



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  
Department of Electronics and Computer Engineering  
Gokongwei College of Engineering  
De La Salle University

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In Partial Fulfillment of the  
Requirements for the Degree of  
Bachelor of Science in Computer Engineering

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by  
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February, 2025



De La Salle University

## 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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**Dr. Reggie C. Gustillo**  
*Adviser*

February 12, 2025



## 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

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AC      Alternating Current ..... 13



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## NOTATION

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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  $t$ ,  $f$ ,  $j = \sqrt{-1}$ ,  $n$  and  $\exp(\cdot)$ , which refer to the time variable, frequency variable, imaginary unit,  $n$ th variable, and exponential function, respectively.



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## GLOSSARY

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bruises

The black or brown area of the mango that is visible on the skin of the mango.



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## LISTINGS



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## Chapter 1

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## 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



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

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

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

189 Previous studies have been made to automate the sortation process of the mangoes.  
190 Among these is a research done by Abbas et al. (2018), which focuses on classification  
191 of mangoes using their texture and shape features. They do this by, first, acquiring an  
192 image of the mango using a digital camera. Then, these images are fed to the MaZda  
193 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 in 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



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. ;



### 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.



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.	<ul style="list-style-type: none"> <li>To develop a Carabao mango grading and sorting system</li> <li>To grade Carabao mangoes into three categories based on ripeness, size, and bruises of the Carabao mangoes using machine learning.</li> <li>To integrate sensors and actuators to control the conveyor belt and image acquisition system.</li> </ul>
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	<ul style="list-style-type: none"> <li>To make an image acquisition system with a camera and LED light source.</li> <li>To build a flat belt conveyor for moving the mangoes.</li> </ul>
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%.	<ul style="list-style-type: none"> <li>To use a publicly available dataset of at least 10,000 mango images for classification of ripeness, and bruises.</li> </ul>
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.	<ul style="list-style-type: none"> <li>To develop an intuitive UI where users can start and stop the system.</li> <li>To implement a priority-based grading system with sliders for ripeness, bruises, and size.</li> </ul>
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	<ul style="list-style-type: none"> <li>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.</li> <li>To assign score values for each classification level of the mango.</li> </ul>
SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes.	<ul style="list-style-type: none"> <li>To train a machine learning model such as kNN, k-mean, naive Bayes capable of classifying mango ripeness based on the image color</li> <li>To gather a dataset of annotated images with ripeness labels</li> <li>To obtain an evaluation report of performance metrics of the model</li> </ul>



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.	<ul style="list-style-type: none"> <li>To develop an image processing algorithm capable of determining mango size using OpenCV, NumPy, and imutils</li> <li>To classify mangoes based on size and categories into small, medium, and large based on those measures</li> </ul>
SO7: To classify mango bruises based on image data by employing machine learning algorithms.	<ul style="list-style-type: none"> <li>To train a machine learning model such as CNN capable of distinguishing bruised and non-bruised mangoes</li> <li>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</li> <li>To gather a dataset of annotated images based on bruises</li> <li>To obtain an evaluation report of performance metrics of both CNN and machine learning models</li> </ul>

## 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



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 mangoes 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.



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





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.

Lorem ipsum dolor sit amet, consectetur 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, consectetur 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.

## 1.8 Estimated Work Schedule and Budget

The estimated work schedule can be represented as a Gantt Chart or a combination of Project Network Diagram, Work Breakdown Structure, and Critical Path. The budget can



365 be made into a Bill of Materials, financial plan, or if your Thesis is funded and part of  
 366 larger project, the cost, and date for reaching each milestone and/or deliverable for your  
 367 part of the project.

368 For ECE Department undergraduate theses, the individual Gantt Chart or Work Break-  
 369 down Schedule and Bill of Materials will be included in this section and be removed in the  
 370 final document.

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

## 380 1.9 Overview of the Thesis

381 There are seven succeeding chapters. To recall, chapter 1 involves the introduction of  
 382 the thesis topic containing the background of the study, previous studies, objectives and  
 383 deliverables, assumptions, scope, and delimitation, significance of the study, description  
 384 of the project together with the methodology, and Gantt chart and budget. Chapter 2  
 385 involves the existing articles, the lacking in their approaches, and the summary of chapter 2.  
 386 Chapter 3 involves the theoretical considerations of the thesis topic while chapter 4 would



387 consist of the design consideration involving the thesis topic. Chapter 5 would involve the  
388 research methodology containing the testing procedure and setup. Chapter 6 would involve  
389 the results and discussion based on the methodology while chapter 7 would involve the  
390 conclusion, recommendations, and future suggestions.



