



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

A Thesis
Presented to the Faculty of the
Department of Electronics and Computer Engineering
Gokongwei College of Engineering
De La Salle University

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

by
BANAL Kenan A.
BAUTISTA Francis Robert Miguel F.
HERMOSURA Don Humphrey L.
SALAZAR Daniel G.

March, 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:

BANAL, Kenan A.
BAUTISTA, Francis Robert Miguel F.
HERMOSURA, Don Humphrey L.
SALAZAR, Daniel G.

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**.

Dr. Reggie C. Gustillo
Adviser

March 26, 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.



55

TABLE OF CONTENTS

56

Oral Defense Recommendation Sheet	ii
-----------------------------------	----

57

Abstract	iii
----------	-----

58

Table of Contents	iv
-------------------	----

59

List of Figures	vii
-----------------	-----

60

List of Tables	viii
----------------	------

61

Abbreviations and Acronyms	ix
----------------------------	----

62

Notations	x
-----------	---

63

Glossary	xi
----------	----

64

Listings	xii
----------	-----

65

Chapter 1 INTRODUCTION	1
------------------------	---

66

1.1 Background of the Study	2
---------------------------------------	---

67

1.2 Prior Studies	4
-----------------------------	---

68

1.3 Problem Statement	5
---------------------------------	---

69

1.4 Objectives and Deliverables	6
---	---

70

1.4.1 General Objective (GO)	6
--	---

71

1.4.2 Specific Objectives (SOs)	7
---	---

72

1.4.3 Expected Deliverables	7
---------------------------------------	---

73

1.5 Significance of the Study	9
---	---

74

1.5.1 Technical Benefit	10
-----------------------------------	----

75

1.5.2 Social Impact	11
-------------------------------	----

76

1.5.3 Environmental Welfare	11
---------------------------------------	----

77

1.6 Assumptions, Scope, and Delimitations	11
---	----

78

1.6.1 Assumptions	11
-----------------------------	----

79

1.6.2 Scope	12
-----------------------	----

80

1.6.3 Delimitations	12
-------------------------------	----

81

1.7 Estimated Work Schedule and Budget	13
--	----

82

1.8 Overview of the Thesis	14
--------------------------------------	----



83	Chapter 2 LITERATURE REVIEW	15
84	2.1 Existing Work	16
85	2.1.1 Sorting Algorithms	19
86	2.2 Lacking in the Approaches	20
87	2.3 Summary	21
88	Chapter 3 THEORETICAL CONSIDERATIONS	23
89	3.1 Introduction	24
90	3.2 Relevant Theories and Models	24
91	3.3 Technical Background	25
92	3.4 Conceptual Framework Background	25
93	3.5 Summary	25
94	Chapter 4 DESIGN CONSIDERATIONS	27
95	4.1 Introduction	28
96	4.2 System Architecture	28
97	4.3 Hardware Considerations	29
98	4.4 Software Considerations	29
99	4.5 Security and Reliability Considerations	29
100	4.6 Scalability and Efficiency Considerations	29
101	4.7 User Interface	30
102	4.8 Constraints and Limitations	30
103	4.9 Technical Standards	30
104	4.10 Prototyping and Simulation	30
105	4.11 Design Validation	31
106	4.12 Summary	31
107	Chapter 5 METHODOLOGY	32
108	5.1 Introduction	35
109	5.2 Research Approach	35
110	5.3 Hardware Design	35
111	5.4 Software Design	36
112	5.5 Data Collection Methods	37
113	5.6 Testing and Evaluation Methods	37
114	5.6.1 Ripeness Training and Testing	39
115	5.6.2 Bruises Training and Testing	39
116	5.6.3 Size Determination	39
117	5.7 Formula for User Priority	39
118	5.8 Ethical Considerations	39
119	5.9 Summary	39



120	Chapter 6 RESULTS AND DISCUSSIONS	41
121	6.1 Training and Testing Results of the Model	47
122	6.2 Physical Prototype	47
123	6.3 Software Application	47
124	6.4 Summary	48
125	Chapter 7 CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DI-	
126	RECTIVES	49
127	7.1 Concluding Remarks	50
128	7.2 Contributions	50
129	7.3 Recommendations	50
130	7.4 Future Prospects	50
131	References	52
132	Appendix A STUDENT RESEARCH ETHICS CLEARANCE	54
133	Appendix B ANSWERS TO QUESTIONS TO THIS THESIS	56
134	Appendix C REVISIONS TO THE PROPOSAL	65
135	Appendix D REVISIONS TO THE FINAL	71
136	Appendix E VITA	75
137	Appendix F ARTICLE PAPER(S)	76



