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**Short Paper***

# Carabao Mango Export Quality Checker Using MATLAB Image Processing

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**Special Issue on International Research Conference on Computer Engineering and Technology Education 2023 (IRCCETE 2023). Guest Associate Editors:* **Dr. Nelson C. Rodelas, PCpE** (*Computer Engineering Department, College of Engineering, University of the East-Caloocan City; nelson.rodelas@ue.edu.ph*) and **Engr. Ana Antoniette C. Illahi**, PCpE *(Asst. Professor & Vice Chair, Department of Computer and Electronics Engineering, Gokongwei College of Engineering, De La Salle University, Taft Ave., Manila; ana.illahi@dlsu.edu.ph*).

**Abstract**

*Purpose* – Mango plays an important role in the Philippine exporting business. In the peak of mango exporting in the Philippines there are some exported fresh carabao mango to other countries that are ripped, damaged, not sweet and did not pass the safety regulations of other countries. The main reasons are pest, exporting damages, and wrong classification. Most of the exporting companies in the Philippines used the manual method or the traditional method of classifying mango by barely using their hands for touching and observation. With this being said, the objective of this research is to create a device that will automatically detect the quality and classify the carabao mango whether it is for export or not.

*Methodology* – The proponents used the image processing methodology. MATLAB, Arduino, and image processing techniques such as image enhancing, deblurring, edge detection, and color segmentation were adapted in the process to ensure the attainment of the objectives. The device was tested using several trials to meet designed objective metrics.

*Results* - As a result, the device was able to achieve the following data. The speed of classifying the quality of the mango was measured with an overall value of 8.132 seconds and for accuracy the device attained an accuracy of 91.2 %.

*Conclusion* – With the determined results, the proponents proved that the device successfully met the defined objective metrics. An “excellent” rating results were achieved for the speed of classifying the quality of the mango, while its accuracy was rated “good” as defined on the proponent’s metrics.

*Recommendation* - The proponents recommend for the improvement of the project is that future researchers should adopt better coding techniques to allow simultaneous quality checking and classification for different types of mangos.

*Keywords* – manual method, MATLAB, Arduino, image processing techniques, mango

## INTRODUCTION

Mangifera Indica is the scientific name of the mango, it is one of the commercially important high-value fruit crops in the Philippines (Bayogan, 2012). This species has adapted to a wide variety of climates where it has become naturalized all over the world. The mango is the national fruit of the Philippine and known as the sweetest mango in the world based on the 1995 World Guinness Book of Record in Guimaras in the Western Visayas region. Guimaras is home to over 50,000 mango trees, making it the most important producer of mango in the country (Guiness, 2009). It is said that mangoes from this region are being served in the White House in the US and the Buckingham Palace in England. But the top producers of mango in the Philippines is the Ilocos region placing Guimaras for second producers of mango. The carabao mango or also known as "Manila super mango" was the record holder as the sweetest mango in the world. Due to this the Philippine joined the exporting trade in the year 1980 (Guardian, 2016). Carabao mango recorded the highest output at 423.36 thousand metric tons representing 80.1 percent of the total mango production this period (PSA, 2018). Other varieties of mango that are export by the country are the Pico mango, Kat Chamita mango.

The Philippines was ranked as 7th in exports of fresh and dried mango in the global market, but producer of fresh mango has problems in complying the needed quality due to the limited performance in identifying the mango before it will be export in the global market. The main problem of the Philippine export is the Sanitary and Phytosanitary Compliance or known as SPS (W.T.O.) (Lantican et al., 2009). The Philippines is primarily present in the production and processing stages of the chain. Fresh mango exports are limited given poor performance in cold chain management, packaging, and pre-export SPS treatments, which prevent exporters from complying with standards required by key markets (Stark, 2017). The objective of treatment and management in the supply chain is to have suitable condition to extend storage life and quality attributes of the fruit (Sivakumar et al., 2011).

