



1

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

4

---

5 A Thesis  
6 Presented to the Faculty of the  
7 Department of Electronics and Computer Engineering  
8 Gokongwei College of Engineering  
9 De La Salle University

10

---

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

14

---

15 by

16 BANAL Kenan A.  
17 BAUTISTA Francis Robert Miguel F.  
18 HERMOSURA Don Humphrey L.  
19 SALAZAR Daniel G.

20 March, 2025



21

## ORAL DEFENSE RECOMMENDATION SHEET

22

23

24

25

26

27

28

29

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.

30

31

32

33

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**.

34

35

36

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

37

March 30, 2025



38

## ABSTRACT

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

53  
54

*Index Terms*—Machine Learning, Carabao Mangoes, Sorting and Grading Mangoes, Ma-  
chine Vision, Microcontroller.



## TABLE OF CONTENTS

55	<b>Oral Defense Recommendation Sheet</b>	ii
56	<b>Abstract</b>	iii
57	<b>Table of Contents</b>	iv
58	<b>List of Figures</b>	viii
59	<b>List of Tables</b>	ix
60	<b>Abbreviations and Acronyms</b>	x
61	<b>Notations</b>	xi
62	<b>Glossary</b>	xii
63	<b>Listings</b>	xiv
64	<b>Chapter 1 INTRODUCTION</b>	1
65	1.1 Background of the Study . . . . .	2
66	1.2 Prior Studies . . . . .	4
67	1.3 Problem Statement . . . . .	5
68	1.4 Objectives and Deliverables . . . . .	6
69	1.4.1 General Objective (GO) . . . . .	6
70	1.4.2 Specific Objectives (SOs) . . . . .	7
71	1.4.3 Expected Deliverables . . . . .	7
72	1.5 Significance of the Study . . . . .	9
73	1.5.1 Technical Benefit . . . . .	10
74	1.5.2 Social Impact . . . . .	11
75	1.5.3 Environmental Welfare . . . . .	11
76	1.6 Assumptions, Scope, and Delimitations . . . . .	11
77	1.6.1 Assumptions . . . . .	11
78	1.6.2 Scope . . . . .	12
79	1.6.3 Delimitations . . . . .	12
80	1.7 Estimated Work Schedule and Budget . . . . .	13
81	1.8 Overview of the Thesis . . . . .	14



83	<b>Chapter 2 LITERATURE REVIEW</b>	<b>15</b>
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	<b>Chapter 3 THEORETICAL CONSIDERATIONS</b>	<b>23</b>
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 Software Concepts . . . . .	26
94	3.5.1 Thresholding . . . . .	26
95	3.5.2 Object Size Calculation . . . . .	26
96	3.5.3 Convolutional Neural Network . . . . .	26
97	3.5.4 Classification Report . . . . .	26
98	3.5.4.1 Confusion Matrix . . . . .	26
99	3.5.4.2 Precision . . . . .	27
100	3.5.4.3 Recall . . . . .	27
101	3.5.4.4 F1 Score . . . . .	27
102	3.5.4.5 Accuracy . . . . .	28
103	3.6 Hardware Concepts . . . . .	28
104	3.6.1 Camera Module . . . . .	28
105	3.6.2 4 Channel Relay . . . . .	28
106	3.6.3 1:3 Pulley Belt . . . . .	28
107	3.7 Summary . . . . .	28
108	<b>Chapter 4 DESIGN CONSIDERATIONS</b>	<b>29</b>
109	4.1 Introduction . . . . .	30
110	4.2 System Architecture . . . . .	30
111	4.3 Hardware Considerations . . . . .	31
112	4.3.1 General Prototype Framework . . . . .	31
113	4.3.2 Prototype Flowchart . . . . .	34
114	4.3.3 Prototype 3D Model . . . . .	34
115	4.3.4 Hardware Specifications . . . . .	34
116	4.3.4.1 Raspberry Pi . . . . .	34
117	4.3.4.2 Raspberry Pi Camera . . . . .	36
118	4.3.4.3 DC Motor . . . . .	37
119	4.3.4.4 MicroSD Card . . . . .	39
120	4.3.4.5 LED Lights . . . . .	40



