Non-Destructive Carabao Mango Sorter and Grader based on Physical Characteristics

using Machine Learning

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A Thesis
Presented to the Faculty of the
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In Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Computer Engineering

————————————

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ORAL DEFENSE RECOMMENDATION SHEET

This thesis, entitled **Non-Destructive Carabao Mango Sorter and Grader based on Physical Characteristics using Machine Learning**, prepared and submitted by thesis group, AISL-1-2425-C5, composed of:

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in partial fulfillment of the requirements for the degree of **Bachelor of Science in Computer Engineering** (**BS-CPE**) has been examined and is recommended for acceptance and approval for **ORAL DEFENSE**.

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ABSTRACT

Carabao Mangoes are one of the sweetest mangoes in the world and one of the major producers of this is the Philippines. However, mangoes go through many screening processes, one of them being sorting and grading during post harvesting which is labor intensive, prone to human error, and can be inefficient if done manually. Previous researchers have taken steps to automate the process, however, their works often focus on only specific traits, and do not try to encapsulate all the physical traits of the mangoes altogether. Furthermore, previous researchers made the grading system static or unchangeable to the user. In this study, the researchers will develop an automated Carabao mango grader and sorter based on ripeness, size, and bruises with an interchangeable mango attribute priority through non-destructive means. Using machine vision, image processing, Machine Learning, microcontrollers and sensors the mangoes will be physically sorted into designated bins via a conveyor belt system which can be controlled and monitored via a graphical user interface. The approach will streamline the post-harvest process and cut down on human errors and labor costs, helping maintain the high quality of Carabao mango exports. *Index Terms*—Machine Learning, Carabao Mangoes, Sorting and Grading Mangoes, Machine Vision, Microcontroller.

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ABBREVIATIONS

NOTATION

Throughout this thesis, mathematical notations conform to ISO 80000-2 standard, e.g., variable names are printed in italics, the only exception being acronyms like, e.g., SNR, which are printed in regular font. Constants are also set in regular font like j. Standard functions and operators are also set in regular font, e.g., in $\sin(\cdot)$, $\max\{\cdot\}$. Commonly used notations are t, f, $\mathrm{j} = \sqrt{-1}$, n and $\exp(\cdot)$, which refer to the time variable, frequency variable, imaginary unit, nth variable, and exponential function, respectively.

GLOSSARY

137	bruises	The black or brown area of the mango that is visible on the skin of the mango.
138	Carabao mango	A popular variety of mango grown in the Philippines, known for its sweet and juicy flesh.
139	accuracy score	A performance metric that measures the overall proportion of correct predictions made by a machine learning model.
140	CNN	A type of deep neural network that is highly effective in analyzing and processing visual data, such as images. CNNs mimic the human brain's approach to processing visual information through the use of neurons to learn patterns and identify them in images.
141	microcontroller	A small computing device that controls other parts of a system such as sensors

142 **LISTINGS**

143 **Chapter 1**

144 **INTRODUCTION**

1.1 Background of the Study

Mangoes, also known as the Mangifera indica, are a member of the cashew family. This fruit can often be seen being farmed by countries such as Myanmar, the Philippines, and India as they have a tropical dry season. Being in a tropical country is an important aspect for mango cultivation as it ensures proper growth for mangoes. If aspects such as temperature and rainfall are not ideal, it may affect the quality of the mango (Britannica, nd). Carabao mangoes is a variety of a mango that is found and cultivated in the Philippines.

Fig. 1.1   Carabao Mangoes at Different Ripeness Stages (Guillermo et al., 2019)

It is known for its sweet signature taste that was recognized sweetest in the world in the Guinness Book of World Records in 1995. The mango was named after the national animal of the Philippines, a native breed of buffalo. On average, it is 12.5 cm in length and 8.5 cm in diameter, having a bright yellow color when ripe as seen in Figure 1.1. It is often cultivated during late May to early July (DBpedia, nd).

As the Philippines is a tropical country, mangoes are a highly valued fruit as it is not only the country's national fruit but also amongst the leading agricultural exports of the country, ranking only third below bananas and pineapples. This gives the country the 9th slot amongst the leading exporters of Mangoes across the world. Attributed to this ranking

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is the country's export of both fresh and dried mangoes, as well as low tariff rates. This allows the country to export a large quantity of the fruit in countries such as Singapore, Japan, and the USA as they can enter duty free markets provided by the World Trade Organization and Japan. Due to this, the mangoes have become a major source of income to an estimated 2.5 million farmers in the country (Centino et al., 2020).

Before mangoes are sold in markets, they first undergo multiple post-harvest processes. This is to ensure that the mangoes that arrive in markets are utmost quality before being sold to consumers. Moreover, it ensures that mangoes are contained and preserved properly such that they do not incur damages and/or get spoiled on its transportation to the market. Processing of the mango involves pre-cooling, cleaning, waxing, classification, grading, ripening, packaging, preservation, storage, packing, and transportation (Patel et al., 2019) (Rizwan Iqbal and Hakim, 2022).

Among the processes that mangoes undergo, classification and grading is important as it allows the manufacturer to separate mangoes with good qualities versus mangoes with poor qualities. According to a study by (Lacap et al., 2021), size, length, width, volume, density, indention, and grooves are aspects that determine the maturity of mangoes. These traits are being checked along with the ripeness of the mango, sightings of bruise injury, and cracks on the fruit (Lacap et al., 2021) as these aspects affect the sellability of the fruit as well as the chances of it getting spoiled sooner.

Previous studies have been made to automate the sortation process of the mangoes. Among these is a research done by Abbas et al. (2018), which focuses on classification of mangoes using their texture and shape features. They do this by, first, acquiring an image of the mango using a digital camera. Then, these images are fed to the MaZda package, which is a software originally developed for magnetic resonance imaging. Within

the MaZda package is the B11 program, which uses Principal Component Analysis, Linear Discriminant Analysis, Nonlinear Discriminant Analysis, and texture classification to extract features from the mango, which in this case are the length, width, and texture. This data is then compared to a database in order to classify any given mango (Abbas et al., 2018).

Another study is done by Rizwan Iqbal and Hakim (2022), which classifies mangoes based on their color, volume, size, and shape This is done by making use of Charge Coupled Devices, Complementary Metal-Oxide Semiconductor sensors, and 3-layer Convolutional Neural Network. To classify the mangoes, images are first captured and preprocessed to be used as a data set (Rizwan Iqbal and Hakim, 2022). This data set is then augmented to be used as a model for the 3-layer Convolutional Neural Network. After extracting the features of the mango, the 3-layer Convolutional Neural Network is used as a method for their classification as it can mimic the human brain in pattern recognition, and process data for decision making. This is important as some mangoes have very subtle differences which make it difficult to differentiate them.