138

LIST OF FIGURES

139	1.1	Carabao Mangoes at Different Ripeness Stages (Guillermo et al., 2019)	2
140	1.2	Gantt Chart	13
141	3.1	Theoretical Framework Diagram.	24
142	3.2	Conceptual Framework Diagram.	25



143

LIST OF TABLES

144	1.1	Expected Deliverables per Objective	8
145	1.1	Expected Deliverables per Objective	9
146	2.1	Comparison of Existing Studies	18
147	2.2	Comparison of Sorting Algorithm Models	21
148	5.1	Summary of methods for reaching the objectives	33
149	6.1	Summary of methods for achieving the objectives	42
150	D.1	Summary of Revisions to the Thesis	72



151

ABBREVIATIONS

152

AC Alternating Current 13

153

CNN Convolution Neural Network 14



154

NOTATION

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



161

GLOSSARY

162

accuracy score

A performance metric that measures the overall proportion of correct predictions made by a machine learning model.

163

bruises

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

164

Carabao mango

A popular variety of mango grown in the Philippines, known for its sweet and juicy flesh.

165

microcontroller

A small computing device that controls other parts of a system such as sensors



De La Salle University

166

LISTINGS



De La Salle University

167

Chapter 1

168

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



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

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

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

204 Previous studies have been made to automate the sortation process of the mangoes.
205 Among these is a research done by Abbas et al. (2018), which focuses on classification
206 of mangoes using their texture and shape features. They do this by, first, acquiring an
207 image of the mango using a digital camera. Then, these images are fed to the MaZda
208 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



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 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"> To develop a Carabao mango grading and sorting system. To grade Carabao mangoes into three categories based on ripeness, size, and bruises 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.	<ul style="list-style-type: none"> 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%.	<ul style="list-style-type: none"> 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.	<ul style="list-style-type: none"> 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.	<ul style="list-style-type: none"> 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.

Continued on next page



TABLE 1.1 EXPECTED DELIVERABLES PER OBJECTIVE

Objectives	Expected Deliverables
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"> • To train a machine learning model such as kNN, k-means, or Naïve 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.
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"> • To develop an image processing algorithm capable of determining mango size using OpenCV, NumPy, and imutils. • To classify mangoes based on size into small, medium, and large based on measurements.
SO7: To classify mango bruises based on image data by employing machine learning algorithms.	<ul style="list-style-type: none"> • 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-means, 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 other 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.



295 A recent study showed that their automated citrus sorter and grader using computer vision
 296 can reduce the human labor cost and time to sort and grade when comparing the automated
 297 citrus sorter and grader to manual human labor Chakraborty et al. (2023).

298 Another benefit to automating sorting and grading mangoes is the improvement in
 299 quality control. This implies that compared to human labor, automating sorting and
 300 grading mangoes can uniformly assess the quality of mangoes based on size, color, and
 301 bruises, ensuring that the expected grade and high-quality mangoes reach the consumer.
 302 By accurately identifying substandard mangoes, the system helps in reducing waste and
 303 ensuring that only marketable fruits are processed further.

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

310 **1.5.1 Technical Benefit**

- 311 1. The development of an automated Carabao mango sorter would increase the quality
 312 control of classifying Carabao mango based on ripeness, size, and bruising.
- 313 2. The accuracy in sorting Carabao mangoes will be significantly improved while
 314 reducing the errors due to human factors in manual sorting.
- 315 3. The automated Carabao mango sorter carefully sorts the mangoes while ensuring
 316 that they remain free from bruising or further damage during the process



317 **1.5.2 Social Impact**

- 318 1. The reduction in manual labor creates opportunities in maintenance and technologies
319 in the automated Carabao mango sorter.
- 320 2. The automated Carabao mango sorter system improves Carabao mango standards
321 and enhances the satisfaction of the buyers and the customers through guaranteeing
322 consistent Carabao mango grade.
- 323 3. Opportunity to increase sales and profit for the farmers through consistent quality
324 and grade Carabao mangoes while reducing the physical labor to sort it.

325 **1.5.3 Environmental Welfare**

- 326 1. With the utilization of non-destruction methods of classifying Carabao mangoes
327 together with an accurate sorting system, overall waste from Carabao mangoes is
328 reduced and the likelihood of improperly sorted mangoes is decreased.
- 329 2. Automation of sorting and grading Carabao mangoes promotes sustainable farming
330 practices.