121	4.3.4.6 Power Supply . . . . .	41
122	4.3.4.7 4 Channel Relay Module . . . . .	42
123	4.4 Software Considerations . . . . .	44
124	4.4.1 PyTorch . . . . .	44
125	4.4.2 OpenCV . . . . .	44
126	4.4.3 Tkinter . . . . .	44
127	4.4.4 CustomTkinter . . . . .	44
128	4.5 Security and Reliability Considerations . . . . .	44
129	4.6 Scalability and Efficiency Considerations . . . . .	45
130	4.7 User Interface . . . . .	45
131	4.8 Constraints and Limitations . . . . .	45
132	4.9 Technical Standards . . . . .	45
133	4.10 Prototyping and Simulation . . . . .	46
134	4.11 Design Validation . . . . .	46
135	4.12 Summary . . . . .	46
136	<b>Chapter 5 METHODOLOGY</b>	<b>47</b>
137	5.1 Introduction . . . . .	50
138	5.2 Research Approach . . . . .	50
139	5.3 Hardware Design . . . . .	50
140	5.4 Software Design . . . . .	51
141	5.5 Data Collection Methods . . . . .	52
142	5.6 Testing and Evaluation Methods . . . . .	52
143	5.6.1 Ripeness Training and Testing . . . . .	53
144	5.6.2 Bruises Training and Testing . . . . .	53
145	5.6.3 Size Determination . . . . .	53
146	5.7 Formula for User Priority . . . . .	53
147	5.8 Ethical Considerations . . . . .	53
148	5.9 Summary . . . . .	54
149	<b>Chapter 6 RESULTS AND DISCUSSIONS</b>	<b>55</b>
150	6.1 Training and Testing Results of the Model . . . . .	60
151	6.1.1 Ripeness Classification Results . . . . .	60
152	6.1.2 Bruises Classification Results . . . . .	61
153	6.2 Size Determination Results . . . . .	61
154	6.3 User Priority Formula . . . . .	61
155	6.4 Physical Prototype . . . . .	61
156	6.5 Software Application . . . . .	61
157	6.6 Summary . . . . .	61



158	<b>Chapter 7 CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIRECTIVES</b>	<b>62</b>
159	7.1 Concluding Remarks . . . . .	63
160	7.2 Contributions . . . . .	63
161	7.3 Recommendations . . . . .	63
162	7.4 Future Prospects . . . . .	63
164	<b>References</b>	<b>65</b>
165	<b>Appendix A STUDENT RESEARCH ETHICS CLEARANCE</b>	<b>67</b>
166	<b>Appendix B ANSWERS TO QUESTIONS TO THIS THESIS</b>	<b>69</b>
167	<b>Appendix C REVISIONS TO THE PROPOSAL</b>	<b>78</b>
168	<b>Appendix D REVISIONS TO THE FINAL</b>	<b>84</b>
169	<b>Appendix E VITA</b>	<b>88</b>
170	<b>Appendix F ARTICLE PAPER(S)</b>	<b>89</b>



171

## LIST OF FIGURES

172	1.1	Carabao Mangoes at Different Ripeness Stages (Guillermo et al., 2019) . . . . .	2
173	1.2	Gantt Chart . . . . .	13
174	3.1	Theoretical Framework Diagram. . . . .	24
175	3.2	Conceptual Framework Diagram. . . . .	25
176	4.1	Prototype Framework . . . . .	31
177	4.2	Prototype Main Flowchart . . . . .	32
178	4.3	Initial 3D Model of the Prototype . . . . .	33
179	4.4	Raspberry Pi 4 Model B . . . . .	34
180	4.5	Raspberry Pi Camera Module Version 2 . . . . .	36
181	4.6	12 Volt DC Gear Motor . . . . .	38
182	4.7	SanDisk Ultra MicroSD Card . . . . .	39
183	4.8	LED Light Strip . . . . .	40
184	4.9	Bench Power Supply . . . . .	41
185	4.10	4 Channel Relay Module . . . . .	43