Related news to this is the uphill battle of the Philippine Mango Exporters, Robert Chua, owner of Robbie Trading in Cebu city, states that the volume of exports of the year is low because less than 10% of the mango produced doesn't meet the quality standard which leads the other exporter to focus on other local fruits (Yzza, 2017). Quality has a strong influence on exports. Low quality mangoes will deter customer in buying mangoes again (Sirisimbon et al., 2008). Post harvest technology is applied for the main reason of keeping fruit quality and safety as high as possible until it reaches the final customer (Esguerra et al, 2018). The export demand for mango is influenced by various quality attributes vested in them (Thulasiram et al., 2016). Among all attribute's studied, variety was found to have the greatest influence on the trade of mango as it accounted for 38.86% of relative importance and the individual utility for each variety. The common attribute that the exporters want is the color of the mango which is yellow, and the size also has a main purpose together with the damage mango which exporter automatically turned down (Plaza, 2017). Color is determined by light source, reflected light from the light source, and visual sensitivity of the observer (Abarra et al., 2018). Past devices were made in knowing the qualities of the mango, together with the determination of the characteristics of it. With the help of this study the procedure in determining the mango quality and the grade is helpful in identifying the export quality of mangos which most of the mango exporting companies including the ANI Agricultural Incorporated have been facing.

For this reason, the proponents' general objective is to develop a system that can help the ANI Agricultural Inc and other mango exporting companies in determining the quality of the mango before it will be exported focusing on the damage detected, weight and color of the mango. That system should be fast, accurate, and adaptable to overcome common drawbacks of the industry and hence increase their productivity.

***Conceptual Framework***

In Figure 1, shows the conceptual framework of the system. The input is the carabao mango taken after hydro-cooling process. In the process, image processing technique will be applied to determine the important attributes of the carabao mango for export such as its size, its weight, color, and the damage of the mangoes based on the ANI Agriculture Inc. standard of exporting fruits to other countries. The output stage is where it uses a monitor to show the size, and the quality of the Carabao mango.

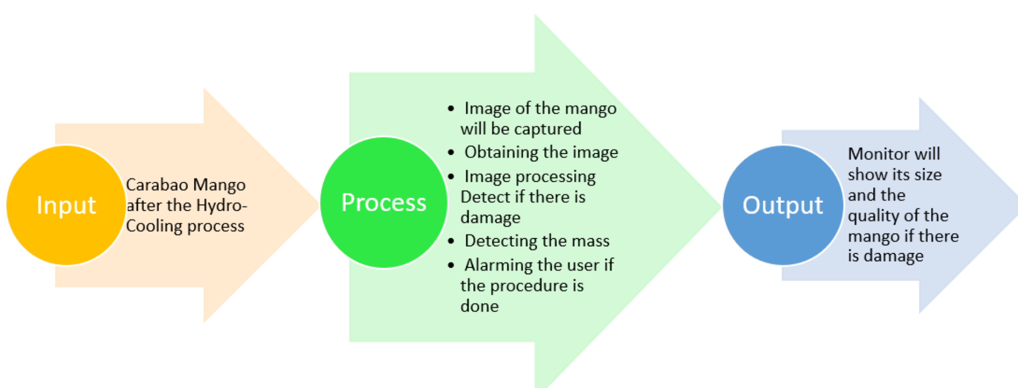


*Figure 1.* Conceptual framework

## METHODS AND PROCEDURES

### *Functional Analysis*

Figure 2 presents the interrelation of the input, process and output of the proposed design project which is the form of glass box to further discuss the breakdown of the following process. The mango will be inputted to a place where the mango will be hold. The mango will now be captured using two cameras as an input for the image interface. There are four functions in the image interface namely Image deblurring, color segmentation, image enhancing, and edge detection to interpret the mango if there is damage and the color of the mango. Together with determining the weight of it. After the process it will activate the alarm as prescribed by the OSHA standard number 1926.555 to indicate that the system has completed its process. The last function will show the output of all the acquired data of the system.

