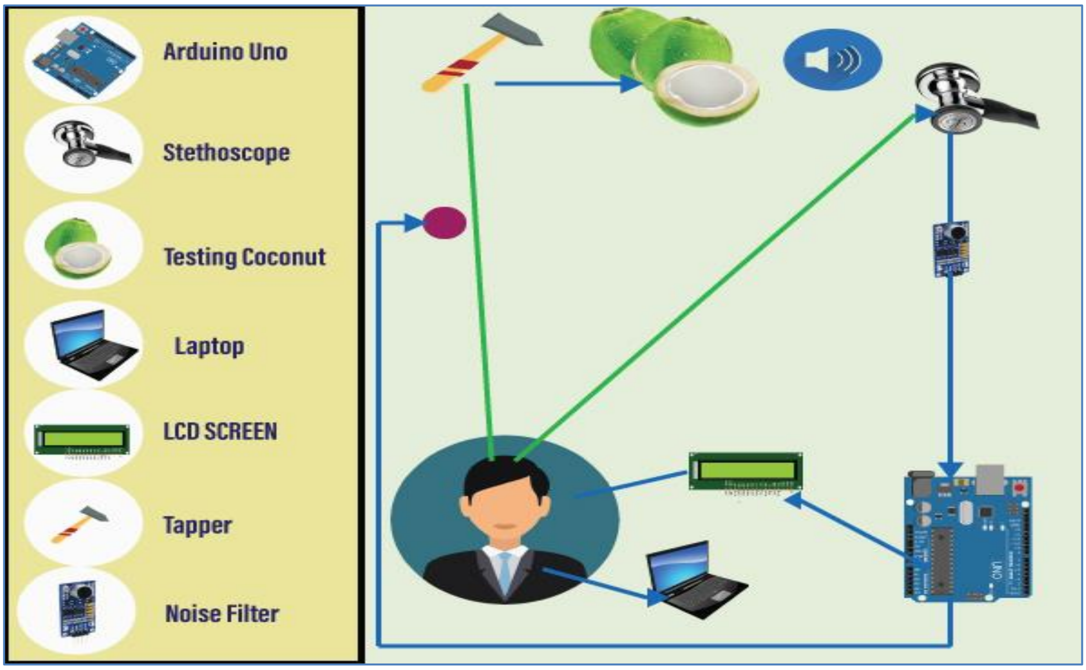

Fig. 4: Basic System Model.

B. Mathematical Model and Algorithm

A dominant algorithm used for processing sound is the Fast Fourier Transform Algorithm.

$$X_k = \sum_{n=0}^{N-1} Xne^{-i12\pi knt}/N \qquad [3]$$

Where, k = 0, 1, 2 ... ... N -1

N = FFT Size, X_n = Time Domain Samples, X_k= Frequency Domain Samples

A signal's transformation from time domain to frequency domain is accomplished via the fast Fourier transform. As a result, characteristics like frequency, amplitude, and average power may be calculated. Here is how to calculate the Fast Fourier transform:

- *Algorithm:*
- Step 1: Input command / tap coconut
- Step 2: Sound resonation through the stethoscope to the maxx4466
- Step 3: Computation of signal
- Step 4: Frequency conversion
- Step 5: Prediction output

IV. RESULTS AND DISCUSSION

The coconut maturity prediction system is a structure built with three key parts; the 'Tapper' for tapping the coconut to produce sound, the 'Stage' which the stethoscope, sound sensor, ESP 32 microcontroller and circuitry for detecting the sound, picking the frequency and processing it for prediction output using the algorithm in the program written on the microcontroller. The Stage is a flat plan where the coconut is mounted on to be operated by the Tapper.The third part is the 'Top Panel' which contains the display screen and control nob. The display screen gives output of processed decision made by the microcontroller using the algorithm. Below figures of the various parts.

Displayed Message on LCD: **"Coconut Maturity Predictxn System"**

Fig. 5: Image of Completed proposed system

Below is a table of the system parameters.