186

## LIST OF TABLES

187	1.1 Expected Deliverables per Objective . . . . .	8
188	1.1 Expected Deliverables per Objective . . . . .	9
189	2.1 Comparison of Existing Studies . . . . .	18
190	2.2 Comparison of Sorting Algorithm Models . . . . .	21
191	3.1 Confusion Matrix Example . . . . .	26
192	5.1 Summary of methods for reaching the objectives . . . . .	48
193	6.1 Summary of methods for achieving the objectives . . . . .	56
194	D.1 Summary of Revisions to the Thesis . . . . .	85



## 195 ABBREVIATIONS

196	AC	Alternating Current .....	13
197	CNN	Convolution Neural Network .....	14
198	DC	Direct Current .....	24
199	GUI	Graphical User Interface .....	45
200	LED	Light Emitting Diode .....	40
201	UI	User Interface .....	45



202

## NOTATION

203	$B(P)$	Bruises Priority .....	61
204	$b(p)$	Bruises Prediction .....	61
205	$R(P)$	Ripeness Priority .....	61
206	$r(p)$	Ripeness Prediction .....	61
207	$S(P)$	Size Priority .....	61
208	$s(p)$	Size Prediction .....	61
209	$D(p, d, f)$	Real World Dimension .....	26
210	$p$	Pixel Dimension .....	26
211	$d$	Distance from Camera to Object .....	26
212	$f$	Focal Length .....	26



## GLOSSARY

213		
214	accuracy score	A performance metric that measures the overall proportion of correct predictions made by a machine learning model.
215	bruises	The black or brown area of the mango that is visible on the skin of the mango.
216	Carabao mango	A popular variety of mango grown in the Philippines, known for its sweet and juicy flesh.
217	CNN	A type of deep neural network that is highly effective in analyzing and processing visual data, such as images.
218	computer vision	The use of cameras and algorithms to provide imaging-based inspection and analysis.
219	confusion matrix	A table that summarizes the performance of a classification model, showing the number of true positives, true negatives, false positives, and false negatives.
220	F1-Score	A balanced performance metric that is the harmonic mean of precision and recall, taking both into account.
221	machine learning	A subset of Artificial Intelligence that enables systems to learn and improve from data.
222	microcontroller	A small computing device that controls other parts of a system such as sensors.
223	Precision	A performance metric that reflects the percentage of instances classified as positive that are truly positive.
224	recall	A performance metric that measures the proportion of actual positive instances that the model correctly identified.



# De La Salle University

225

User Priority-Based Grading

A customizable grading system where users can assign weights to grading factors.



De La Salle University

226

## LISTINGS



De La Salle University

227

## **Chapter 1**

228

# **INTRODUCTION**



## 229      **1.1 Background of the Study**

230      Mangoes, also known as the *Mangifera indica*, are a member of the cashew family. This  
231      fruit can often be seen being farmed by countries such as Myanmar, the Philippines, and  
232      India as they have a tropical dry season. Being in a tropical country is an important  
233      aspect for mango cultivation as it ensures proper growth for mangoes. If aspects such as  
234      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)

235  
236      It is known for its sweet signature taste that was recognized sweetest in the world in the  
237      Guinness Book of World Records in 1995. The mango was named after the national animal  
238      of the Philippines, a native breed of buffalo. On average, it is 12.5 cm in length and 8.5  
239      cm in diameter, having a bright yellow color when ripe as seen in Figure 1.1. It is often  
240      cultivated during late May to early July (DBpedia, nd).

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



# De La Salle University

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

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

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

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



269 the MaZda package is the B11 program, which uses Principal Component Analysis, Linear  
270 Discriminant Analysis, Nonlinear Discriminant Analysis, and texture classification to  
271 extract features from the mango, which in this case are the length, width, and texture. This  
272 data is then compared to a database in order to classify any given mango (Abbas et al.,  
273 2018).