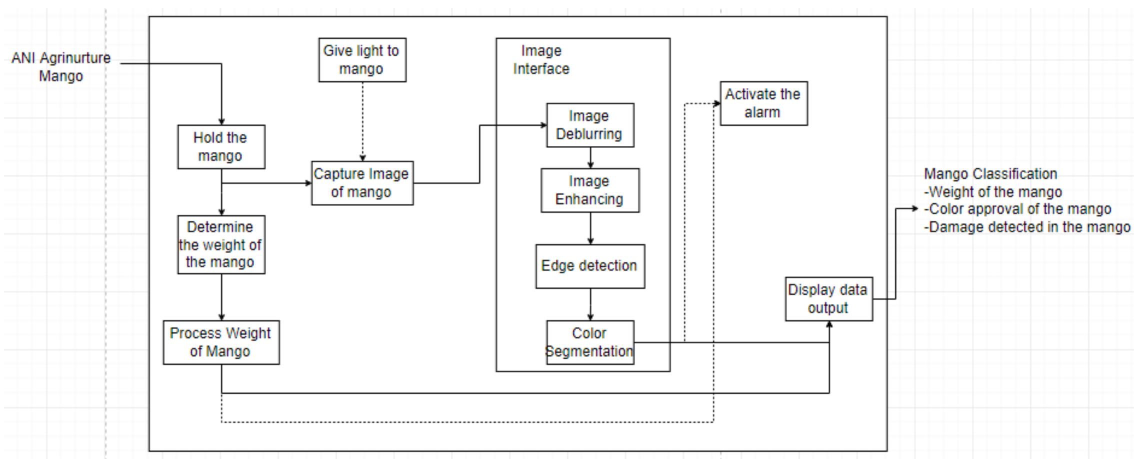


*Figure 2*. Functional analysis of the prototype model

## ***Project Process***

The first step is to insert the mango in the device and press start on the program. The acquired images must be pre-processed to confirm precise examination. For this part, image enhancement was done by increasing the contrast. This step is included as it is necessary for enclosures that has low lighting. The method that is used is named as Correct Non-uniform Illumination. After the pre-processing part, deblurring was then applied to increase the sharpness in the image. The fundamental task of image deblurring is to de-convolute the degraded image (Ramya and Christial, 2011). The deblurring process used is the Weiner filter capturing the desired image quality of the mango.

Two branches follow this step. One is for the quality, the other is for the color. In the section of identifying the color, removing the background through Weiner filter was done to disregard the other colors in the image and only identify the color of the object which is the mango. The. RGB method was used for the images acquired from the top camera and bottom camera. With the use of the RGB method it will easily identify the color of the mango thus classifying it as a yellow or green type of mango. In the section of identifying the quality the edges were the basis for knowing if the mango has damages also including lines, dot, and deep cuts.

Canny method features extraction is the main process used for this along with the edge detection method. As there is a feature training, a database must also be included. The database includes the raw images of a damaged mango and a healthy mango.

The acquired image that went through pre-processing will be compared to the processed images in the database, thus identifying the percentage of how close the acquired image is, to the damaged/healthy images in the database. Once the color and the mango quality are identified, the system will now determine the export quality of the mango. The last part is an alarm to alert the user that the processing of the mango is done.

## *Software Design*

The system design of the project is based on pass experiments, research and studies related to image processing, system processing, accuracy, and speed in terms of identifying and classifying mango and other objects that were used to choose means in determining the suitable methods in the system design. The system flowchart which shows the flow of data along the device. Basically, the flowchart is the same as the block diagram only using different representation. The desired outputs such if the mango is ready for export or it will be rejected and will be displayed by the device. The device will then restart whenever another mango will be inputted for testing, otherwise, it will stop. Figure 3 illustrates the software design training phase of the whole project system. The system will detect the data and analyze it when the system determines the image of the mango it will then save the following acquired data for it to detect other related images of mango. The training of the machine is needed to determine images of mango that are related and to have more data for the project to serve as basis.

## *Hardware Design*

Figure 4 shows the connections and relationship of the parts of the device from the input to the output. The main input will be the mango. The box will be the one to contain the mango for testing purposes. Observed that each component that are enclosed with a broken line are found and to be attached inside the box. The glass will serve as the place whereas the mango will be placed. The light will be the one to give lighting for the mango because of the box. The weight that will be detected by the weight sensor will then be converted into electrical signal and will send the data on the Arduino Mega 2560. The camera will be place in the top and bottom to fully capture the sides of the mango. Once the image is captured, it will then be going to a process called correct non-uniform illumination to remove noise from the picture. The Wein Filter will correct the blurriness of the image if the device is move after capturing the image. The canny method will be the one to detect the block spots in the mango. The RGB method is used to know the correct color for the mango before exporting. In RGB method, the ripening stage is detected based on the red, green, and blue components (Salunke and Patil, 2015).Thus, the laptop or pc will show the data that was acquired by the system and will show it to the user.