1.2   Prior Studies

A paper written by Amna et al. (2023), designed an automated fruit sorting machine based on the quality through an image acquisition system and CNN. Furthermore, the results of the paper show that the image processing detection score was 89% while that of the tomatoes was 92% while the CNN model had higher validity of 95% for mangoes and 93% for tomatoes. 15%, while the percentage of distinction between the two groups was reported to be 5% respectively (Amna et al., 2023). Despite the high accuracy score in

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detecting mango defects, the fruit sorting system only sorts based on the mango defects and not on ripeness, and weight.

Furthermore, the research paper presented by Guillergan et al. (2024) designed an Automated Carabao mango classifier, in which the mango image database is used to extract the features like size, area along with the ratio of the spots for grading using Naïve Bayes Model. For the results, the Naïve Bayes' model recognized large and rejected mangoes with 95% accuracy and the large and small/medium difference with a 7% error, suggesting an application for quality differentiation and sorting in the mango business industry. Despite the high accuracy of classifying Carabao mangoes, the researchers used a high quality DSLR camera for the image acquisition system without any microcontroller to control the mangoes (Guillergan et al., 2024).

1.3   Problem Statement

As mangoes are among the top exports of the Philippines (Centino et al., 2020), assessing the physical deformities is a necessity. The physical deformities of the Carabao mango can determine the global competitiveness of the country. Having higher quality exports can often lead to gaining competitive edge, increase in demand, increase export revenues, and becoming less susceptible to low-wage competition (D'Adamo, 2018). In order to increase the quality of mango fruit exports, a key post-harvest process is done, which is sorting and grading. Mango sorting and grading then becomes important to determine which batches are of high quality and can be sold for a higher price, and which batches are of low quality and can only be sold for a low price (Co., nd). Traditionally, fruit sorting and grading is inefficient as it is done manually by hand. Some tools are used such as

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porous ruler to determine fruit size and color palette for color grading (Co., nd). However, among the problems encountered in the process of manually sorting and grading mangoes are susceptibility to human error and requiring a number of laborers to do the task.

With the current advancements in technology, some researchers have already taken steps to automate the process of sorting and grading mangoes. However, these attempts would often only consider some of the aspects pertaining to size, ripeness, and bruises but not all of them at the same time. Lastly, not all research approaches were able to implement a hardware for their algorithm, limiting their output to only a software implementation and not an embedded system. As such the proposed system would assess the export quality of the Carabao mango based on all the mentioned mango traits, namely size, bruises, and ripeness while also taking into consideration being non-destructive. These aspects are important because, as was previously mentioned, there is a need to develop a Carabao mango sorter that takes into account all these aspects at the same time while being non-destructive.

1.4 Objectives and Deliverables

1.4.1 General Objective (GO)

- GO: To develop a user-priority-based grading and sorting system for Carabao mangoes, using machine learning and computer vision techniques to assess ripeness, size, and bruises. ;

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1.4.2 Specific Objectives (SOs)

- SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes. ;

- SO2: To get the precision, recall, F1 score, confusion matrix, and train and test accuracy metrics for classifying the ripeness and bruises with an accuracy score of at least 90%.;

- SO3: To create a microcontroller-based system to operate the image acquisition system, control the conveyor belt, and process the mango images through machine learning. ;

- SO4: To grade mangoes based on user priorities for size, ripeness, and bruises. ;

- SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes. ;

- SO6: To classify mango size based on image data by getting its length and width using OpenCV, geometry, and image processing techniques. ;

- SO7: To classify mango bruises based on image data by employing machine learning algorithms.

1.4.3 Expected Deliverables

Table 1.1 and 1.2 shows the outputs, products, results, achievements, gains, realizations, and/or yields of the Thesis.

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TABLE 1.1 EXPECTED DELIVERABLES PER OBJECTIVE

Objectives	Expected Deliverables
GO: To develop a user-priority-based grading and sorting system for Carabao mangoes, using machine learning and computer vision techniques to assess ripeness, size, and bruises.	• To develop a Carabao mango grading and sorting system • To grade Carabao mangoes into three categories based on ripeness, size, and bruises of the Carabao mangoes using machine learning. • To integrate sensors and actuators to control the conveyor belt and image acquisition system.
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	• To make an image acquisition system with a camera and LED light source. • To build a flat belt conveyor for moving the mangoes.
SO2: To get the precision, recall, F1 score, confusion matrix, and train and test accuracy metrics for classifying the ripeness and bruises with an accuracy score of at least 90%.	• To use a publicly available dataset of at least 10,000 mango images for classification of ripeness, and bruises.
SO3: To create a microcontroller-based system to operate the image acquisition system, control the conveyor belt, and process the mango images through machine learning.	• To develop an intuitive UI where users can start and stop the system. • To implement a priority-based grading system with sliders for ripeness, bruises, and size.
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	• To utilize a linear combination formula as the overall mango score, where each classification level contributes a grade, weighted by the priority assigned to the three properties. • To assign score values for each classification level of the mango.
SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes.	• To train a machine learning model such as kNN, k-mean, naive Bayes capable of classifying mango ripeness based on the image color • To gather a dataset of annotated images with ripeness labels • To obtain an evaluation report of performance metrics of the model

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TABLE 1.2   EXPECTED DELIVERABLES PER OBJECTIVE CONTINUED

Objectives	Expected Deliverables
SO6: To classify mango size based on image data by getting its length and width using OpenCV, geometry, and image processing techniques.	• To develop an image processing algorithm capable of determining mango size using OpenCV, NumPy, and imutils • To classify mangoes based on size and categories into small, medium, and large based on those measures
SO7: To classify mango bruises based on image data by employing machine learning algorithms.	• To train a machine learning model such as CNN capable of distinguishing bruised and non-bruised mangoes • To train a machine learning model such as kNN, k-mean, and Naïve Bayes capable of assessing the extent of bruising on the mangoes if it is significant or partial • To gather a dataset of annotated images based on bruises • To obtain an evaluation report of performance metrics of both CNN and machine learning models

1.5   Significance of the Study

Automating the process of sorting and grading mangoes increases efficiency and productivity for the user which would in effect remove human error in sorting and grading and decrease the human labor and time taken to sort and grade the mangoes. This is especially important for farmers with a large amount of fruit such as mangoes and a lesser labor force. A recent study showed that their automated citrus sorter and grader using computer vision can reduce the human labor cost and time to sort and grade when comparing the automated citrus sorter and grader to manual human labor Chakraborty et al. (2023).

Another benefit to automating sorting and grading mangoes is the improvement in quality control. This implies that compared to human labor, automating sorting and grading mangoes can uniformly assess the quality of mangoes based on size, color, and bruises, ensuring that the expected grade and high-quality mangoes reach the consumer. By accurately identifying substandard mangoes, the system helps in reducing waste and

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ensuring that only marketable fruits are processed further.