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## Chapter 2

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## LITERATURE REVIEW



## 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



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

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



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



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 or Convolutional Neural Networks. 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





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



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.



508 On the other hand, although researchers have already taken steps to automate the process  
509 of mango sorting and grading, there is still a need for an implementation that takes into  
510 account size, ripeness, and bruises altogether whilst being non-destructive and having its  
511 own embedded system. The research articles shown above show the different computer  
512 vision and CNN approaches for sorting and classifying mangoes. For example, a system  
513 created by Adam et al. (2022) was more focused on ripeness detection. Samaniego et al.  
514 (2023) considered photonic systems for grading mango fruit based on color and weight.  
515 On the other hand, Guillermo et al. (2019) implemented the Naïve Bayes classification  
516 model on mangoes with high accuracy, which thereby did not include any microcontroller.  
517 There was an attempt to study each of those parameters separately and that is why the  
518 multifactorial approach was not used. With this in mind, the system being proposed does  
519 exactly what was mentioned, to implement a non-destructive and automated sorting and  
520 grading system for Carabao mangoes that takes into account size, ripeness, and bruises  
521 altogether using machine learning, as well as having its own embedded system. This system  
522 will be mainly composed of a conveyor belt, servo motors, a camera, microcontrollers, and  
523 an LCD display for the user interface. By doing so, the system should be able to improve  
524 the efficiency and productivity of mango sorting and grading, remove the effect of human  
525 error and reduce time consumption. The studies also provided critical insights regarding the  
526 effective algorithms that can be used in classification stages in image processing. The use  
527 of CNN had the most accuracy with manageable potential challenges. Lastly, by scaling  
528 the implementation, the overall export quality of the Carabao mangoes can be improved.



529

## Chapter 3

530

## THEORETICAL CONSIDERATIONS



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. Discuss in this chapter the relevant theories and concepts that should support your proposed solutions.

This chapter is for providing the context to your panelist/reader. It is actually an expanded form of the Background of the Study that you have put in Chapter 1.

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Fig. 3.1 A quadrilateral image example.

## 581 3.1 Summary

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



583

## Chapter 4

584

## DESIGN CONSIDERATIONS





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 Introduction

This chapter discusses the design considerations for the mango sorting and grading system, focusing on the technical and engineering decisions required for its development. The design process aims to create a scalable, efficient, and user-friendly system that leverages machine learning for accurate mango classification.



## 603 4.2 System Architecture

604 The system architecture is represented through a block diagram, showcasing modules  
605 such as image acquisition, preprocessing, feature extraction, machine learning model, and  
606 grading output. Each module is described in detail, emphasizing its role in the overall  
607 system. For instance, the image acquisition module uses high-resolution cameras to capture  
608 mango images, while the preprocessing module enhances image quality for better feature  
609 extraction.

## 610 4.3 Hardware Considerations

611 The hardware components include high-resolution cameras, lighting systems for consistent  
612 image capture, and microcontrollers like Raspberry Pi or Arduino for system control,  
613 actuators like motors and servo motors to move the mangoes. The choice of hardware is  
614 justified based on cost, performance, and compatibility with the software framework.

## 615 4.4 Software Considerations

616 The software stack includes Python for programming, TensorFlow or PyTorch for machine  
617 learning, and OpenCV for image processing. These tools are selected for their robustness,  
618 ease of use, and extensive community support, ensuring efficient system development.



## 4.5 Security and Reliability considerations

Potential vulnerabilities, such as data corruption during image capture, are addressed through redundancy and error-checking mechanisms. Reliability is ensured by implementing fault-tolerant designs and rigorous testing protocols.

## 4.6 Scalability and Efficiency Considerations

The system is designed to handle large volumes of mangoes by optimizing the machine learning model and using parallel processing techniques. Efficiency is improved through techniques like model quantization and hardware acceleration.

## 4.7 User Interface

A user-friendly interface is designed to display grading results, system status, and error messages. Wireframes illustrate the layout, ensuring usability and accessibility for operators.

## 4.8 Constraints and Limitations

Challenges include variations in mango appearance due to lighting and environmental factors. Trade-offs are made between model complexity and real-time performance to balance accuracy and speed.



## 635 4.9 Technical Standards

636 The system adheres to industry standards for image processing and machine learning,  
637 ensuring compatibility and interoperability with other systems.