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

## 284 1.2 Prior Studies

285 A paper written by Amna et al. (2023), designed an automated fruit sorting machine based  
286 on the quality through an image acquisition system and CNN. Furthermore, the results  
287 of the paper show that the image processing detection score was 89% while that of the  
288 tomatoes was 92% while the CNN model had higher validity of 95% for mangoes and  
289 93% for tomatoes. 15%, while the percentage of distinction between the two groups was  
290 reported to be 5% respectively (Amna et al., 2023). Despite the high accuracy score in



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

293 Furthermore, the research paper presented by Guillergan et al. (2024) designed an  
294 Automated Carabao mango classifier, in which the mango image database is used to extract  
295 the features like size, area along with the ratio of the spots for grading using Naïve Bayes  
296 Model. For the results, the Naïve Bayes' model recognized large and rejected mangoes with  
297 95% accuracy and the large and small/medium difference with a 7% error, suggesting an  
298 application for quality differentiation and sorting in the mango business industry. Despite  
299 the high accuracy of classifying Carabao mangoes, the researchers used a high quality  
300 DSLR camera for the image acquisition system without any microcontroller to control the  
301 mangoes (Guillergan et al., 2024).

### 302 **1.3 Problem Statement**

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



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

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

## 326 **1.4 Objectives and Deliverables**

### 327 **1.4.1 General Objective (GO)**

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



### 331      **1.4.2 Specific Objectives (SOs)**

- 332      • SO1: To make an image acquisition system with a conveyor belt for automatic sorting  
333      and grading mangoes. ;
- 334      • SO2: To get the precision, recall, F1 score, confusion matrix, and train and test  
335      accuracy metrics for classifying the ripeness and bruises with an accuracy score of at  
336      least 90%.;
- 337      • SO3: To create a microcontroller-based system to operate the image acquisition  
338      system, control the conveyor belt, and process the mango images through machine  
339      learning. ;
- 340      • SO4: To grade mangoes based on user priorities for size, ripeness, and bruises. ;
- 341      • SO5: To classify mango ripeness based on image data using machine learning  
342      algorithms such as kNN, k-mean, and Naïve Bayes. ;
- 343      • SO6: To classify mango size based on image data by getting its length and width  
344      using OpenCV, geometry, and image processing techniques. ;
- 345      • SO7: To classify mango bruises based on image data by employing machine learning  
346      algorithms.

### 347      **1.4.3 Expected Deliverables**

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



TABLE 1.1 EXPECTED DELIVERABLES PER OBJECTIVE

Objectives	Expected Deliverables
GO: To develop a user-priority-based grading and sorting system for Carabao mangoes, using machine learning and computer vision techniques to assess ripeness, size, and bruises.	<ul style="list-style-type: none"> <li>• To develop a Carabao mango grading and sorting system.</li> <li>• To grade Carabao mangoes into three categories based on ripeness, size, and bruises using machine learning.</li> <li>• To integrate sensors and actuators to control the conveyor belt and image acquisition system.</li> </ul>
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	<ul style="list-style-type: none"> <li>• To make an image acquisition system with a camera and LED light source.</li> <li>• To build a flat belt conveyor for moving the mangoes.</li> </ul>
SO2: To get the precision, recall, F1 score, confusion matrix, and train and test accuracy metrics for classifying the ripeness and bruises with an accuracy score of at least 90%.	<ul style="list-style-type: none"> <li>• To use a publicly available dataset of at least 10,000 mango images for classification of ripeness and bruises.</li> </ul>
SO3: To create a microcontroller-based system to operate the image acquisition system, control the conveyor belt, and process the mango images through machine learning.	<ul style="list-style-type: none"> <li>• To develop an intuitive UI where users can start and stop the system.</li> <li>• To implement a priority-based grading system with sliders for ripeness, bruises, and size.</li> </ul>
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	<ul style="list-style-type: none"> <li>• To utilize a linear combination formula as the overall mango score, where each classification level contributes a grade, weighted by the priority assigned to the three properties.</li> <li>• To assign score values for each classification level of the mango.</li> </ul>

*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"> <li>To train a machine learning model such as kNN, k-means, or Naïve Bayes capable of classifying mango ripeness based on the image color.</li> <li>To gather a dataset of annotated images with ripeness labels.</li> <li>To obtain an evaluation report of performance metrics of the model.</li> </ul>
SO6: To classify mango size based on image data by getting its length and width using OpenCV, geometry, and image processing techniques.	<ul style="list-style-type: none"> <li>To develop an image processing algorithm capable of determining mango size using OpenCV, NumPy, and imutils.</li> <li>To classify mangoes based on size into small, medium, and large based on measurements.</li> </ul>
SO7: To classify mango bruises based on image data by employing machine learning algorithms.	<ul style="list-style-type: none"> <li>To train a machine learning model such as CNN capable of distinguishing bruised and non-bruised mangoes.</li> <li>To train a machine learning model such as kNN, k-means, and Naïve Bayes capable of assessing the extent of bruising on the mangoes if it is significant or partial.</li> <li>To gather a dataset of annotated images based on bruises.</li> <li>To obtain an evaluation report of performance metrics of both CNN and other machine learning models.</li> </ul>

350

## 1.5 Significance of the Study

351

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.