Table 1: Parameters Table:

Frequency Range	Result
< 125hz	No Result ‘Try Again’
126Hz – 250 Hz	Juicy
251Hz – 500Hz	Semi - Juicy
501Hz – 1KHz	Fleshy
1.1KHz – 4KHz	Very Fleshy
‘> 4.1KHz	No Result ‘Try Again’

A. Mathematical Explanation of system prediction

The system algorithm functions with a mathematical algorithm to make decision. Therefore, a mathematical calculation can be performed using the specified parameters to determine the result mathematically. The complexity of Fast Fourier Transform is less than O (N * log2 (N)), and this allows for faster transformation due to lesser computation required. Input data amount needed for an FFT is power of two (2) e.g., 4, 8… 32 etc. The module of a complex number (arrow length) contains data about the strength (amplitude) of the examined signal at a certain frequency. The root of the sum of the squares of the hypotenuses, or tw. Pythagoras, may be used to compute the modulus of the sample number "z," yielding | z | = 5. (The length of the hypotenuse). The phase of the signal is shown by the angle made between the "arrow" and the X axis, which may be determined using the formula arctg (vImag / vReal). As a result, the time domain has given way to the frequency domain. The ESP 32 ADC can accept input voltages between 0 and 3.3 volts.

Frequency = (vReal[i]/amplitude * 0.5); where vReal is Real voltage from the ADC or analog pin A0 of the microcontroller.

B. System Test and Result

In this unit, we bought coconut fruits from a seller and asked him to identify specifically which one was Juicy, Semi-Juicy and Fleshy in which we labelled the fruits for identification. This was done to make a comparison between the predictions the sellers make and our system in addition, we are looking at the accuracy when they coconut fruit is opened at the end to verify.

C. System Test Case

In test case, we used a coconut fruit that was said to be fleshy by the seller. After the test, the result showed that the coconut was not all fleshy but semi-juicy as shown below:

Displayed Message on LCD: **“Test In Progress, Semi Juicy 251 Hz”**

Fig. 6: System Test Case 1

After the system test, we decided to open it to verify, then we realized that the fruit contain as much juice as flesh which validate the system's result as shown above.The graph shows the time-domain and frequency-domain representation of a low-pass filtered signal with a cutoff frequency of (125-251) Hz. The top subplot displays the original signal, which is a sine wave of frequency 10 Hz, while the bottom subplot displays the filtered signal. It can be observed that the low-pass filter effectively removes the higher frequency components of the signal above the cutoff frequency, resulting in a smoother and less oscillatory signal.

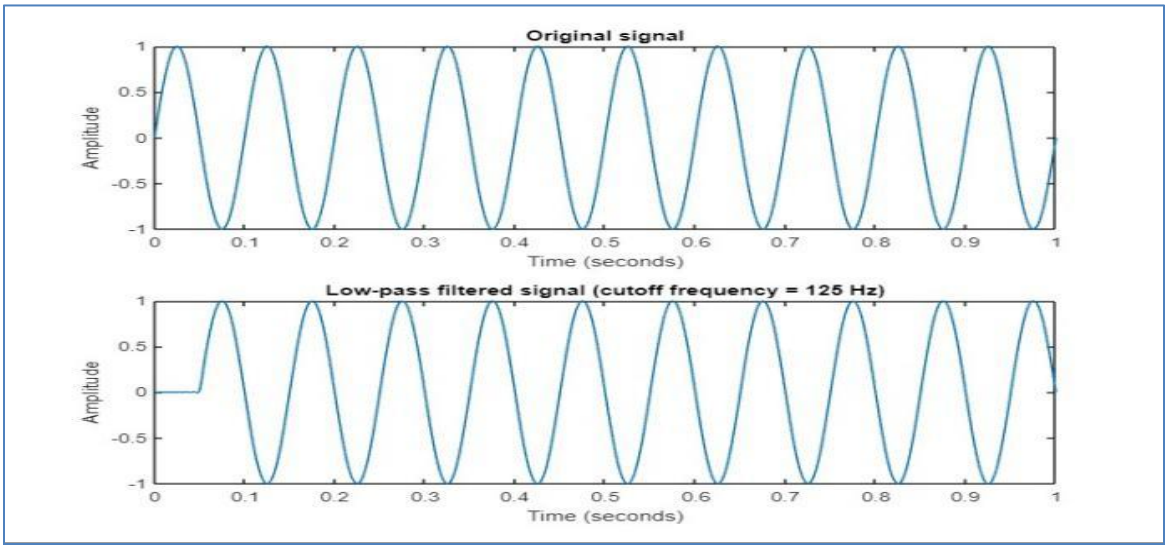

Fig. 7: A Signal of (125-250) Hz Graph

D. System Test Case 2

In test case 2, we used a coconut fruit that was said to be juicy by the seller. After the test, the result showed that the coconut fruit was juicy and the seller was right in predicting.