## 638 4.10 Prototyping and Simulation

639 Prototypes are developed using tools like MATLAB and Simulink to simulate the system's  
640 performance. These simulations help identify design flaws and optimize the system before  
641 deployment.,

## 642 4.11 Design Validation

643 The design is validated through testing, including unit testing of individual modules and  
644 integration testing of the entire system. Peer reviews and iterative improvements ensure the  
645 system meets the desired performance metrics.

## 646 4.12 Summary

647 This chapter outlined the key design considerations, including system architecture, hardware  
648 and software choices, and validation methods. These decisions are critical for developing a  
649 reliable and efficient mango sorting and grading system.

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### 695 4.13 Standards

696 Standards are essential for successful projects and impactful research. They provide a  
697 common framework and ensure consistency, quality, and safety across various disciplines.  
698 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 methodologies to meet or exceed these standards. Document your use of standards in this section, including how and why specific standards were chosen. Finally, evaluate your results against the established standards, justifying any deviations from the norm with sound reasoning and evidence.

## 4.14 Summary

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



De La Salle University

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## Chapter 5

711

## METHODOLOGY





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.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??
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%.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??

*Continued on next page*



*Continued from previous page*

Objectives	Methods	Locations
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.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??
SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??

## 5.1 Introduction

The methodology for this research outlines the development of the Carabao Mango sorter using machine learning and computer vision. The sorting system uses a conveyor belt



715 system which delivers the mangoes into the image acquisition system. This system captures  
716 the image of the mangoes which will then be going through the various stages of image  
717 processing and classification into grades which will depend on the priority of the user.  
718 This methodology ensures that the grading of the mangoes will be accurate while being  
719 non-destructive.

## 720 **5.2 Research Approach**

721 This study applies the experimental approach for research in order to develop and properly  
722 test the proposed system. The experimental approach of the methodology will allow the  
723 researchers to fine-tune the parameters and other factors in the classification of mangoes in  
724 order to get optimal results with high accuracy scores while maintaining the quality of the  
725 mangoes. This approach will also allow for real-time data processing and classification  
726 which will improve the previous static grading systems.

## 727 **5.3 Experimental Setup**

728 The prototype consists of hardware and software components for automated mango sorting  
729 and grading purposes. The hardware includes the conveyor belt system used to transfer  
730 mangoes from scanning to sorting smoothly. A camera and lighting system are able to  
731 collect high-resolution images for analysis. The DC motors and stepper motors are respon-  
732 sible for driving the conveyor belt and sorting actuators. The entire system is controlled by  
733 a microcontroller (Raspberry Pi/Arduino), coordinating actions of all components. A laser  
734 sensor detects mangoes, allowing the system to take images thereby. Sorting actuators then



direct mangoes into selected bins based on their classification to make sorting efficient.

In addition to their hardware, the rest of the software components are of utmost importance to mango classification. Image processing algorithms in OpenCV and CNN models extract features such as color, size, and bruises that are known to determine quality parameters of mangoes. Mangoes are classified based on ripeness and defects by using machine learning algorithms, which further enhances accuracy using deep learning techniques. A user interface (UI) is designed for users to control and observe the system in real time. Finally, the interface programming of the microcontroller provides the necessary synchronization between sensors, actuators, and motors throughout the sorting operation scenario.

## 5.4 Data Collection Methods

The system acquires high-resolution images of mangoes under pre-specified lighting conditions through systematic acquisition. Apart from that, this corpus of data is based on the real-time images acquired from the camera system, where classification operations are carried out based on real-time data. Pre-processing image operations such as color segmentation, histogram equalization, and thresholding are also carried out in order to enhance image clarity and feature detection. Then, the feature extraction process is carried out, where the intensity of color, shape, and texture are analyzed for the detection of characteristic features in terms of the mango. The data will be labeled to ground truth values by expert mango graders so that the classification model is trained on accurate and reliable data. All these aspects lead to the creation of a reliable dataset for the machine learning algorithm that will allow the system to classify and grade mangoes more accurately.



## 5.5 Testing and Evaluation Methods

In a bid to ensure the mango sorting and grading system is accurate and reliable, there is intensive testing conducted at different levels. Unit testing is initially conducted on each component separately, for instance, the conveyor belt, sensors, and cameras, to ensure that each of the components works as expected when operating separately. After component testing on an individual basis, integration testing is conducted to ensure communication between hardware and software is correct to ensure the image processing system, motors, and sorting actuators work in concert as required. System testing is conducted to conduct overall system performance testing in real-world conditions to ensure mangoes are accurately and efficiently sorted and graded.