352

353

354



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

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

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

### 370 **1.5.1 Technical Benefit**

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



- 377 **1.5.2 Social Impact**
- 378 1. The reduction in manual labor creates opportunities in maintenance and technologies  
379 in the automated Carabao mango sorter.
- 380 2. The automated Carabao mango sorter system improves Carabao mango standards  
381 and enhances the satisfaction of the buyers and the customers through guaranteeing  
382 consistent Carabao mango grade.
- 383 3. Opportunity to increase sales and profit for the farmers through consistent quality  
384 and grade Carabao mangoes while reducing the physical labor to sort it.
- 385 **1.5.3 Environmental Welfare**
- 386 1. With the utilization of non-destruction methods of classifying Carabao mangoes  
387 together with an accurate sorting system, overall waste from Carabao mangoes is  
388 reduced and the likelihood of improperly sorted mangoes is decreased.
- 389 2. Automation of sorting and grading Carabao mangoes promotes sustainable farming  
390 practices.
- 391 **1.6 Assumptions, Scope, and Delimitations**
- 392 **1.6.1 Assumptions**
- 393 1. The Carabao mangoes are from the same source together with the same variation
- 394 2. The Carabao mangoes do not have any fruit borer and diseases



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

401        **1.6.2 Scope**

- 402        1. The prototype would be specifically designed to grade and sort Carabao Mangoes  
403              based on only ripeness, size, and visible skin bruises.
- 404        2. The mangoes used as the subject will be solely sourced from markets in the Philip-  
405              pines.
- 406        3. The Carabao mangoes would be graded into three levels.
- 407        4. The prototype will be using a microcontroller-based system locally stored on the  
408              device itself to handle user interaction.
- 409        5. Computer vision algorithms to be used will include image classification.

410        **1.6.3 Delimitations**

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



- 413      2. Additionally, the project prototype will only be able to capture, sort, and grade one  
 414      mango subject at a time which means the mangoes have to be placed in the conveyor  
 415      belt in a single file line for accurate sorting.
- 416      3. For the bruises, the system will only be able to detect external bruises and may not  
 417      identify the non-visible and internal bruises.
- 418      4. The system does not load the mangoes onto the conveyor belt itself. Assistance is  
 419      required to put mangoes into the conveyor belt to start the sorting process
- 420      5. The prototype will be powered using Alternating Current (AC) power and will be  
 421      plugged into a wall socket which is only suitable for indoor use.

## 422      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				HERMOSURA AND SALAZAR							
Buying and Collecting of Materials					BANAL AND BAUTISTA							
Training and Testing the CNN model						HERMOSURA AND SALAZAR						
Integrating the sensors and actuators to the Arduino Uno						BANAL AND BAUTISTA						
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 Surviving of the System with the Carabao Mangoes							BANAL, BAUTISTA, HERMOSURA, SALAZAR					
Data Gathering								BANAL, BAUTISTA, HERMOSURA, SALAZAR				

Fig. 1.2 Gantt Chart

423      As seen above, Table 1.2 shows the Gantt Chart together with the assigned task. For  
 424      the first part of the THSCP4A, the group would primarily revise and fine tune Chapters  
 425      1 and 2 while also preparing for the defense. After that for THSCP4B, the yellow team  
 426      which consists of two members, Hermosura and Salazar, would start buying and collecting



427 the materials needed for assembling the prototype. While team yellow is doing that,  
428 team purple which consists of Banal and Baustista would start training and validating the  
429 Convolution Neural Network (cnn) model based on the Carabao mango image dataset.  
430 After that integration of the sensors and actuators together with the integration of the cnn  
431 model and beginning of coding of the Application to the Raspberry Pi would be done. Once  
432 that cnn model is deployed and the Application works testing of the Carabao mangoes to  
433 the prototype would be done. During THSCP4C, data gathering would be done together  
434 with polishing and revising of the final paper.