331 **1.6 Assumptions, Scope, and Delimitations**

332 **1.6.1 Assumptions**

- 333 1. The Carabao mangoes are from the same source together with the same variation
- 334 2. The Carabao mangoes do not have any fruit borer and diseases



- 335 3. All the components do not have any form of defects
- 336 4. The prototype would have access to constant electricity/power source.
- 337 5. The Carabao mangoes to be tested would be in the post-harvesting stage and in the
- 338 grading stage.
- 339 6. The image-capturing system would only capture the two sides of the mango which
- 340 are the two largest surface areas of the skin.

341 **1.6.2 Scope**

- 342 1. The prototype would be specifically designed to grade and sort Carabao Mangoes
- 343 based on only ripeness, size, and visible skin bruises.
- 344 2. The mangoes used as the subject will be solely sourced from markets in the Philip-
- 345 pines.
- 346 3. The Carabao mangoes would be graded into three levels.
- 347 4. The prototype will be using a microcontroller-based system locally stored on the
- 348 device itself to handle user interaction.
- 349 5. Computer vision algorithms to be used will include image classification.

350 **1.6.3 Delimitations**

- 351 1. The project would only be able to perform sorting and grading on one specific fruit
- 352 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 Estimated Work Schedule and Budget

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

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 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.

1.8 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. Chapter 3 involves the theoretical considerations of the thesis topic while chapter 4 would consist of the design consideration involving the thesis topic. Chapter 5 would involve the research methodology containing the testing procedure and setup. Chapter 6 would involve the results and discussion based on the methodology while Chapter 7 would involve the conclusion, recommendations, and future suggestions.



De La Salle University

386

Chapter 2

387

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



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

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



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



524

Chapter 3

525

THEORETICAL CONSIDERATIONS



3.1 Introduction

Likewise, the purpose of this chapter is to go through the important theories in developing the prototype together with training and testing the machine learning model.

3.2 Relevant Theories and Models

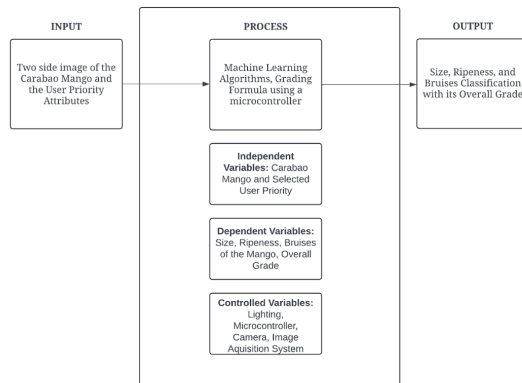


Fig. 3.1 Theoretical Framework Diagram.

The theoretical framework seen in figure x revolves around the concepts that revolve around the research topic. Embedded systems include the Raspberry Pi, which is the microcontroller that will be the brain of the system, DC motors, 4 channel relays, and the conveyor belt. The machine learning portion includes a neural network model, namely the Convolutional Neural Network, which will use computer vision as a method of seeing and classifying the mangoes based on their physical traits. The image processing will include methods such as size calculation and background removal using OpenCV. Lastly, the Carabao mango will be the test subject of the system.



3.3 Technical Background

At its core, the system will be using machine learning concepts pertaining to CNN and OpenCV, and may use other algorithms such as Naive Bayes and k-Nearest Neighbors to supplement the classification tasks, particularly for assessing mango ripeness, bruise detection, and size determination. The system will be built on an embedded framework, integrating a Raspberry Pi microcontroller to control the RaspberryPi camera, actuators, LED lights, and motors. A user-friendly GUI will also be utilized to ensure users can customize the prioritization of the mango sorting system.

3.4 Conceptual Framework Background

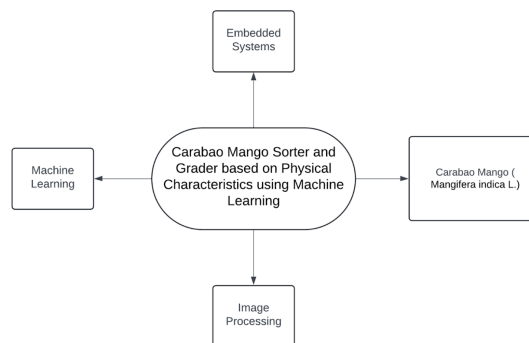


Fig. 3.2 Conceptual Framework Diagram.

3.5 Summary

Overall, chapter 3 establishes key concepts and theoretical considerations that form the foundation of the Carabao mango sorter and grading system. It discusses and connects



550 each component together, explaining how each component such as the RaspberryPi and
551 DC motors work together to create a system that utilizes machine learning and computer
552 vision techniques to classify mangoes based on user priority.