Likewise, the scalability of automating sorting and grading mangoes is simpler, especially for lower labor force farmers with large volumes of mangoes. Because of the possibility of large-scale operations by automating sorting and grading mangoes, farmers can now handle large volumes of mangoes, making them suitable for commercial farms and processing plants. Moreover, it can be adapted to different varieties of mangoes and potentially other fruits with minor modifications.

1.5.1 Technical Benefit

1. The development of an automated Carabao mango sorter would increase the quality control of classifying Carabao mango based on ripeness, size, and bruising.

2. The accuracy in sorting Carabao mangoes will be significantly improved while reducing the errors due to human factors in manual sorting.

3. The automated Carabao mango sorter carefully sorts the mangoes while ensuring that they remain free from bruising or further damage during the process

1.5.2 Social Impact

1. The reduction in manual labor creates opportunities in maintenance and technologies in the automated Carabao mango sorter.

2. The automated Carabao mango sorter system improves Carabao mango standards and enhances the satisfaction of the buyers and the customers through guaranteeing consistent Carabao mango grade.

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3. Opportunity to increase sales and profit for the farmers through consistent quality and grade Carabao mangoes while reducing the physical labor to sort it.

1.5.3 Environmental Welfare

1. With the utilization of non-destruction methods of classifying Carabao mangoes together with an accurate sorting system, overall waste from Carabao mangoes is reduced and the likelihood of improperly sorted mangoes is decreased.

2. Automation of sorting and grading Carabao mangoes promotes sustainable farming practices.

1.6 Assumptions, Scope, and Delimitations

1.6.1 Assumptions

1. The Carabao mangoes are from the same source together with the same variation

2. The Carabao mangoes do not have any fruit borer and diseases

3. All the components do not have any form of defects

4. The prototype would have access to constant electricity/power source.

5. The Carabao mangoes to be tested would be in the post-harvesting stage and in the grading stage.

6. The image-capturing system would only capture the two sides of the mango which are the two largest surface areas of the skin.

1.6.2 Scope

1. The prototype would be specifically designed to grade and sort Carabao Mangoes based on only ripeness, size, and visible skin bruises.

2. The mangoes used as the subject will be solely sourced from markets in the Philippines.

3. The Carabao mangoes would be graded into three levels.

4. The prototype will be using a microcontroller-based system locally stored on the device itself to handle user interaction.

5. Computer vision algorithms to be used will include image classification.

1.6.3 Delimitations

1. The project would only be able to perform sorting and grading on one specific fruit which is the Carabao mango and will not be able to sort other types of mangoes.

2. Additionally, the project prototype will only be able to capture, sort, and grade one mango subject at a time which means the mangoes have to be placed in the conveyor belt in a single file line for accurate sorting.

3. For the bruises, the system will only be able to detect external bruises and may not identify the non-visible and internal bruises.

4. The system does not load the mangoes onto the conveyor belt itself. Assistance is required to put mangoes into the conveyor belt to start the sorting process

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5. The prototype will be powered using alternating current (ac) power and will be plugged into a wall socket which is only suitable for indoor use.

1.7   Description and Methodology of the Thesis

A purpose of the description here is to re-steer/remind the panelist/reader again by tersely describing what your thesis is about (i.e. the problem and the main goal you want to achieve) in another way without sounding repetitive.

Your methodology is your means of achieving your stated objectives. What you put here is the summary of your methodology chapter.

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1.8   Estimated Work Schedule and Budget

As seen above, Table 1.2 shows the Gantt Chart together with the assigned task. For the first part of the THSCP4A, the group would primarily revise and fine tune Chapters 1 and 2 while

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TASKS	THSCP4A				THSCP4B				THSCP4C			
	Week 1-3	Week 4-6	Week 7-9	Week 10-13	Week 1-3	Week 4-6	Week 7-9	Week 10-13	Week 1-3	Week 4-6	Week 7-9	Week 10-13
Topic Proposal and Defense	BANAL, BAUTISTA, HERMOSURA, SALAZAR											
Buying and Collecting of Materials					HERMOSURA AND SALAZAR							
Training and Testing the CNN model					BANAL AND BAUTISTA							
Integrating the sensors and actuators to the Arduino Uno						HERMOSURA AND SALAZAR						
Coding of the Application with CNN model to the Raspberry Pi and connecting it to the Arduino Uno						BANAL AND BAUTISTA						
Polishing and Revising the UI App							BANAL AND BAUTISTA					
Testing and Surveying of the System with the Carabao Mangoes							BANAL, BAUTISTA, HERMOSURA, SALAZAR					
Data Gathering									BANAL, BAUTISTA, HERMOSURA, SALAZAR			

Fig. 1.2   Gantt Chart

also preparing for the defense. After that for THSCP4B, the yellow team which consists of two members, Hermosura and Salazar, would start buying and collecting the materials needed for assembling the prototype. While team yellow is doing that, team purple which consists of Banal and Baustista would start training and validating the convolution neural network (cnn) model based on the Carabao mango image dataset. After that integration of the sensors and actuators together with the integration of the cnn model and beginning of coding of the Application to the Raspberry Pi would be done. Once that cnn model is deployed and the Application works testing of the Carabao mangoes to the prototype would be done. During THSCP4C, data gathering would be done together with polishing and revising of the final paper.

1.9   Overview of the Thesis

There are seven succeeding chapters. To recall, chapter 1 involves the introduction of the thesis topic containing the background of the study, previous studies, objectives and deliverables, assumptions, scope, and delimitation, significance of the study, description of the project together with the methodology, and Gantt chart and budget. Chapter 2 involves the existing articles, the lacking in their approaches, and the summary of chapter 2.

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372 Chapter 3 involves the theoretical considerations of the thesis topic while chapter 4 would

373 consist of the design consideration involving the thesis topic. Chapter 5 would involve the

374 research methodology containing the testing procedure and setup. Chapter 6 would involve

375 the results and discussion based on the methodology while Chapter 7 would involve the

376 conclusion, recommendations, and future suggestions.

Chapter 2

LITERATURE REVIEW

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2.1 Existing Work

The research paper written by Adam et al. (2022) developed a ripeness grader for Carabao mangoes. The Carabao mango ripeness grade calculated based on object and color detection which were written in microcontroller. These are the systems designed by the researchers that consists of Raspberry Pi 4, Arduino Uno, camera, touch screen LCD, MQ3 gas sensor, ventilation system. The proposed system was able to ascertain an overall reliability of 95%: therefore, the specified objective of ascertaining the ripeness level of the mangoes was met with success. However, accuracy and reliability of the software system are there since the hardware design does not seem to be workable when one must deal with the scores of mangoes (Adam et al., 2022). In addition, the design of the hardware does not integrate any form of physical automating, say like the conveyor belt. Besides, the hardware system only works efficiently when deciding the ripeness grade of mangoes separately.