To test system performance, various measures of performance are used to evaluate. Accuracy is used to measure the percentage of correctly classified mangoes to ensure the system maintains high precision levels. Precision and recall are used to measure consistency of classification to determine if the system classifies different ripeness levels and defects correctly. A confusion matrix is used to measure correct and incorrect classification to ensure the machine learning model is optimized and that minimum errors are achieved. Throughput analysis is also used to determine the rate and efficiency of sorting to ensure that the system maintains high capacity without bottlenecks to sort mangoes. Using these methods of testing, the system is constantly optimized to ensure high-quality and reliable mango classification.



## 5.6 Ethical Considerations

Ethical considerations ensure that the system is operated safely and responsibly. Data privacy is ensured by securely storing and anonymizing extracted images and classification data so that unauthorized access becomes impossible. The system is also eco-friendly through non-destructive testing, saving mangoes while also ensuring that they are of good quality. Safety in operations is also ensured by protecting moving parts to prevent mechanical harm and incorporating fail-safes to securely stop operation in case of malfunction. Addressing these concerns, the system is not only accurate and efficient but also secure, eco-friendly, and safe for operators, thus a sustainable solution to automated mango sorting and grading.

## 5.7 Summary

This chapter explained how to create an automatic Carabao mango sorter and grader using machine learning and computer vision. The system integrates hardware and software resources, including a conveyor belt, cameras, sensors, and actuators, to offer accurate, real-time sorting by ripeness, size, and bruises. Various testing and evaluation processes ensure its performance to offer reliability. Ethical issues are data privacy, environmental sustainability, and operation safety. With enhanced efficiency, reduced human error, and enhanced quality, this system provides an affordable, scalable, and non-destructive solution to post-harvest mango classification in agricultural industries.



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## Chapter 6

797

## RESULTS AND DISCUSSIONS



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

807 The next items below is not related to the description of this results and discussions  
 808 chapter, but serves as an opener for the L<sup>A</sup>T<sub>E</sub>X portion of this template.

809 In aggregate form, Table 6.1 shows the outcomes and completions in applying the  
 810 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. ?? on p. ??

*Continued on next page*





*Continued from previous page*

Objectives	Results	Locations
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??
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%.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??
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.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??

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Continued from previous page

Objectives	Results	Locations
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??
SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes.	<ol style="list-style-type: none"> <li>1. First itemtext</li> <li>2. Second itemtext</li> <li>3. Last itemtext</li> <li>4. First itemtext</li> <li>5. Second itemtext</li> </ol>	Sec. ?? on p. ??

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**6.1 Summary**

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



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## **Chapter 7**

859

## **CONCLUSIONS, RECOMMENDATIONS, AND**

860

## **FUTURE DIRECTIVES**



## 861 7.1 Concluding Remarks

862 In this Thesis, . . .

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

## 866 7.2 Contributions

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

- 870 • the ;
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## 873 7.3 Recommendations

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## 7. Conclusions, Recommendations, and Future Directives



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## 919 7.4 Future Prospects

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

922 1. the . . . .

923 2. the . . . .

924 3. the . . . .



## 7. Conclusions, Recommendations, and Future Directives



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925 Note that for ECE undergraduate theses, as per the directions of the thesis adviser,  
926 Recommendations and Future Directives will be removed for the hardbound copy but will  
927 be retained for database storage.



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## **Appendix A**

# **STUDENT RESEARCH ETHICS CLEARANCE**



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**RESEARCH ETHICS CLEARANCE FORM<sup>1</sup>**  
**For Thesis Proposals**

Names of Student Researcher(s):

Dela Cruz, Juan Z.

College: **Gokongwei College of Engineering**Department: **Electronics and Communications Engineering**Course: **PhD-ECE**Expected Duration of the Project: from: **April 2015**to: **April 2017**

Ethical considerations

None

*(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. Francisco D. Baltasar**

Name and Signature of Adviser/Mentor:

Date: **April 8, 2017**

Noted by:

**Dr. Rafael W. Sison**

Name and Signature of the Department Chairperson:

Date: **April 8, 2017**

<sup>1</sup> The same form can be used for the reports of completed projects. The appropriate heading need only be used.