Displayed Message on LCD**: "Test In Progress, Juicy Juicy 225"**

Fig. 8: System Test Case 2

After the system test, we decided to open the coconut fruit to verify, then we realized that the fruit was juicy and this validates the system and the seller's result as shown above.The graph shows a peak in the power/frequency at the center frequency of the passband(188 Hz) indicated by the vertical dashed lines, reflecting the selective nature of thebandpass filter in passing frequencies within the passband range while attenuatingfrequencies outside the range. The graph also shows the attenuation of frequencies outsidethe passband range, with significant attenuation below 225 Hz and above 250 Hz.The graph confirms that the filter is effective in passing frequencies within the desiredpassbandrange while effectively blocking frequencies outside the range. The xlimfunctionis used to set the limits of the x-axis to the passband frequency range for clarity.

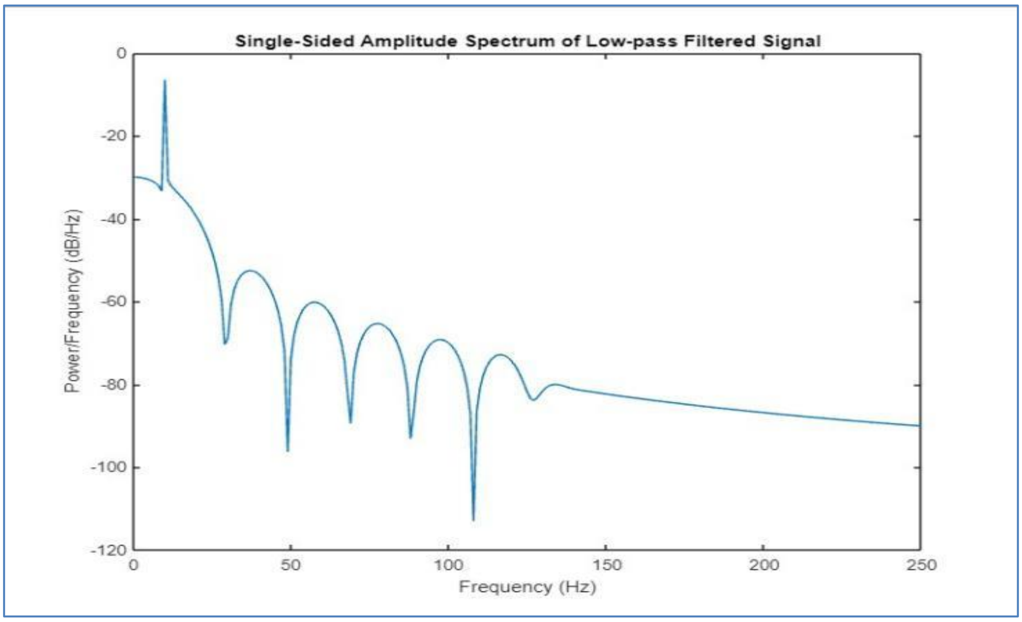

Fig. 9: A signal of 225Hz to 250Hz Graph

E. Coconut Test 3

In our last test case 3, we used a coconut fruit which was said to be semi juicy by the seller. After applying the system test, the out put was juicy as indicated by the system. This result is literally opposing the prediction the seller made.

Displayed Message on LCD: **"Test In Progress, Juicy 300"**

Fig. 10: Coconut Test 3

To validate the result given by the seller and the system we also went further to verify by opening the fruit. The observation made indicated that the fruit was juicy.