A study done by Samaniego et al. (2023) is another research paper that supports and has relevant information concerning the topic. The researchers proposed a fully-perovskite photonic system which has the capability to identify and sort or grade mango based on features such as color, weight and, conversely, signs of damages (Samaniego et al., 2023). Some of the techniques in image processing that the researchers used included image enhancement, image deblurring, edge detection using MATLAB and Arduino as well as color image segmentation. By carrying out the multiple trials on the device they achieved a classification speed of 8.132 seconds and an accuracy of 91.2%. The proponents' metrics used for the ratings were speed wherein the results were rated "excellent" while the accuracy rating given was "good". One of the limitations of the paper is that the researchers were only limited to the color, texture, and size of the Carabao mango

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402　　　　Furthermore, the research paper presented by Guillergan et al. (2024) designed an
403　Automated Carabao mango classifier, in which the mango image database is used to extract
404　the features like weight, size, area along with the ratio of the spots for grading using
405　Naïve Bayes Model. Concerning the quantitative test design, one had to control and
406　experiment with various methods of image processing that would improve the likelihood
407　of improved classification. The paper methodology entailed sample collection from 300
408　Carabao mangoes, picture taking using a DSLR camera, and feature deconstruction for
409　categorization (Guillergan et al., 2024). The system prototype and the software were
410　designed with the programming language C# with integration of Aforge. NET routines.
411　The performance of this model was checked with the help of the dataset containing 250
412　images, precision, recall, F-score key indicators were used. The investigation discovered
413　that the Naïve Bayes' model recognized large and rejected mangoes with 95% accuracy
414　and the large and small/medium difference with a 7% error, suggesting an application for
415　quality differentiation and sorting in the mango business industry. The limitations in the
416　researchers' paper include the researchers were able to achieve high accuracy after using a
417　high quality DSLR camera and the fact that the researchers were not able to incorporate the
418　use of microcontrollers.

419　　　　Another study by Tomas et al. (2022) proposed SVM-based system for classifying
420　the maturity stages of bananas, mangoes, and calamansi. With the use of 1729 images of
421　bananas together with 711 mango images and 589 calamansi, the researchers were able to
422　achieve a high accuracy score of above 90% for all fruits. Some pre-processing techniques
423　used to get this high accuracy are the change in hue, saturation, and value channels in the
424　mango image (Tomas et al., 2022). To better understand the harvest time of mangoes, the
425　paper by Abu et al. (2021) examined the association of the harvest season with seasonal

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heat units, rainfall, and physical fruit attributes for Haden, Kent, Palmer, and Keitt mango varieties to establish export and domestic market maturity standards. For the results of the paper, it shows that temperature, rainfall, and physical characteristics have a reliable, non-destructive indicators for determining mango maturity (Abu et al., 2021). This shows that physical characteristics and temperature are important when exporting fruits such as mangoes.

TABLE 2.1   COMPARISON OF EXISTING STUDIES

Existing Study	Limitations	Accuracy Rating
Adam et al. (2022)	No physical automation, not suitable for large amounts of mangoes, only classifies ripeness and only a sample size of 10 mangoes.	95%
Samaniego et al. (2023)	Focuses only on color and size.	91.2%
Guillergan et al. (2024)	Relies on high-quality DSLR cameras, and limited automation due to not integrating microcontrollers.	95%
Supekar and Wakode (2020)	No physical automation implemented. Ripeness, size, and shape-based classification achieved 100%, 98.19%, and 99.20% accuracy respectively on their own. However, errors occurred when taking into account all these aspects together for grading mangoes, causing an accuracy rating deduction.	88.88%

Previous studies on mango grading have achieved an accuracy rating of up to 95%, as shown in Table 2.1. However, these studies either relied on a small sample size, which limits statistical significance, or utilized expensive equipment, which may be impractical. In light of this, the researchers have set a target accuracy rating of greater than or equal to 90%. This target ensures that the system being developed is comparable to, or better than, existing studies that used larger sample sizes or assessed multiple mango traits at the

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same time. Furthermore, this research aims to distinguish itself by not only maintaining or exceeding the 90% accuracy rating but also incorporating a graphical user interface (GUI) for selective priority-based mango classification. The system will integrate both software and hardware components, and it will evaluate a greater number of mango traits for grading purposes.

2.1.1   Sorting Algorithms

In previous studies, researchers have implemented various artificial intelligence algorithms in order to determine the optimal and most effective method for sorting mangoes. One of the algorithms that was used in the classification of mangoes was the CNN. A study done by Zheng and Huang (2021) explored the effectiveness of CNN, specifically in classifying mangoes through image processing. The system that the researchers developed graded mangoes into four groups which was based on the Chinese National Standard (Zheng and Huang, 2021). These mangoes were examined by their shape, color uniformity, and external defects. The system that was developed had an impressive accuracy of 97.37% in correctly classifying the mangoes into these grading categories Support Vector Machine was also one of the classification algorithms that was implemented to detect flaws in mangoes. In that study by Veling (2019), SVM was used in the classification of diseases from mangoes. The study used 4 different diseases/defects for testing (Veling, 2019). The diseases were Anthracnose, Powdery Mildew, Black Banded, and Red Rust. and provided 90% accuracy for both the leaves and the fruit

In the study done by Schulze et al. (2015), Simple Linear Regression, Multiple Linear Regression, and Artificial Neural Network models were all studied and compared for the purpose of size-mass estimation for mango fruits. The researchers found that the

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Artificial Neural Network yielded a high accuracy rating for mass estimation and for mango classification based on size with a success rate of 96.7% (Schulze et al., 2015). This is attributed to the Artificial Neural Network model's ability to learn both linear and nonlinear relationships between the inputs and the outputs. However, a problem can occur with the use of the model, which is overfitting. This issue occurs when the model is overtrained with the data set such that it will start to recognize unnecessary details such as image noise which results in poor generalization when fed with new data. With this in mind, additional steps will be necessary to mitigate the issue. Another research article written by Alejandro et al. (2018) implements a method for sorting and grading Carabao mangoes. This research focuses on the use of Probabilistic Neural Network, which is another algorithm that is used for pattern recognition and classification of objects. For this study, the researchers focused on the area, color, and the black spots of the mango for their Probabilistic Neural Network model (Alejandro et al., 2018). Their research using the model yielded an accuracy rating of 87.5% for classification of the mangoes which means it is quite accurate for classifying mangoes within the predefined categories. However, problems were encountered with the use of the model when trying to identify mangoes that did not fit the predefined size categories of small, medium, and large. This means that the PNN model may become challenged when presented with a mango with outlying traits or traits that were very different from the data set.