553

Chapter 4

554

DESIGN CONSIDERATIONS



Likewise, the objective of chapter 4 is to describe the researcher's design consideration when developing and testing the prototype. For an overview of the design of the prototype, the researchers considered different computer vision models in classifying the ripeness and bruises together with other algorithms to determine the size of the mango. Likewise, the hardware design was also taken into consideration where the physical design of the conveyor belt was taken into account.

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.

4.2 System Architecture

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



4.3 Hardware Considerations

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

4.4 Software Considerations

The software stack includes Python for programming, TensorFlow or PyTorch for machine learning, and OpenCV for image processing. These tools are selected for their robustness, 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.

4.9 Technical Standards

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

4.10 Prototyping and Simulation

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



605 4.11 Design Validation

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

609 4.12 Summary

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



De La Salle University

613

Chapter 5

614

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"> 1. Hardware design: Build an image acquisition system with a conveyor belt, LED lights, and Raspberry Pi Camera 2. Software design: Coded a Raspberry Pi application to grade and sort the Carabao mangoes 	Sec. 5.2 on p. 35
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	<ol style="list-style-type: none"> 1. Hardware implementation: Design and build an image acquisition system prototype 	Sec. 5.3 on p. 35
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"> 1. Performance testing: Train and test the machine learning algorithm for classifying bruises and ripeness 2. Data collection: Gather our own Carabao mango dataset together with an online dataset 	Sec. 5.5 on p. 37

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"> 1. Algorithm development: To develop a code for the image acquisition system 2. Hardware design: To design a schematic for the microcontroller based system 	Sec. 5.3 on p. 35
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	<ol style="list-style-type: none"> 1. Formula development: Formulated an equation based on the inputted user priority and the predicted mango classification 	Sec. 5.7 on p. 39
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"> 1. Performance testing: Train and test the machine learning algorithm for classifying bruises 	Sec. 5.6.2 on p. 39
SO6: To classify mango size based on image data by getting its length and width using OpenCV, geometry, and image processing techniques.	<ol style="list-style-type: none"> 1. Performance testing: Train and test the machine learning algorithm for classifying ripeness 	Sec. 5.6.1 on p. 39
SO7: To classify mango bruises based on image data by employing machine learning algorithms.	<ol style="list-style-type: none"> 1. Accuracy testing: Get the percent accuracy testing for getting the length and width of the Carabao mango 	Sec. 5.6.3 on p. 39



615

5.1 Introduction

616

617

618

619

620

621

622

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

623

5.2 Research Approach

624

625

626

627

628

629

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

630

5.3 Hardware Design

631

632

633

634

The prototype consists of hardware and software components for automated mango sorting and grading purposes. The hardware includes the conveyor belt system used to transfer mangoes from scanning to sorting smoothly. A camera and lighting system are able to collect high-resolution images for analysis. The DC motors and stepper motors are



635 responsible for driving the conveyor belt and sorting actuators. The entire system is
636 controlled by a microcontroller (Raspberry Pi 4b), coordinating actions of all components.
637 Sorting actuators then direct mangoes into selected bins based on their classification to
638 make sorting efficient.

639 **5.4 Software Design**

640 For the programming language used for the prototype and training and testing the CNN
641 model, Python was used for training and testing the CNN model and it was also used in the
642 microcontroller to run the application containing the UI and CNN model. PyTorch was the
643 main library used in using the EfficientNet model that is used in classifying the ripeness
644 and bruises of the mango. Likewise, tkinter is the used library when designing the UI in
645 Python.

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



5.5 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 flipping, rotating, resizing, normalization, and Gaussian blur 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. 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.

5.6 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.



$$\text{Precision} = \frac{TP}{TP + FP} \quad (5.1)$$

$$\text{Recall} = \frac{TP}{TP + FN} \quad (5.2)$$

675 To test system performance, various measures of performance are used to evaluate.
 676 As seen on equation 5.4, accuracy is used to measure the percentage of correctly clas-
 677 sified mangoes to ensure the system maintains high precision levels. Precision as seen
 678 on equation 5.1 and recall as seen on equation 5.2 are used to measure consistency of
 679 classification to determine if the system classifies different ripeness levels and defects
 680 correctly. Furthermore, the F1 score formula as seen on equation 5.3 is used to evaluate the
 681 performance of the model's classification.

$$F_1 = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \quad (5.3)$$

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \quad (5.4)$$

682 A confusion matrix is used to measure correct and incorrect classification to ensure the
 683 machine learning model is optimized and that minimum errors are achieved. Throughput
 684 analysis is also used to determine the rate and efficiency of sorting to ensure that the
 685 system maintains high capacity without bottlenecks to sort mangoes. Using these methods
 686 of testing, the system is constantly optimized to ensure high-quality and reliable mango
 687 classification.