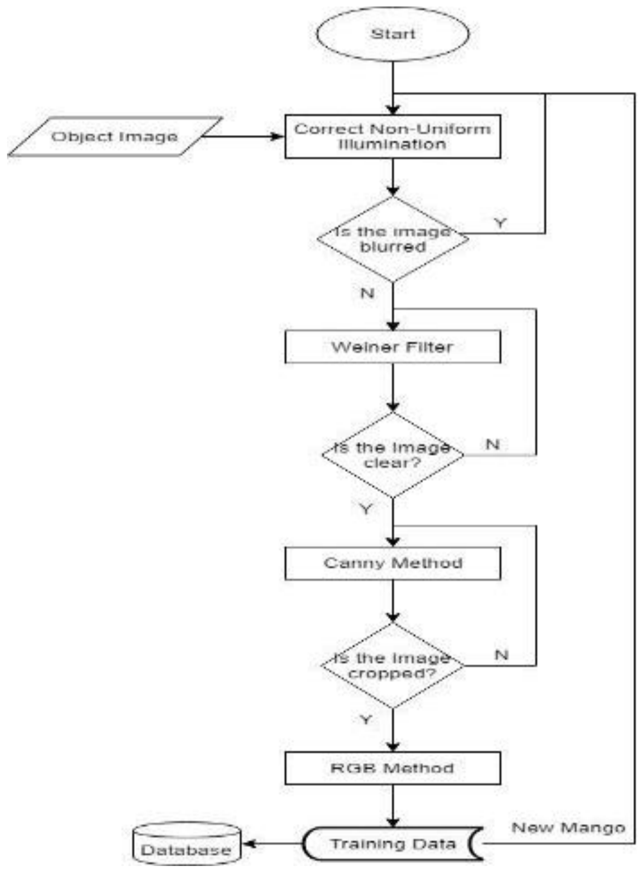


*Figure 3*. Software Design Training Phase

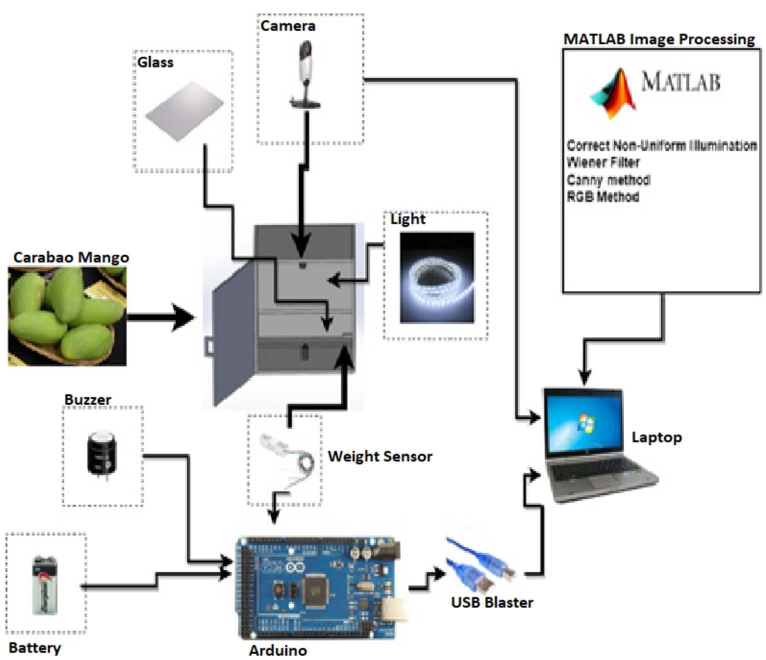


*Figure 4*. System Block Diagram

## ESULTS

### *Display Data Output*

Figure 5.a and figure 5.b shows sample of data output displayed during the conduct of testing. Both outputs showcase images that went through during image processing. From its original image, to enhanced image, then segmented image, and the deblurred image. In figure 5.a the mango was classified as for export quality, while figure 5.b shows that the mango does not possess the attributes of being export quality.