2.2   Lacking in the Approaches

The majority of past researchers such as Amna et al. (2023) and Guillermo et al. (2019) were able to implement a fruit and mango sorter together with an accurate AI algorithm

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TABLE 2.2 COMPARISON OF SORTING ALGORITHM MODELS

Sorting Algorithm Model	Accuracy Rating	Criteria	Problems Encountered
Convolution Neural Network	97.37%	shape, color, defects	Minor blemishes affected the accuracy.
Support Vector Machine	90%	mango defects and diseases	The model is sensitive to noise, which requires intensive image preprocessing.
Artificial Neural Network	96.7%	for mango size and mass	Overfitting
Probabilistic Neural Network	87.5%	for mango area, color, and black spots	Difficulty in identifying mangoes that have outlying features or did not fit the predefined categories

to detect the ripeness defects. This means that none of the previous research papers were able to integrate an interchangeable user-priority-based grading together with size, ripeness, and bruises using machine learning for Carabao mango sorter and grader. Our research however would implement an automated Carabao mango sorter in terms of size, ripeness, and bruises with its own UI, conveyor belt, stepper motors, and bins for collecting the different ripeness and defect grade of the Carabao mango.

2.3 Summary

To reiterate, there is an innovative gap that needs to be filled with regards to the process of sorting and grading Carabao mangoes. The traditional methods for conducting this process manually by hand, by a porous ruler, by a sugar meter, and by a color palette can be prone to human error and expensive costs due to the number of laborers required to do the task.

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On the other hand, although researchers have already taken steps to automate the process of mango sorting and grading, there is still a need for an implementation that takes into account size, ripeness, and bruises altogether whilst being non-destructive and having its own embedded system. The research articles shown above show the different computer vision and CNN approaches for sorting and classifying mangoes. For example, a system created by Adam et al. (2022) was more focused on ripeness detection. Samaniego et al. (2023) considered photonic systems for grading mango fruit based on color and weight. On the other hand, Guillermo et al. (2019) implemented the Naïve Bayes classification model on mangoes with high accuracy, which thereby did not include any microcontroller. There was an attempt to study each of those parameters separately and that is why the multifactorial approach was not used. With this in mind, the system being proposed does exactly what was mentioned, to implement a non-destructive and automated sorting and grading system for Carabao mangoes that takes into account size, ripeness, and bruises altogether using machine learning, as well as having its own embedded system. This system will be mainly composed of a conveyor belt, servo motors, a camera, microcontrollers, and an LCD display for the user interface. By doing so, the system should be able to improve the efficiency and productivity of mango sorting and grading, remove the effect of human error and reduce time consumption. The studies also provided critical insights regarding the effective algorithms that can be used in classification stages in image processing. The use of CNN had the most accuracy with manageable potential challenges. Lastly, by scaling the implementation, the overall export quality of the Carabao mangoes can be improved.

515 **Chapter 3**

516 **THEORETICAL CONSIDERATIONS**

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To start, computer vision plays an important and pivotal role in machine learning as it equips machines and other systems with the ability to perceive, interpret and understand visual information from our physical environment. Equipping computer systems with this human-like vision capability can be very helpful in many applications such as autonomous driving, advanced medical image analysis and many more. One of the most basic yet very critical functions of computer vision is to process and analyze images to detect and classify objects. This is one of the most important attributes of vision as it can be very useful once computers can correctly recognize and identify different objects. This is where machine learning algorithms further improve its significance. As these computer vision models are exposed to more visual data and information, it can improve in terms of its accuracy and correctness when it comes to identifications and even predictions. This adaptability can be very critical on the performance of these machine vision models in different settings with different lighting conditions which can effectively alter image quality.

3.1 Summary

Provide the gist of this chapter such that it reflects the contents and the message.

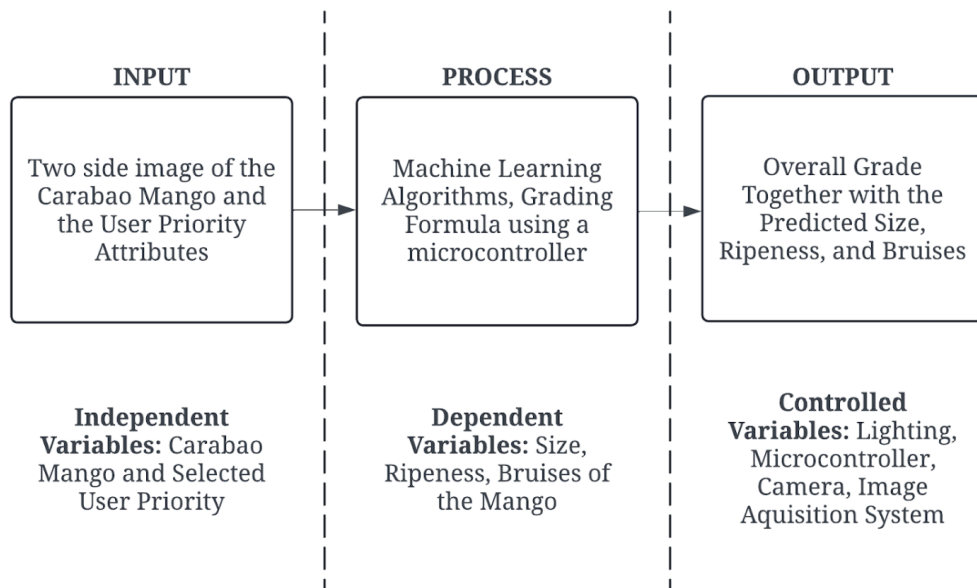De La Salle University

Fig. 3.1   Conceptual Framework

532 **Chapter 4**

533 **DESIGN CONSIDERATIONS**

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Before starting the first section, provide an overview of the purpose of this chapter and its contents, and how they are relevant to your methodology.

Your primary goal in the Design Considerations chapter is to describe to your panelist/readers the key topics that fall further under Theoretical Considerations, but should be placed here instead since they are geared towards your Methodology. These key topics are those that you have directly adopted in making your solution/methodology. You can think of the connection of the Design Considerations chapter to the Theoretical Considerations chapter in this way: if your Theoretical Considerations chapter serves as the main foundation of a building, then the Design Considerations chapter functions as the columns.

The Design Considerations chapter is an avenue for explaining why you considered the topics here for your proposed methodology. This chapter is different from your methodology, because topics you discuss here are already accepted as part of the body of knowledge, and may have not been developed by you.