688 **5.6.1 Ripeness Training and Testing**

689 **5.6.2 Bruises Training and Testing**

690 **5.6.3 Size Determination**

691 **5.7 Formula for User Priority**

692 **5.8 Ethical Considerations**

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

702 **5.9 Summary**

703 This chapter explained how to create an automatic Carabao mango sorter and grader using
 704 machine learning and computer vision. The system integrates hardware and software
 705 resources, including a conveyor belt, cameras, sensors, and actuators, to offer accurate,
 706 real-time sorting by ripeness, size, and bruises. Various testing and evaluation processes



707 ensure its performance to offer reliability. Ethical issues are data privacy, environmental
708 sustainability, and operation safety. With enhanced efficiency, reduced human error, and
709 enhanced quality, this system provides an affordable, scalable, and non-destructive solution
710 to post-harvest mango classification in agricultural industries.



711

Chapter 6

712

RESULTS AND DISCUSSIONS



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

722 The next items below is not related to the description of this results and discussions
 723 chapter, but serves as an opener for the L^AT_EX portion of this template.

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

TABLE 6.1 SUMMARY OF METHODS FOR ACHIEVING THE OBJECTIVES

Objectives	Methods	Locations
------------	---------	-----------

Continued on next page



Continued from previous page

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.	<p>Expected Results:</p> <ol style="list-style-type: none"> 1. Successfully developed a user-priority-based grading and sorting system using machine learning and computer vision which can assess the mangoes' ripeness, size and bruises. <p>Actual Results:</p> <ol style="list-style-type: none"> 1. More work needs to be done to fine tune the software components to achieve higher accuracy such as changing hyperparameters or using a newer version of EfficientNet 2. More work needs to be done to make the hardware component more robust such as by fixing the camera and LED lights in place 	Sec. ?? on p. ??
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	<p>Expected Results:</p> <ol style="list-style-type: none"> 1. Successfully integrated a conveyor belt with the image acquisition in order to achieve efficient flow of automated sorting and grading of the mangoes. 2. Successfully integrated LED strips to provide optimal lighting for image capturing of the mangoes. 3. Successfully fixed the hardware components in place <p>Actual Results:</p> <ol style="list-style-type: none"> 1. Successfully integrated a conveyor belt with the image acquisition in order to achieve efficient flow of automated sorting and grading of the mangoes. 2. Successfully integrated LED strips to provide optimal lighting for image capturing of the mangoes. 3. Need to fix the hardware components in place 	Sec. ?? on p. ??

Continued on next page



Continued from previous page

Objectives	Methods	Locations
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%.	<p>Expected Results:</p> <ol style="list-style-type: none"> 1. Successfully achieved at least 90 percent accuracy, precision, recall, f1 score for ripeness classification of Carabao mangoes 2. Successfully achieved at least 90 percent accuracy, precision, recall, f1 score for bruises classification of Carabao mangoes <p>Actual Results:</p> <ol style="list-style-type: none"> 1. Successfully achieved at least 93% accuracy for ripeness classification of Carabao mangoes 2. Successfully achieved at least 73% accuracy for bruise classification of Carabao Mangoes 	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.	<p>Expected Results:</p> <ol style="list-style-type: none"> 1. Successfully made a conveyor belt system to move the mangoes through the image acquisition system to the sorting system 2. Successfully mounted the image acquisition system on the the prototype 3. Successfully made the frame for the conveyor belt and image acquisition system to sit on <p>Actual Results:</p> <ol style="list-style-type: none"> 1. Successfully made a conveyor belt system to move the mangoes through the image acquisition system to the sorting system 2. Temporarily mounted the image acquisition system on the the prototype 3. Successfully made the frame for the conveyor belt and image acquisition system to sit on 	Sec. ?? on p. ??

Continued on next page



Continued from previous page

Objectives	Methods	Locations
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	<p>Expected Results:</p> <ol style="list-style-type: none"> 1. Successfully grade mangoes based on the user priorities on the physical characteristics of the mango 2. Successfully verified with qualified individual the results 3. Successfully utilize the weighted equation to evaluate mango grade based on user priorities <p>Actual Results:</p> <ol style="list-style-type: none"> 1. Successfully grade mangoes based on the user priorities on the physical characteristics of the mango 2. Successfully utilize the weighted equation to evaluate mango grade based on user priorities 3. Need to look for a qualified person to evaluate the graded mango for ground truth 	Sec. ?? on p. ??