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## **Appendix B**

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## **ANSWERS TO QUESTIONS TO THIS THESIS**



## 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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1020 **B2.1.1 What is/are your basis/bases for the improvement/s?**

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1030 **B2.1.2 Why did you choose that/those basis/bases?**

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1040 **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 business people?**

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

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1149 **B6.1 Will your results warrant the level of mathematics used**  
1150 **(i.e., will the end justify the means)?**

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1160 **B7 Is/are there an/\_ alternative way/s to get to the**  
1161 **same solution/s?**

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1171 **B7.1 Can you come up with illustrating examples, or even**  
1172 **better, counterexamples to your proposed solution/s?**

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1182 **B7.2 Is there an approximation that can arrive at essentially**  
 1183 **the same proposed solution/s more easily?**

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1193 **B8 If you were the examiner of your Thesis, how**  
 1194 **would you present the Thesis in another way? Give**  
 1195 **your remarks, especially for your methodology and**  
 1196 **the results and discussions.**

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1206 **B8.1 What are the weaknesses of your Thesis, specifically your**  
 1207 **methodology and the results and discussions?**

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## **Appendix C**

1218

## **REVISIONS TO THE PROPOSAL**

## PRO1 Panel Comments and Revisions – Appendix Z

### PRO1 Panel Comments and Revisions

1219

Zoom Recording:

[https://zoom.us/rec/share/mrn9zBtPz3bJ5laVcy2E8-iBno8A6fBRgOCacMrhmzLPCNO0IDxXBHiK\\_xzdicEb.MzbHGzrD7rL3tVgJ?startTime=1731326444000](https://zoom.us/rec/share/mrn9zBtPz3bJ5laVcy2E8-iBno8A6fBRgOCacMrhmzLPCNO0IDxXBHiK_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 getting 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



## 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 previousl y

1220

## PRO1 Panel Comments and Revisions – Appendix Z



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## PRO1 Panel Comments and Revisions

1221

Zoom Recording:

[https://zoom.us/rec/share/mrn9zBtPz3bJ5laVcy2E8-iBno8A6fBRgOCacMrhmzLPCNO0IDxXBHiK\\_xzdicEb.MzbHGzrD7rL3tVgJ?startTime=1731326444000](https://zoom.us/rec/share/mrn9zBtPz3bJ5laVcy2E8-iBno8A6fBRgOCacMrhmzLPCNO0IDxXBHiK_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

## PRO1 Panel Comments and Revisions – Appendix Z



De La Salle University

you detect the correct categorization of sweetness? How to automate the classification of the sweetness.

1222

- [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.

## PRO1 Panel Comments and Revisions – Appendix Z



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

1223

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:

A handwritten signature in black ink, appearing to read "Dr. Donabel de Veas Abuan".

**Dr. Donabel de Veas Abuan**  
*Chair of Panel*

Date: November 11 2024

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



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## **Appendix D**

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## **REVISIONS TO THE FINAL**



1226 Make a table with the following columns for showing the summary of revisions to the  
1227 proposal based on the comments of the panel of examiners.

1228 1. Examiner

1229 2. Comment

1230 3. Summary of how the comment has been addressed

1231 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. Gustillo	1. First itemtext	1. First itemtext	Sec. ?? on p. ??, Sec. ?? on p. ??, Fig. 3.1 on p. 27
	2. Second itemtext	2. Second itemtext	
	3. Last itemtext	3. Last itemtext	
	4. First itemtext	4. First itemtext	
	5. Second itemtext	5. Second itemtext	
		First itemtext	
		Second itemtext	
		Last itemtext	
		First itemtext	
		Second itemtext	

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Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Donable de Veas Abuan	1. First itemtext	1. First itemtext	Sec. ?? on p. ??, Sec. ?? on p. ??, Fig. 3.1 on p. 27
	2. Second itemtext	2. Second itemtext	
	3. Last itemtext	3. Last itemtext	
	4. First itemtext	4. First itemtext	
	5. Second itemtext	5. Second itemtext	
		First itemtext	
		Second itemtext	
		Last itemtext	
		First itemtext	
		Second itemtext	
Engr. Jose Martin Maningo	1. First itemtext	1. First itemtext	Sec. ?? on p. ??, Sec. ?? on p. ??, Fig. 3.1 on p. 27
	2. Second itemtext	2. Second itemtext	
	3. Last itemtext	3. Last itemtext	
	4. First itemtext	4. First itemtext	
	5. Second itemtext	5. Second itemtext	
		• First itemtext	
		• Second itemtext	
		• Last itemtext	
		• First itemtext	
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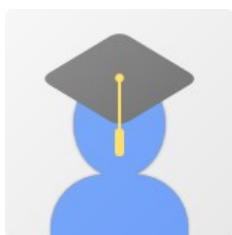
*Continued from previous page*