4.1 Standards

Standards are essential for successful projects and impactful research. They provide a common framework and ensure consistency, quality, and safety across various disciplines. By adhering to established standards, your work becomes more reliable, interoperable, and valuable in real-world applications. Standards also demonstrate your understanding of industry best practices and enhance the credibility of your research.

To effectively integrate standards into your project, begin by identifying relevant standards related to your specific field. Thoroughly research and understand the requirements and guidelines outlined within these standards. Align your project objectives and method-

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556 ologies to meet or exceed these standards. Document your use of standards <u>in this section</u>,

557 including how and why specific standards were chosen. Finally, evaluate your results

558 against the established standards, justifying any deviations from the norm with sound

559 reasoning and evidence.

4.2 Summary

561 Provide the gist of this chapter such that it reflects the contents and message.

562 **Chapter 5**

563 **METHODOLOGY**

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564 Put an overview of the contents of chapter. Mention here your methodology flow

565 through a figure and provide an overview of it and how your methodology achieves your

566 objectives. How your methodology achieves each of your specific objectives is what

567 your panelists/examiners will be looking for. Specify how your methodology achieves

568 your general objective and specific objectives. A point-by-point comparison how your

569 methodology achieves each of your specific objectives is expected in the final Thesis.

570 Also make sure that you refer clearly to the chapters on the Literature Review, Theoreti-

571 cal Considerations, and Design Considerations showing how your methodology ties with

572 those that you have discussed in those chapters.

573 Make an overview of the contents of the chapter. Put here your methodology flow

574 through a figure and provide an overview of it.

575 In summative form, Table 5.1 indicates the approaches, designs, modes, processes,

576 programs, techniques, and/or ways that the Thesisreaches the objectives.

TABLE 5.1 SUMMARY OF METHODS FOR REACHING THE OBJECTIVES

Objectives	Methods	Locations
GO: To develop a user-priority-based grading and sorting system for Carabao mangoes, using machine learning and computer vision techniques to assess ripeness, size, and bruises.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33

Continued on next page

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Objectives	Methods	Locations
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33
SO2: To get the precision, recall, F1 score, confusion matrix, and train and test accuracy metrics for classifying the ripeness and bruises with an accuracy score of at least 90%.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33
SO3: To create a microcontroller-based system to operate the image acquisition system, control the conveyor belt, and process the mango images through machine learning.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33

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Continued from previous page

Objectives	Methods	Locations
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33
SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33

5.1 Implementation

Summarize the process used to create/set-up the work with an explanation of such process, instruments, and materials that you used if any. If the description is lengthy, use condensed bullet points.

Rule of thumb: Implementation is how you made your work; (keywords: implemented, created, made, soldered, programmed, etc.).

If you wrote a program or made a simulation, you must state how the program or simulation functions in this section. An algorithm or a pseudocode as shown in Table **??** is a good example.

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5.2 Evaluation

Describe the procedures for evaluating the correct behavior and outcome of your work, including what information you need to gather and how you will obtain or measure it.

Rule of thumb: Evaluation is how you tested your work; (keywords: measured, tested, compared, simulated, etc.).

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5.3   Summary

682   Provide the gist of this chapter such that it reflects the contents and the message.

683 **Chapter 6**

684 **RESULTS AND DISCUSSIONS**

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Show in this chapter proofs why your proposed solution works. However, presenting results ("It worked") without an appropriate explanation does not show thorough understanding. Aside from the data and results that you have obtained, and their explanation, the discussion includes why components of your proposed solution work did or did not work in accordance to what you described in the evaluation process, and how the proposed solution performed and faired. Interpret the results and the reasons why they were obtained. If your results are incorrect, apparent discrepancies from theory should be pointed out and explained. In essence, what do the results mean? Citing existing publication can help you compare your results and your explanations.

The next items below is not related to the description of this results and discussions chapter, but serves as an opener for the LATEXportion of this template.

In aggregate form, Table 6.1 shows the outcomes and completions in applying the methodology of the Thesisper objective.

TABLE 6.1   SUMMARY OF RESULTS FOR ACHIEVING THE OBJECTIVES

Objectives	Results	Locations
GO: To develop a user-priority-based grading and sorting system for Carabao mangoes, using machine learning and computer vision techniques to assess ripeness, size, and bruises.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33

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Objectives	Results	Locations
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33
SO2: To get the precision, recall, F1 score, confusion matrix, and train and test accuracy metrics for classifying the ripeness and bruises with an accuracy score of at least 90%.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33
SO3: To create a microcontroller-based system to operate the image acquisition system, control the conveyor belt, and process the mango images through machine learning.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33

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Objectives	Results	Locations
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33
SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33

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6.1   Summary

Provide the gist of this chapter such that it reflects the contents and the message.

Chapter 7

CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIRECTIVES

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7.1 Concluding Remarks

In this Thesis, ...

Put here the main points that should be known and learned about the work topic. Summarize or give the gist of the essential principles and inferences drawn from your results.

7.2 Contributions

The interrelated contributions and supplements that have been developed by the author(s) in this Thesis are listed as follows. Only those that are unique to the authors' work are included.

- the ;

- the ;

- the ;

7.3 Recommendations

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7.4 Future Prospects

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807 There are several prospects that may be extended for further studies. . . . So the suggested
808 topics are listed in the following.

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810 2. the . . . .

811 3. the . . . .

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812   Note that for ECE undergraduate theses, as per the directions of the thesis adviser,

813 Recommendations and Future Directives will be removed for the hardbound copy but will

814 be retained for database storage.

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868 **Appendix A**

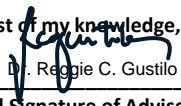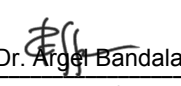869 **STUDENT RESEARCH ETHICS CLEARANCE**

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RESEARCH ETHICS CLEARANCE FORM[1]
For Thesis Proposals

Names of Student Researcher(s): BANAL, Kenan A. BAUTISTA, Francis Robert Miguel F. HERMOSURA, Don Humphrey L. SALAZAR, Daniel G
College:GCOE
Department:ECE
Course: Computer Engineering
Expected Duration of the Project: from: January 4 2025   to: January 4 2026
Ethical considerations *(The Ethics Checklists may be used as guides in determining areas for ethical concern/consideration)*
To the best of my knowledge, the ethical issues listed above have been addressed in the research. Dr. Reggie C. Gustilo _____ **Name and Signature of Adviser/Mentor:** **Date:**   February 5, 2025
Noted by: Dr. Argel Bandala _____ **Name and Signature of the Department Chairperson:** **Date:**   February 6, 2025

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[1] The same form can be used for the reports of completed projects. The appropriate heading need only be used.

Appendix B

ANSWERS TO QUESTIONS TO THIS THESIS

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B1   How important is the problem to practice?