Continued on next page



Continued from previous page

Objectives	Methods	Locations
SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes.	<p>Expected Results:</p> <ol style="list-style-type: none"> 1. Achieve at least 90% accuracy on performance metrics 2. Obtain performance metrics for kNN, k-mean, and Naive Bayes methods for comparison and show the superior performance of using CNN 3. Successfully fine tuned the CNN model to achieve the highest accuracy possible, choosing the best performing among Efficient-Net b0-b7, and testing other CNN hyperparameters <p>Actual Results:</p> <ol style="list-style-type: none"> 1. Successfully trained a CNN model using EfficientNet-b0 and Adam Optimizer to detect ripeness based on color 2. Successfully achieved at least 90 percent accuracy, precision, recall, f1 score for ripeness classification of Carabao mangoes 	Sec. ?? on p. ??
SO6: To classify mango size based on image data by getting its length and width using OpenCV, geometry, and image processing techniques.	<p>Expected Results:</p> <ol style="list-style-type: none"> 1. Successfully classified mango size using computer vision techniques 2. Successfully tuned to have an accurate size with an 80 percent accuracy rating <p>Actual Results:</p> <ol style="list-style-type: none"> 1. Successfully classified mango size using computer vision techniques 2. Calculation of mango size is somewhat inaccurate and needs more fine tuning 	Sec. ?? on p. ??

Continued on next page



Continued from previous page

Objectives	Methods	Locations
SO7: To classify mango bruises based on image data by employing machine learning algorithms.	<p>Expected Results:</p> <ol style="list-style-type: none"> 1. Achieve at least 90% accuracy on performance metrics 2. Successfully fine tuned the CNN model to achieve the highest accuracy possible, choosing the best performing among EfficientNet b0-b7, and testing other CNN hyperparameters <p>Actual Results:</p> <ol style="list-style-type: none"> 1. Successfully trained a CNN model using EfficientNet-b0 and Adam Optimizer to bruises 2. Successfully achieved at least 90 percent accuracy, precision, recall, f1 score for bruise classification of Carabao mangoes 	Sec. ?? on p. ??

6.1 Training and Testing Results of the Model

Add the f1-score and etc here

6.2 Physical Prototype

Add pictures of the hardware prototype here with description

6.3 Software Application

Show the raspberry pi app UI and demonstrate it here



732

6.4 Summary

733

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



734 **Chapter 7**

735 **CONCLUSIONS, RECOMMENDATIONS, AND**

736 **FUTURE DIRECTIVES**



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

The researchers recommend...

7.4 Future Prospects

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

7. Conclusions, Recommendations, and Future Directives



De La Salle University

754 1. the

755 2. the

756 3. the

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



REFERENCES

- Abbas, Q., Niazi, S., Iqbal, M., and Noureen, M. (2018). Mango Classification Using Texture & Shape Features. *IJCSNS International Journal of Computer Science and Network Security*, 18(8).
- Abu, M., Olympio, N. S., and Darko, J. O. (2021). Determination of Harvest Maturity for Mango (<i>Mangifera indica</i> L.) Fruit by Non-Destructive Criteria. *Agricultural Sciences*, 12(10):1103–1118.
- Adam, J. A. P., Dato, K. S., Impelido, M. C. D., Tobias, R. G., and Pilueta, N. U. (2022). Non-destructive microcontroller-based carabao mango ripeness grader.
- Alejandro, A. B., Gonzales, J. P., Yap, J. P. C., and Linsangan, N. B. (2018). Grading and sorting of Carabao mangoes using probabilistic neural network. page 020065, Bandung, Indonesia.
- Amna, M. W. A., Guiqiang, L., and Muhammad Zuhaib AKRAM, M. F. (2023). Machine vision-based automatic fruit quality detection and grading. *Frontiers of Agricultural Science and Engineering*, 0(0):0.
- Britannica (n.d.). Mango history cultivation and facts.
- Centino, M. F., Castano, M. C. N., and Ebo, J. B. F. (2020). The Current Status of Philippine Mango in the Global Value Chain.
- Chakraborty, S. K., Subeesh, A., Dubey, K., Jat, D., Chandel, N. S., Potdar, R., Rao, N. G., and Kumar, D. (2023). Development of an optimally designed real time automatic citrus fruit grading-sorting machine leveraging computer vision-based adaptive deep learning model. *Engineering Applications of Artificial Intelligence*, 120:105826.
- Co., Z. F. I. (n.d.). What is fruit sorting.
- D’Adamo, G. (2018). The determinants of export quality in the euro area. *Quarterly Report on the Euro Area (QREA)*, 17(1):23–31. Publisher: Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.
- DBpedia (n.d.). About: Carabao.
- Guillergan, G., Sabay, R., Madrigal, D., and Bual, J. (2024). Naive Bayes Classifier in Grading Carabao Mangoes. *Technium: Romanian Journal of Applied Sciences and Technology*, 22:14–32.
- Guillermo, M. C. S., Naciongayo, D. S., and Galela, M. G. C. (2019). Determining ‘Carabao’ Mango Ripeness Stages Using Three Image Processing Algorithms.
- Lacap, A., Bayogan, E. R., Secretaria, L., Joyce, D., Ekman, J., and Goldwater, A. (2021). Bruise Injury and Its Effect on ‘Carabao’ Mango Fruit Quality. *Philippine Journal of Science*, 150(6B).
- Patel, K. K., Khan, M. A., Kumar, Y., and Yadav, A. K. (2019). Novel Techniques in Post Harvest Management of Mango- An Overview. *South Asian Journal of Food Technology and Environment*, 05(02):821–835.