*Figure 5.a*. Displayed Data Output


*Figure 5.b.* Displayed Data Output

Table 1 below illustrates the overall system test conducted by the proponents. It indicates the accuracy and speed determined during the test. Table also reflects the detected data and compare it to the expectation. The table likewise shows the classification results based on the detected data. In addition, the last column of the table presented the measured speed for each of the trial conducted.

Table 1. Overall System Test

| Trial No. | Expected | | | Detected | | | | | Is the Classification Correct? (yes/no) | | | System Speed (seconds) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Color | | Texture | | Size | Color | Texture | Size | |
| | Color | Texture | Size | Green | Yellow | Healthy | Damaged | | | | | |
| 1 | Green | Healthy | Super Small | | | | | Super Small | yes | yes | yes | 7.92 |
| 2 | | | | | | | | Super Small | yes | yes | yes | 8.21 |
| 3 | | | | | | | | Super Small | yes | yes | yes | 7.92 |
| 4 | | | | | | | | Small | yes | yes | no | 8.18 |
| 5 | | | Small | | | | | Small | yes | yes | yes | 8.21 |
| 6 | | | | | | | | Small | yes | yes | yes | 8.30 |
| 7 | | | | | | | | Small | yes | yes | yes | 7.99 |
| 8 | | | Medium | | | | | Medium | yes | yes | yes | 8.55 |
| 9 | | | | | | | | Medium | yes | yes | yes | 8.21 |
| 10 | | | Large | | | | | Large | yes | yes | yes | 7.89 |
| 11 | | Damaged | Super Small | | | | | Super Small | yes | yes | yes | 7.92 |
| 12 | | | | | | | | Super Small | yes | yes | yes | 8.83 |
| 13 | | | | | | | | Super Small | yes | yes | yes | 7.99 |
| 14 | | | Small | | | | | Super Small | yes | yes | yes | 8.18 |
| 15 | | | | | | | | Small | yes | no | yes | 8.18 |
| 16 | | | | | | | | Small | yes | no | yes | 7.80 |
| 17 | | | Medium | | | | | Small | yes | yes | yes | 8.20 |
| 18 | | | | | | | | Medium | yes | yes | yes | 8.01 |
| 19 | | | Large | | | | | Medium | yes | yes | yes | 7.99 |
| 20 | | | | | | | | Large | yes | yes | yes | 8.05 |
| 21 | Yellow | Healthy | Super Small | | | | | Super Small | yes | yes | yes | 8.62 |
| 22 | | | | | | | | no | no | yes | no | 7.92 |
| 23 | | | Small | | | | | Small | yes | yes | yes | 7.82 |
| 24 | | | Medium | | | | | Medium | yes | yes | yes | 8.32 |
| 25 | | | Large | | | | | Large | yes | yes | yes | 7.90 |
| 26 | | Damaged | Super Small | | | | | Super Small | yes | no | yes | 7.99 |
| 27 | | | | | | | | Super Small | yes | yes | yes | 8.24 |
| 28 | | | Small | | | | | Small | yes | yes | yes | 7.92 |
| 29 | | | Medium | | | | | Medium | no | yes | yes | 8.33 |
| 30 | | | Large | | | | | Large | yes | yes | yes | 8.30 |

## *Summary of Findings*

Table 2 shows the summary of findings after a series of testing. It shows the objectives, the actual values, and the final evaluation. The final evaluation of results is based on Table 1.1.A reflected in Chapter 1. For the accuracy testing, 30 mangoes are used. The result for the accurate identification for the color is 90% which falls under the scale of 86% to 91% and evaluated as "Good" in the proponent's metrics. For the accurate identification for the weight is 95.46% which falls under the scale of 94% to 97% and evaluated as "Good" in the proponent's metrics. For the accurate identification for the weight is 90% which falls under the scale of 89.3% to 94.2% and evaluated also as "Good" in the proponent's metrics. For the speed, the average duration of the system was 8.132 seconds which is in the scale of 74 seconds or faster and evaluated as excellent. The user friendliness of the project was excluded because of the pandemic that is happening in the Philippines the proponents decided to hold of the survey and making the user-friendliness of the project remove as one its objectives.