The first plot shows two subplots. The top subplot shows the original signal, which is a sine wave of frequency 150 Hz, plotted against time. The bottom subplot shows the same signal after it has been filtered using a bandpass filter with a passband between 251 Hz - 300 Hz. This plot shows how the filter removes the frequencies outside the passband, leaving only the frequencies within the passband in the filtered signal.The second plot shows the frequency spectrum of the filtered signal. This plot shows the power of the filtered signal at each frequency, in decibels (dB) relative to 1 Hz. The x-axis is the frequency in Hz, and the y-axis is the power/frequency in dB/Hz. The plot is limited to the passband frequency range of 251 Hz +00 Hz. This plot shows how the bandpass filter removes the frequencies outside the passband, leaving only the frequencies within the passband in the filtered signal.

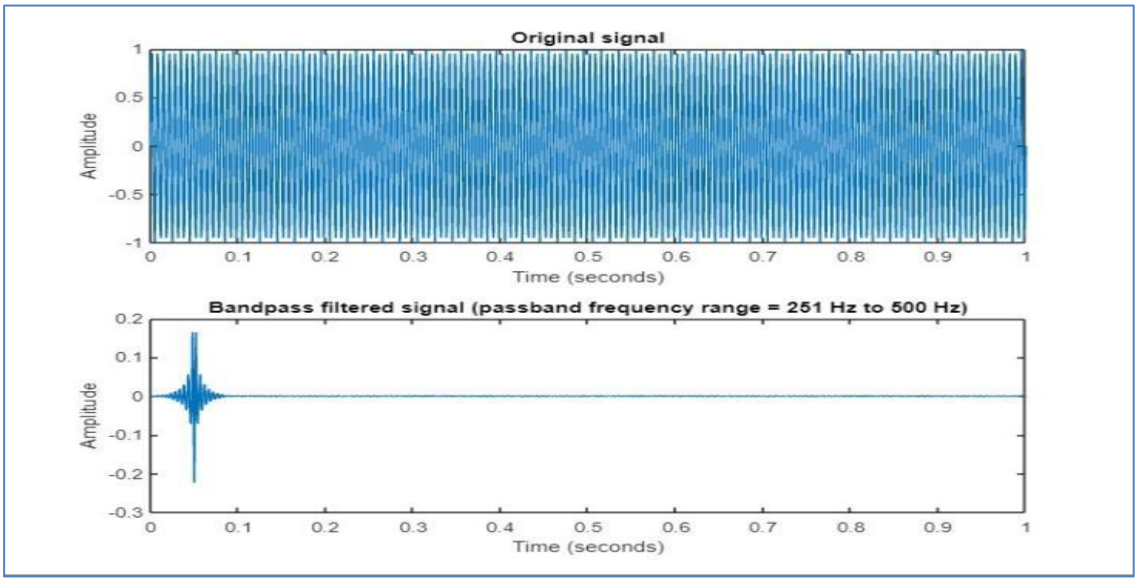

Fig. 11: A signal of 251Hz to 500Hz Graph

F. Discussion

In conclusion, we can make a justification of the comparison of a regular seller and our system. The test cases showed the similarities and differences margin which we consider to be a positive feedback for our work.

V. CONCLUSION AND RECOMMENDATION

A. Summary

Following are many points that summarize the findings of this study:

- A bandpass digital filter of the IIR elliptic type is used to handle the acoustic signal of a coconut being knocked using a microcontroller. The rationale is that it outperforms bandpass digital filters of the FIR Blackman type in terms of efficiency and frequency responsiveness.
- With a total of 20 test samples and 24 training data samples, the Fourier Fast Transform technique test yielded a system test success percentage of 80%.

B. Conclusion

20 coconuts were used as training samples and test samples, and the results were recorded based on the variety, size, and maturity level of the coconuts in each sample. In the test that was done to see if our system could anticipate when a coconut fruit would reach maturity, it had an 80% success rate.

C. Limitation

Our limitation faced was external noise signals. Even though we optimized the system to cancel noise, it is still a limitation when the noise exceed our set band.

D. Recommendation

The following ideas are made for the future study:

- To increase the accuracy of the frequency data of the coconut knocking sound signal and to remove noise signals that are not caused by fruit knocking sounds, a series of analog filters should be added.
- Utilizing Voice Activity Detection (VAD) to streamline sound selection throughout the tapping process will ensure that the sound of the coconut knocking dominates the whole processed sound signal spectrum and that tapping noise gradually decreases.

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