- 794 Rizwan Iqbal, H. M. and Hakim, A. (2022). Classification and Grading of Harvested Mangoes
795 Using Convolutional Neural Network. *International Journal of Fruit Science*, 22(1):95–109.
- 796 Samaniego, L. A., De Jesus, L. C. M., Apostol, J. D., Betonio, D. C., Medalla, J. D. B., Peruda Jr,
797 S. R., Brucal, S. G. E., and Yong, E. D. (2023). Carabao mango export quality checker using
798 matlab image processing. *International Journal of Computing Sciences Research*, 7:2080–2094.
- 799 Schulze, K., Nagle, M., Spreer, W., Mahayothee, B., and Müller, J. (2015). Development and
800 assessment of different modeling approaches for size-mass estimation of mango fruits (*Mangifera*
801 *indica* L., cv. ‘Nam Dokmai’). *Computers and Electronics in Agriculture*, 114:269–276.
- 802 Supekar, A. D. and Wakode, M. (2020). Multi-Parameter Based Mango Grading Using Image
803 Processing and Machine Learning Techniques. *INFOCOMP Journal of Computer Science*,
804 19(2):175–187. Number: 2.
- 805 Tomas, M. C., Celino, J. P. L., Escalambre, I. E., and Secreto, B. P. (2022). Detection of Overall
806 Fruit Maturity of Local Fruits Using Support Vector Machine through Image Processing. In *2022*
807 *12th International Conference on Software Technology and Engineering (ICSTE)*, pages 96–102.
- 808 Veling, P. S. (2019). Mango Disease Detection by using Image Processing. *International Journal*
809 *for Research in Applied Science and Engineering Technology*, 7(4):3717–3726.
- 810 Zheng, B. and Huang, T. (2021). Mango Grading System Based on Optimized Convolutional Neural
811 Network. *Mathematical Problems in Engineering*, 2021:1–11.



De La Salle University

813

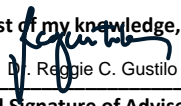
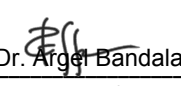
814

Appendix A

STUDENT RESEARCH ETHICS CLEARANCE



815

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)	
<p>To the best of my knowledge, the ethical issues listed above have been addressed in the research.</p> <p> Dr. Reggie C. Gustilo</p>	
<p>Name and Signature of Adviser/Mentor:</p> <p>Date: February 5, 2025</p>	
<p>Noted by:</p> <p> Dr. Argen Bandala</p>	
<p>Name and Signature of the Department Chairperson:</p> <p>Date: February 6, 2025</p>	

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



De La Salle University

816

Appendix B

817

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.

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.

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

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.

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

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.



850 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
851 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

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

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

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

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

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



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

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.

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

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.

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

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.



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

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.

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

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.

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

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.



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

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.

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

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.

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

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.