A possible answer to this question is the summary of your Significance of the Study, and that portion of the Problem Statement where you describe the ideal scenario for your intended audience.

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B2   How will you know if the solution/s that you will achieve would be better than existing ones?

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B2.1   How will you measure the improvement/s?

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B2.1.1 What is/are your basis/bases for the improvement/s?

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B2.1.2 Why did you choose that/those basis/bases?

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B2.1.3 How significant are your measure/s of the improvement/s?

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B3 What is the difference of the solution/s from existing ones?

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B3.1 How is it different from previous and existing ones?

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B4 What are the assumptions made (that are behind for your proposed solution to work)?

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B4.1 Will your proposed solution/s be sensitive to these assumptions?

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B4.2 Can your proposed solution/s be applied to more general cases when some assumptions are eliminated? If so, how?

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B5 What is the necessity of your approach / proposed solution/s?

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B5.1 What will be the limits of applicability of your proposed solution/s?

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B5.2 What will be the message of the proposed solution to technical people? How about to non-technical managers and busines people?

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B6 How will you know if your proposed solution/s is/are correct?

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B6.1   Will your results warrant the level of mathematics used (i.e., will the end justify the means)?

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B7   Is/are there an/ alternative way/s to get to the same solution/s?

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B7.1   Can you come up with illustrating examples, or even better, counterexamples to your proposed solution/s?

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B7.2   Is there an approximation that can arrive at essentially the same proposed solution/s more easily?

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B8   If you were the examiner of your Thesis, how would you present the Thesis in another way? Give your remarks, especially for your methodology and the results and discussions.

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B8.1   What are the weaknesses of your Thesis, specifically your methodology and the results and discussions?

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1104 **Appendix C**
1105 **REVISIONS TO THE PROPOSAL**

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PRO1 Panel Comments and Revisions

Zoom Recording:
https://zoom.us/rec/share/mrn9zBtPz3bJ5laVcy2E8-iBno8A6fBRgOCacMrhmzLPCNO0
lDxXBHiK_xzdicEb.MzbHGzrD7rL3tVgJ?startTime=1731326444000
Passcode: +?qL6DZE

Panelist's Comments and Revisions	Action Taken	Page Number
Capture both two sides of the mango and not just one to remove error	The image capturing system would only capture the two sides of the mango which are the two largest surface areas of the skin.	18
How will you get large dataset with sweetness and how will you classify it?	Remove Sweetness in the SO	13
Size and weight are not the same.	Remove Weight in objectives but retained size in the SO4 and SO6	
Specify in the specific objectives that it will be automatic sorting	SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	13
Add what process will be used to get the size classification	SO6: To classify mango size by gettings its length and width using OpenCV, geometry, and image processing techniques	13
Add what process the ripeness classification will be	SO5: To classify mango ripeness using kNN or nearest neighbors algorithm	13
Get rid of texture in the general objectives	Texture is removed in the SOs	13
Get rid of CNN in general objectives and replace with machine learning	CNN is removed and replaced with machine learning GO: To develop a user-priority-based grading and sorting system for Carabao mangoes, using machine learning to assess ripeness, size, and bruises.	13
Remove Raspberry Pi on the SO's and generalize to "to create a microcontroller based application"	SO3: To create a microcontroller application to operate and control the prototype.	13
Remove SO4. No need for user testing	Removed user test and the new SO4 is SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	13
Fix IPO to the correct input and output	Input: Two side image of the Carabao Mango and the User Priority Attributes Process: Machine Learning Algorithm, Grading Formula, and CNN model using a microcontroller Output: Size, Ripeness, and Bruises	20

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PRO1 Panel Comments and Revisions – Appendix Z

	Classification with its Overall Grade	
Define bruises	The black or brown area of the mango that is visible on the skin of the mango.	6
Dataset should use at least 10,000 images	Added to expected deliverables SO2: To use a publicly available dataset of at least 10,000 mango images for classification of ripeness, and bruises.	14
Add to specific objectives the percentage accuracy	SO2: To get the precision, recall, F1 score, confusion matrix, and train and test accuracy metrics for classifying the ripeness and bruises with an accuracy score of at least 90%.	14
Weight sensor just adds complexity	removed all mention of load sensor, load cell. removed load cell methodology	39,40,41, 42,43,44 previously

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PRO1 Panel Comments and Revisions

Zoom Recording:
https://zoom.us/rec/share/mrn9zBtPz3bJ5laVcy2E8-iBno8A6fBRgOCacMrhmzLPCNO0lDxXBHiK_xzdicEb.MzbHGzrD7rL3tVgJ?startTime=1731326444000
Passcode: +?qL6DZE

Summary:
- Specific Objectives
  - Add:
    - what process will be used to get the sweetness classification
    - what process the ripeness classification will be
    - what process will be used to get the size classification
    - Specify in the specific objectives that it will be automatic sorting
  - Remove:
    - get rid of texture in the general objectives
    - get rid of cnn in general objectives and replace with machine learning
    - remove Raspberry Pi on the SO's and generalize to "to create a microcontroller based application"
    - remove SO4. No need for user testing

Comments:
*[00-00] time stamps from recording
- [15:00] Why only the top side of the mango? Isn't the point of automation to reduce human error? Then what about the bottom side wouldn't that just introduce another error if the mango happens to have defects on the bottom?
- [16:09] What is the load cell for? Size is not the same as weight. if size is taken from the weight wouldn't size be also taken from the image. if size then adding a load cell would just introduce more complexity, if weight then load cell is fine. reminder that size is not the same as weight.
- [17:36] When computer vision, state input and output parameters. Output parameters in this case would be sweetness, ripeness, size and bruising. Input parameters would be images.
- [18:12] No mention of how the dataset would be gathered. Would you be gather your own dataset or using a publicly available dataset
- [21:38] Fix IPO based on mention input and output parameters.
- [21:50] Dataset is lacking. Usually in machine learning at least 10,000 images. can take more than one image per mango. after taking an image of mango can make more out of the image using data augmentations.
- [22:48] Add to specific Objectives the mentioned 80%
- [23:09] Consultant that would grade the mangoes as a third party to remove biases. For both the testing and the training
- [24:55] How do you detect the sweetness of mangoes? Add these to the specific objectives. What are the categories of sweetness? Add these to specific objectives. How do