## 435 **1.8 Overview of the Thesis**

436 There are seven succeeding chapters. To recall, chapter 1 involves the introduction of  
437 the thesis topic containing the background of the study, previous studies, objectives and  
438 deliverables, assumptions, scope, and delimitation, significance of the study, description  
439 of the project together with the methodology, and Gantt chart and budget. Chapter 2  
440 involves the existing articles, the lacking in their approaches, and the summary of chapter 2.  
441 Chapter 3 involves the theoretical considerations of the thesis topic while chapter 4 would  
442 consist of the design consideration involving the thesis topic. Chapter 5 would involve the  
443 research methodology containing the testing procedure and setup. Chapter 6 would involve  
444 the results and discussion based on the methodology while Chapter 7 would involve the  
445 conclusion, recommendations, and future suggestions.



De La Salle University

446

## Chapter 2

447

## LITERATURE REVIEW



## 448 2.1 Existing Work

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

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



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

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



# De La Salle University

495 heat units, rainfall, and physical fruit attributes for Haden, Kent, Palmer, and Keitt mango  
 496 varieties to establish export and domestic market maturity standards. For the results of  
 497 the paper, it shows that temperature, rainfall, and physical characteristics have a reliable,  
 498 non-destructive indicators for determining mango maturity (Abu et al., 2021). This shows  
 499 that physical characteristics and temperature are important when exporting fruits such as  
 500 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%

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



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

### 512 **2.1.1 Sorting Algorithms**

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

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



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

## 549 **2.2 Lacking in the Approaches**

550 The majority of past researchers such as Amna et al. (2023) and Guillermo et al. (2019)  
551 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

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

## 558 2.3 Summary

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



563 On the other hand, although researchers have already taken steps to automate the process  
564 of mango sorting and grading, there is still a need for an implementation that takes into  
565 account size, ripeness, and bruises altogether whilst being non-destructive and having its  
566 own embedded system. The research articles shown above show the different computer  
567 vision and CNN approaches for sorting and classifying mangoes. For example, a system  
568 created by Adam et al. (2022) was more focused on ripeness detection. Samaniego et al.  
569 (2023) considered photonic systems for grading mango fruit based on color and weight.  
570 On the other hand, Guillermo et al. (2019) implemented the Naïve Bayes classification  
571 model on mangoes with high accuracy, which thereby did not include any microcontroller.  
572 There was an attempt to study each of those parameters separately and that is why the  
573 multifactorial approach was not used. With this in mind, the system being proposed does  
574 exactly what was mentioned, to implement a non-destructive and automated sorting and  
575 grading system for Carabao mangoes that takes into account size, ripeness, and bruises  
576 altogether using machine learning, as well as having its own embedded system. This system  
577 will be mainly composed of a conveyor belt, servo motors, a camera, microcontrollers, and  
578 an LCD display for the user interface. By doing so, the system should be able to improve  
579 the efficiency and productivity of mango sorting and grading, remove the effect of human  
580 error and reduce time consumption. The studies also provided critical insights regarding the  
581 effective algorithms that can be used in classification stages in image processing. The use  
582 of CNN had the most accuracy with manageable potential challenges. Lastly, by scaling  
583 the implementation, the overall export quality of the Carabao mangoes can be improved.



584

## Chapter 3

585

# THEORETICAL CONSIDERATIONS



### 586    3.1 Introduction

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

### 589    3.2 Relevant Theories and Models

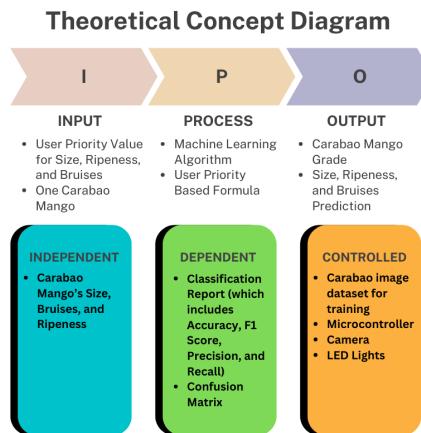


Fig. 3.1 Theoretical Framework Diagram.