979 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
980 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

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

992 **B7 Is/are there an/_ alternative way/s to get to the**
993 **same solution/s?**

994 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
995 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
996 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
997 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
998 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
999 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1000 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1001 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1002 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1003 **B7.1 Can you come up with illustrating examples, or even**
1004 **better, counterexamples to your proposed solution/s?**

1005 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1006 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1007 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1008 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1009 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1010 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue



1011 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 1012 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 1013 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1014 **B7.2 Is there an approximation that can arrive at essentially**
 1015 **the same proposed solution/s more easily?**

1016 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 1017 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 1018 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 1019 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 1020 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 1021 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 1022 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 1023 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 1024 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1025 **B8 If you were the examiner of your Thesis, how**
 1026 **would you present the Thesis in another way? Give**
 1027 **your remarks, especially for your methodology and**
 1028 **the results and discussions.**

1029 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 1030 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 1031 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 1032 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 1033 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 1034 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 1035 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 1036 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 1037 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1038 **B8.1 What are the weaknesses of your Thesis, specifically your**
 1039 **methodology and the results and discussions?**

1040 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 1041 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec



De La Salle University

1042 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1043 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1044 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1045 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1046 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1047 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1048 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



De La Salle University

1049

Appendix C

1050

REVISIONS TO THE PROPOSAL



1051

PRO1 Panel Comments and Revisions – Appendix Z

PRO1 Panel Comments and Revisions

Zoom Recording:

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 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



1052

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



1053

PRO1 Panel Comments and Revisions – Appendix Z

PRO1 Panel Comments and Revisions

Zoom Recording:

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



1054

PRO1 Panel Comments and Revisions – Appendix Z

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.



1055

PRO1 Panel Comments and Revisions – Appendix Z

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:

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

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.



De La Salle University

1056

Appendix D

1057

REVISIONS TO THE FINAL



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. Gustillo	1. First itemtext	1. First itemtext	Sec. ?? on p. ??, Sec. ?? on p. ??, Fig. ?? on p. ??
	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	

Continued on next page



Continued from previous page

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. ?? on p. ??, Sec. ?? on p. ??, 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. ?? on p. ??, Sec. ?? on p. ??, Fig. ?? on p. ??

Continued on next page

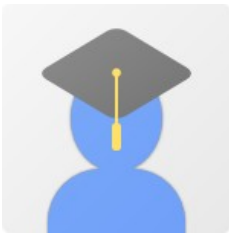


Continued from previous page

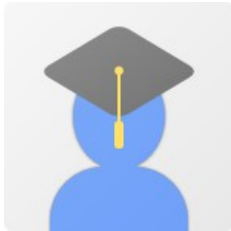
Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Alexander Co Abad	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. ?? on p. ??, Sec. ?? on p. ??, Fig. ?? 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. ?? on p. ??, Sec. ?? on p. ??, Fig. ?? on p. ??



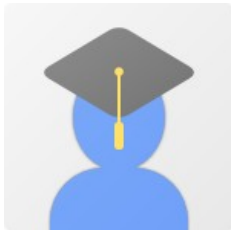
Appendix E VITA



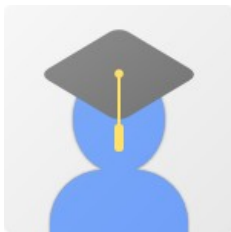
Kenan A. Banal is currently taking up his B.Sc. Computer Engineering studies. He is passionate about software and hardware systems such as Vivado, Arduino, C, and Python.



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.



De La Salle University

1078

Appendix F

1079

ARTICLE PAPER(S)

Article/Forum Paper Format (IEEE LaTeX format)

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

1080

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.

A. Subsection Heading Here

Subsection text 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

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.

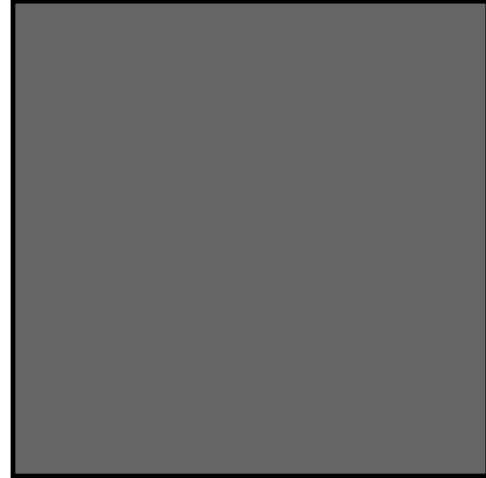


Fig. 1. Simulation results for the network.

TABLE I
AN EXAMPLE OF A TABLE

One	Two
Three	Four

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) Subsubsection Heading Here: Subsubsection text 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.

II. CONCLUSION

The conclusion goes here.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra

1081



(a) Case I



(b) Case II

Fig. 2. Simulation results for the network.

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.

APPENDIX A

PROOF OF THE FIRST ZONKLAR EQUATION

Appendix one text 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.

APPENDIX B

Appendix two text 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.

ACKNOWLEDGMENT

The authors would like to thank...