Table 2. Summary of Findings

| Objective | Measured Parameter | | | Scale | Rating |
|---|---|---|---|---|---|
| | Minimum | Maximum | Average | | |
| Accuracy of identifying the color (%) | 80 | 100 | 90 | 86% - 91% | Good |
| Accuracy of identifying the weight (%) | 81.82 | 100 | 95.46 | 94% - 97% | Good |
| Accuracy of identifying the texture (%) | 80 | 100 | 90 | 89.3% - 94.2% | Good |
| Speed (seconds) | 7.8 | 8.83 | 8.132 | 74s or faster | Excellent |

## DISCUSSION

### *Display Data Output*

Figure 5.a and figure 5.b shows sample of data output displayed during the conduct of testing. In figure 5.a the mango was classified as for export quality, while figure 5.b shows that the mango do not possess the attributes of being export quality.

### *Accuracy*

There are 3 categories to know the accuracy of the device. The first one is if the device is accurate enough to classify the color of the mango. Second is by determining the weight of the mango by stating the size. Lastly is classifying if the mango that was inserted in the device is damage or not. To suffice the data, the proponents will use 30 carabao mango for testing.

### *Color*

To get the accuracy of getting the color of the mango, we used 30 mango which the 20 was green and the 10 was yellow. We will first gather the data recorded from column 10 of table 1 which shows if the system classified the color correctly. Then, we will use the Equation 1 to get the accuracy of each color. Finally, we will get the average of the 2 accuracies, and it will serve as the overall accuracy in terms of the color.

$$Accuracy\ (\%) = \frac{Total\ number\ of\ correctly\ detect\ mango\ color}{Total\ number\ of\ mango\ used}\ x\ 100 \qquad (Equation\ 1)$$

$$Green\ Accuracy\ (\%) = \frac{20}{20} x\ 100 = 100\% \qquad Yellow\ Accuracy\ (\%) = \frac{8}{10} x\ 100 = 80\%$$

$$Overall\ Accuracy\ (\%) = \frac{100+80}{2} x\ 100 \ = 90\%$$

### *Weight*

For the accuracy on determining the weight of the mango, we used 30 mangos. From the 30 samples: 11 were super small, 8 small, 6 medium, and 5 large mangos. We will use the data from the column 12 of table 1 that shows if the system classified the weight of the mango correctly. Then, use Equation 2 to get the accuracy of each size of the mango.

We will get the overall accuracy of the weight of the mango by getting the average of the accuracy of all sizes of the mango.

$$Accuracy\ (\%) = \frac{Total\ number\ of\ correctly\ detect\ mango\ weight}{Total\ number\ of\ mango\ used}\ x\ 100 \qquad (Equation\ 2)$$

$$Super\ Small\ Accuracy\ (\%) = \frac{9}{11} x\ 100 = 81.82\% \qquad Small\ Accuracy\ (\%) = \frac{8}{8} x\ 100 = 100\%$$

$$Medium\ Accuracy\ (\%) = \frac{6}{6} x\ 100 = 100\% \qquad Large\ Accuracy\ (\%) = \frac{5}{5} x\ 100 = 100\%$$

$$Overall\ Accuracy\ (\%) = \frac{81.82 + 100 + 100 + 100}{4} x\ 100 = 95.46\%$$

### *Texture*

In getting the accuracy of determining the damage on the mango, we collected 30 carabao mango samples. The samples contain: 15 healthy, and 15 damaged mangos. We get the data from the column 11 of table 1, where it records if the detected texture were classified correctly. Next, we will use Equation 3 to get the accuracy in determining the damage on the mango. To get the overall accuracy in determining the damage on mango, we get the average of the accuracy of damaged, and healthy mangos.