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



### 598    3.3 Technical Background

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

### 606    3.4 Conceptual Framework Background

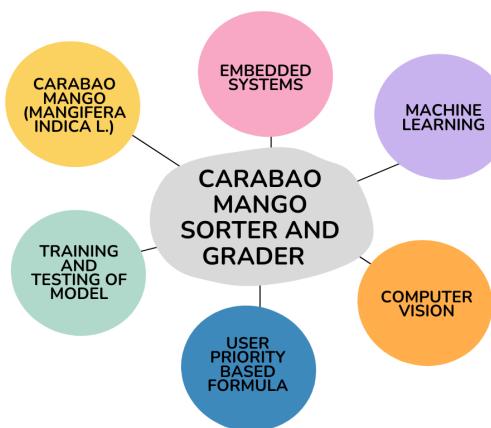


Fig. 3.2 Conceptual Framework Diagram.



## 607    3.5 Software Concepts

### 608    3.5.1 Thresholding

### 609    3.5.2 Object Size Calculation

610    The size of the mango can be determined given:

$$\text{Real World Dimension} = \frac{\text{Pixel Dimension} \times \text{Distance from Camera to Object}}{\text{Focal Length}} \quad (3.1)$$

$$D(p, d, f) = \frac{p \cdot d}{f} \quad (3.2)$$

611    where  $D(p, d, f)$  is the real world dimension of the object,  $p$  is the pixel dimension  
 612    of the object,  $d$  is the distance from the camera to the object, and  $f$  is the focal length of  
 613    the camera.

### 614    3.5.3 Convolutional Neural Network

### 615    3.5.4 Classification Report

#### 616    3.5.4.1 Confusion Matrix

	Predicted Positive	Predicted Negative
Actual Positive	TP	FN
Actual Negative	FP	TN

TABLE 3.1 CONFUSION MATRIX EXAMPLE

617    A confusion matrix is a table that visualizes the performance of a classification model.

618    For a binary classification problem, it has four components:



- 619     • True Positives (TP): Cases correctly predicted as positive
- 620     • True Negatives (TN): Cases correctly predicted as negative
- 621     • False Positives (FP): Cases incorrectly predicted as positive. (Type I error)
- 622     • False Negatives (FN): Cases incorrectly predicted as negative (Type II error)

623     **3.5.4.2 Precision**

$$\text{Precision} = \frac{TP}{TP + FP} \quad (3.3)$$

624     Precision measures how many of the predicted positives are actually positive. It answers  
 625     the question: "When the model predicts the positive class, how often is it correct?" High  
 626     precision means low false positives.

627     **3.5.4.3 Recall**

$$\text{Recall} = \frac{TP}{TP + FN} \quad (3.4)$$

628     Recall, which is also called sensitivity, measures how many of the actual positives were  
 629     correctly identified. It answers the question: "Of all the actual positive cases, how many  
 630     did the model catch?" High recall means low false negatives.

631     **3.5.4.4 F1 Score**

$$F_1 = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \quad (3.5)$$

632     The F1 score is the harmonic mean of precision and recall. It provides a single metric  
 633     that balances both concerns. This is particularly useful when you need to find a balance  
 634     between precision and recall, as optimizing for one often decreases the other.

635     **3.5.4.5 Accuracy**

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \quad (3.6)$$

636     Accuracy measures the proportion of correct predictions (both true positives and true  
637     negatives) among the total cases. While intuitive, accuracy can be misleading with imbal-  
638     anced datasets.

639     

## 3.6 Hardware Concepts

640     

### 3.6.1 Camera Module

641     

### 3.6.2 4 Channel Relay

642     

### 3.6.3 1:3 Pulley Belt

643     

## 3.7 Summary

644     Overall, chapter 3 establishes key concepts and theoretical considerations that form the  
645     foundation of the Carabao mango sorter and grading system. It discusses and connects  
646     each component together, explaining how each component such as the RaspberryPi and  
647     DC motors work together to create a system that utilizes machine learning and computer  
648     vision techniques to classify mangoes based on user priority.