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. ?? on p. ??, Sec. ?? on p. ??, Fig. 3.1 on p. 27
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. ?? on p. ??, Sec. ?? on p. ??, Fig. 3.1 on p. 27

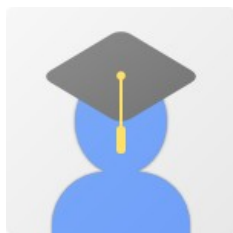




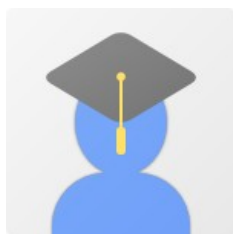
## Appendix E VITA



Kenan A. Banal received the B.Sc., M.Sc., and Ph.D. degrees in chemistry all from the Pamantasan ng Pilipinas, San Juan, Metro Manila, Philippines, in 2020, 2022 and 2025 respectively. He is currently taking up his B.Sc. Computer Engineering studies. He has developed several high-speed packet-switched network systems and node modules. His research interests include high-speed packet-switched networks, high speed radio interface design, discrete simulation and statistical models for packet switches.



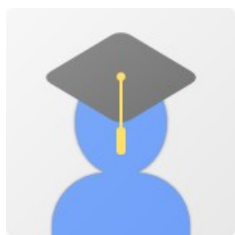
Francis Robert Miguel F. BAUTISTA received the B.Sc., M.Sc., and Ph.D. degrees in chemistry all from the Pamantasan ng Pilipinas, San Juan, Metro Manila, Philippines, in 2020, 2022 and 2025 respectively. He is currently taking up his B.Sc. Computer Engineering studies. He has developed several high-speed packet-switched network systems and node modules. His research interests include high-speed packet-switched networks, high speed radio interface design, discrete simulation and statistical models for packet switches.



Don Humphrey L. HERMOSURA received the B.Sc., M.Sc., and Ph.D. degrees in chemistry all from the Pamantasan ng Pilipinas, San Juan, Metro Manila, Philippines, in 2020, 2022 and 2025 respectively. He is currently taking up his B.Sc. Computer Engineering studies. He has developed several high-speed packet-switched



1252 network systems and node modules. His research interests include high-speed packet-  
1253 switched networks, high speed radio interface design, discrete simulation and statistical  
1254 models for packet switches.



1255 Daniel G. SALAZAR received the B.Sc., M.Sc., and Ph.D. degrees  
1256 in chemistry all from the Pamantasan ng Pilipinas, San Juan, Metro Manila, Philippines,  
1257 in 2020, 2022 and 2025 respectively. He is currently taking up his B.Sc. Computer  
1258 Engineering studies. He has developed several high-speed packet-switched network systems  
1259 and node modules. His research interests include high-speed packet-switched networks,  
1260 high speed radio interface design, discrete simulation and statistical models for packet  
1261 switches.



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## Appendix F

1263

## ARTICLE PAPER(S)

# Article/Forum Paper Format (IEEE LaTeX format)

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

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**Abstract**—The abstract goes here. Lorem ipsum dolor sit amet, consectetur 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, consectetur 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, consectetur 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, consectetur 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.

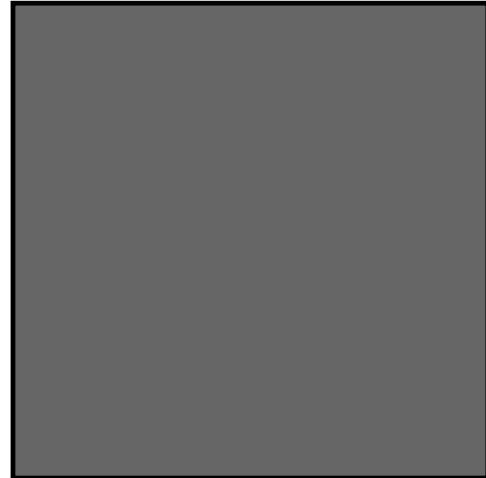


Fig. 1. Simulation results for the network.

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

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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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#### ACKNOWLEDGMENT

The authors would like to thank...