$$Accuracy\ (\%) = \frac{Total\ number\ of\ correct\ determined\ texture\ of\ mango}{Total\ number\ of\ mango\ used}\ x\ 100 \qquad (Equation\ 3)$$

$$Healthy\ Accuracy\ (\%) = \frac{15}{15}\ x\ 100 = 100\% \qquad Damaged\ Accuracy\ (\%) = \frac{12}{15}\ x\ 100 = 80\%$$

$$Overall\ Accuracy\ (\%) = \frac{100 + 80}{2} x\ 100 = 90\%$$

### *B. Speed*

For testing this objective, the proponents used a stopwatch which will be start counting once the mango was placed inside the machine and will be stopped when the output is provided. The proponents used 30 mangos as samples, where it has 2 variations of colors (yellow, and green), 2 variations of texture (healthy, and damaged), and 4 variations of sizes (super small, small, medium, and large). To get the overall speed, we will get the average time of the green and yellow mangoes (*Equation* 4).

$$Speed = \frac{\text{sum of the recorded speed}}{total\ number\ of\ mango} \qquad (Equation\ 4)$$

$$Green = \frac{7.92 + 8.21 + 7.92 + 8.18 + 8.21 + 8.30 + 7.99 + 8.55 + 8.21 + 7.89 + 7.92 + 8.83 + 7.99 + 8.18 + 8.18 + 7.80 + 8.20 + 8.01 + 7.99 + 8.05}{20} = 8.127s$$

$$Yellow = \frac{8.62 + 7.92 + 7.82 + 8.32 + 7.90 + 7.99 + 8.24 + 7.92 + 8.33 + 8.30}{10}\ x\ 100 = 8.136s$$

$$Overall\ Speed = \frac{8.127 + 8.136}{2}\ x\ 100 = 8.132s$$

## CONCLUSIONS AND RECOMMENDATIONS

The proponents were able to accomplish all the attributes of the project and therefore conclude the following: the speed of the device achieved was excellent and extremely better than the previous study with a result of 8.12 seconds in the average as compared to 136 seconds. In classifying the mango with its color, weight and texture the results in terms of percentage did not achieve lower than 90 %. Making the system accurate in classifying the color, weight, and texture. With the determined results, the proponents proved the effectiveness of the used of MATLAB to classify all the important features of the mango, using specified image processing namely: image deblurring, image enhancing, edge detection, and color segmentation. The user-friendliness of the device was not tested because of the pandemic, due to this the user-friendliness was excluded as one of the objectives of the project.

In the development stage of the device, the proponents observed that there are areas for improvement for the betterment of the project. Some of which are the recommendations of the proponents. Despite achieving excellent speed in providing the much-needed result, the proponents would still recommend the use of a faster computer or laptop to improve MATLAB processing. In the distinction of the mango texture resulting into an average of 80% accuracy, the proponents strongly recommend the use of high-resolution camera for better capturing of image during the process. Since the design project is limited to only one mango at a time, then it is recommended the use of a better coding technique for the system can analyze and classify more than one mango taken at the same time.

## IMPLICATIONS

This project would create great impact to the following sectors of the society, the exporters, mango farmers and to the future researchers. This project will be beneficial to the exporters of carabao mango in the Philippines in terms of the quality assurance. This may also help their production increased due to reduction of the time in checking the quality and sorting the mango. It has implications as well for the mango farmers in way that the farmers would have a device that will help them in the segregation of the mango before bringing them into the market. For future researchers, this will serve as one good reference for those who are in the same research agenda concerning innovations in the mango export production.

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## DECLARATIONS

### *Conflict of Interest*

All authors declare that they have no conflicts of interest.

### *Informed Consent*

The study did not involve other humans as participants apart from the main authors during gathering of datasets hence this is not applicable.

### *Ethics Approval*

No humans nor animals were involved in this study; hence this is not applicable.

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Luigi Carlo M. De Jesus is a licensed Electronics Engineer, and Electronics Technician (2nd Placer). He is also a holder of Master of Engineering Major in Computer Engineering and the current Engineering and Science Laboratory Office (ESLO) Head of Asia Pacific College - School of Engineering.

Jannuel D. Apostol is a student taking up Bachelor of Science in Electronics Engineering in Asia Pacific College. Jannuel is the main programmer of the project. He also helped conceptualize, design the project, and helped in the documentation.

Dexter C. Betonio is a BS in Electronics Engineering student in Asia Pacific College. Dexter was the one who created the projects hardware and the project digital concept. Dexter is the one who tested and managed the projects wiring and technical issues.

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