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you detect the correct categorization of sweetness? How to automate the classification of the sweetness.
○ [33:10] Why is the dataset destructive but the testing non destructive? Clarify this further to avoid confusion.
○ [35:09] What is the basis of sweetness using images? Clarify this further.
○ [35:35] How would you know if the classifier is correct or not? What is your ground truth (for the sweetness)?
○ [38:55] When can you say you are getting the top side of the mango? How would you know if the mango images showing the top side or the bottom side of both cheeks of the mango can be captured? If it doesn't matter then any side can be captured so why is it in the limitations that only the top side can be captured. Clarify the limitations.
○ [48:10] What classifier would you use here? What features would you extract from the images?
○ [52:07] Does it explain what process will be used to get the sweetness classification? Add it to the specific objectives
○ [54:00] How will ripeness be classified? Will it use the same dataset as the sweetness classification did? How was ground truth obtained?
○ [55:44] Why not the nearest neighbor? it is more fit in this scenario. Do not specify CNN in the objectives. The embedded systems as well, do not specify the Raspberry pi unless truly sure
○ [57:30] Table is just image processing. Is there a specific objective that would describe how ripeness classification will be done? Add this to the specific objectives.
○ [59:10] How is the weight obtained? Add it to the specific objectives. Remember that size is not proportional to weight. Size could be obtained from the image as the camera is from a fixed distance. Add to specific objectives how to get the size
○ [1:00:00] get rid of texture in the general objectives. get rid of cnn in general objectives and replace with machine learning. as each parameter will use a different method.
○ [1:04:00] remove Raspberry Pi on the SO's and generalize to "to create a microcontroller based application"
○ [1:04:37] remove SO4. no more user testing
○ [1:05:00] The formula used for grading the mangoes, is this used as industry standard? How do they measure the export quality of mango
○ [1:07:00] Specify in the specific objectives that it will be automatic sorting

Here are my comments on my end :)
1. Ensure seamless integration between hardware (sensors, motors, etc.) and software (CNNs, Raspberry Pi). You can consider using a modular approach for easier troubleshooting.

2. How do you gather a comprehensive and diverse dataset for training your CNN. This will enhance the model's robustness and accuracy.

3. Make sure that the weight sensors are calibrated correctly to avoid measurement errors.

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4. Implement data augmentation techniques to enhance your image dataset, which can improve model generalization and accuracy.

5. Design an intuitive user interface for the Raspberry Pi application.

6. Besides precision, recall, and F1 score, consider incorporating confusion matrices to better understand model performance and error types.

7. Conduct user testing of the application to gather feedback on usability and functionality. This can lead to improvements in design and user experience. Consider how the system can be scaled or adapted for different fruits or larger processing volumes in the future.

Noted by:

Dr. Donabel de Veas Abuan
Chair of Panel

Date: November 11 2024

Note: Keep a copy of this Appendix. It is a requirement that has to be submitted in order to qualify for PRO3 Defense.

1111 **Appendix D**

1112 **REVISIONS TO THE FINAL**

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Make a table with the following columns for showing the summary of revisions to the proposal based on the comments of the panel of examiners.

1. Examiner

2. Comment

3. Summary of how the comment has been addressed

4. Locations in the document where the changes have been reflected

TABLE D.1 SUMMARY OF REVISIONS TO THE THESIS

Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Reggie C. Gustilo	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext **First** itemtext **Second** itemtext **Last** itemtext **First** itemtext **Second** itemtext	Sec. 5.1 on p. 33, Sec. 5.2 on p. 36, Fig. **??** on p. **??**

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Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Donable de Veas Abuan	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext **First** itemtext **Second** itemtext **Last** itemtext **First** itemtext **Second** itemtext	Sec. 5.1 on p. 33, Sec. 5.2 on p. 36, Fig. **??** on p. **??**
Engr. Jose Martin Maningo	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext • First itemtext • Second itemtext • Last itemtext • First itemtext • Second itemtext	Sec. 5.1 on p. 33, Sec. 5.2 on p. 36, Fig. **??** on p. **??**

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Continued from previous page

| Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Alexander Co Abad	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33, Sec. 5.2 on p. 36, Fig. **??** on p. **??**
Dr. Rafael W. Sison	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 33, Sec. 5.2 on p. 36, Fig. **??** on p. **??**

1119 **Appendix E**
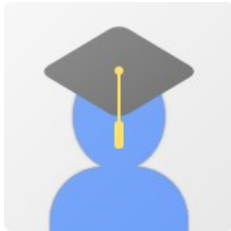
1120 **LIST OF LIMITS AND DESIGN**
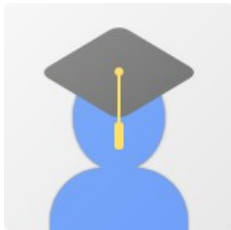
1121 **CONSTRAINTS**
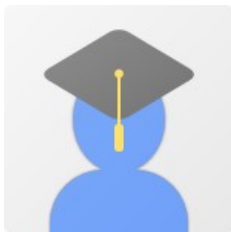
Appendix F
VITA
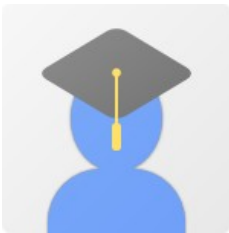
Kenan A. Banal is currently taking up his B.Sc. Computer Engineering studies. He is passionate about software and hardware systems such as Vivado, Arduino, C, and Python.

Francis Robert Miguel F. Bautista is currently taking up his B.Sc. Computer Engineering studies. He is passionate about software and hardware systems such as Vivado, Arduino, C, and Python.

Don Humphrey L. Hermosura is currently taking up his B.Sc. Computer Engineering studies. He is passionate about software and hardware systems such as Vivado, Arduino, C, and Python.

Daniel G. Salazar is currently taking up his B.Sc. Computer Engineering studies. He is passionate about software and hardware systems such as Vivado, Arduino, C, and Python.

1136 **Appendix G**

1137 **ARTICLE PAPER(S)**

Article/Forum Paper Format
(IEEE LaTeX format)

Michael Shell, *Member, IEEE,* John Doe, *Fellow, OSA,* and Jane Doe, *Life Fellow, IEEE*

1138

Abstract—**The abstract goes here.** Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Index Terms—**Computer Society, IEEE, IEEEtran, journal, LaTeX, paper, template.**

I. INTRODUCTION

THIS demo file is intended to serve as a "starter file" for IEEE article papers produced under LaTeX using IEEEtran.cls version 1.8b and later. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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M. Shell was with the Department of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA, 30332.
E-mail: see http://www.michaelshell.org/contact.html
J. Doe and J. Doe are with Anonymous University.

Fig. 1. Simulation results for the network.

TABLE I
AN EXAMPLE OF A TABLE

One	Two
Three	Four

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1) Subsubsection Heading Here: Subsubsection text here.

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II. CONCLUSION

The conclusion goes here.

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(a) Case I (b) Case II

Fig. 2. Simulation results for the network.

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APPENDIX A
PROOF OF THE FIRST ZONKLAR EQUATION

Appendix one text goes here.

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APPENDIX B

Appendix two text goes here. [?].

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