649

## Chapter 4

650

# DESIGN CONSIDERATIONS



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

## 657 **4.1 Introduction**

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

## 662 **4.2 System Architecture**

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



## 669      4.3 Hardware Considerations

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

### 674      4.3.1 General Prototype Framework

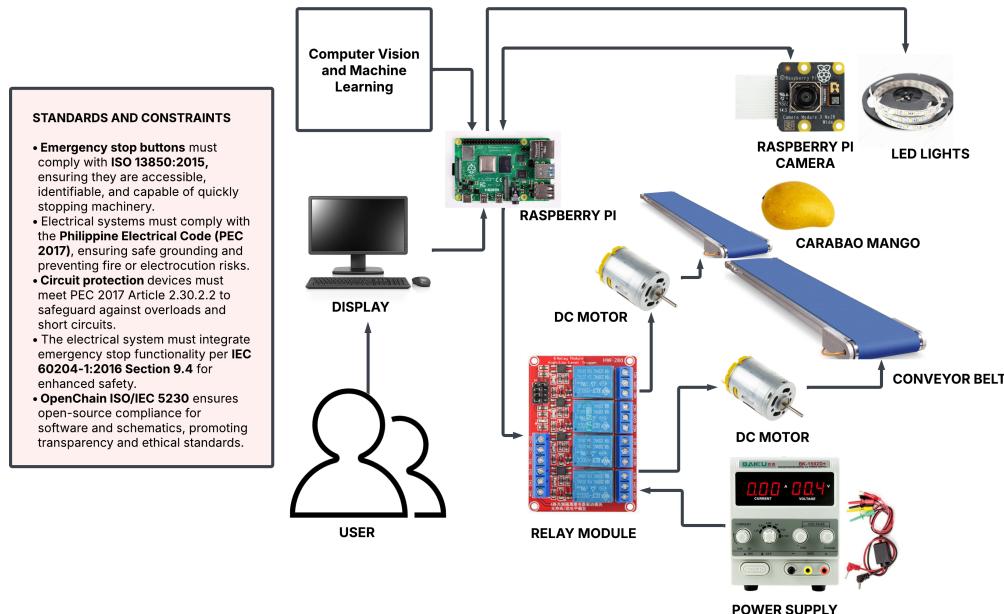


Fig. 4.1 Prototype Framework

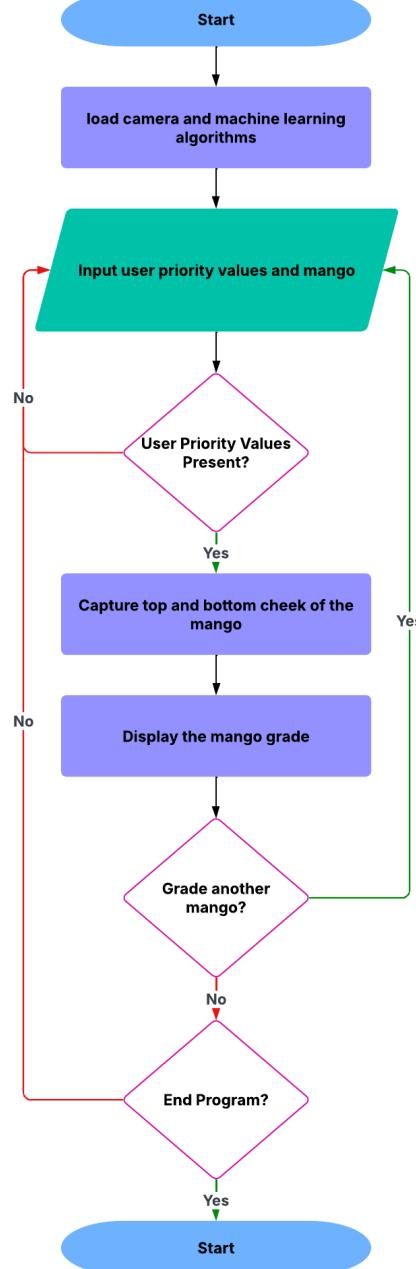


Fig. 4.2 Prototype Main Flowchart



De La Salle University

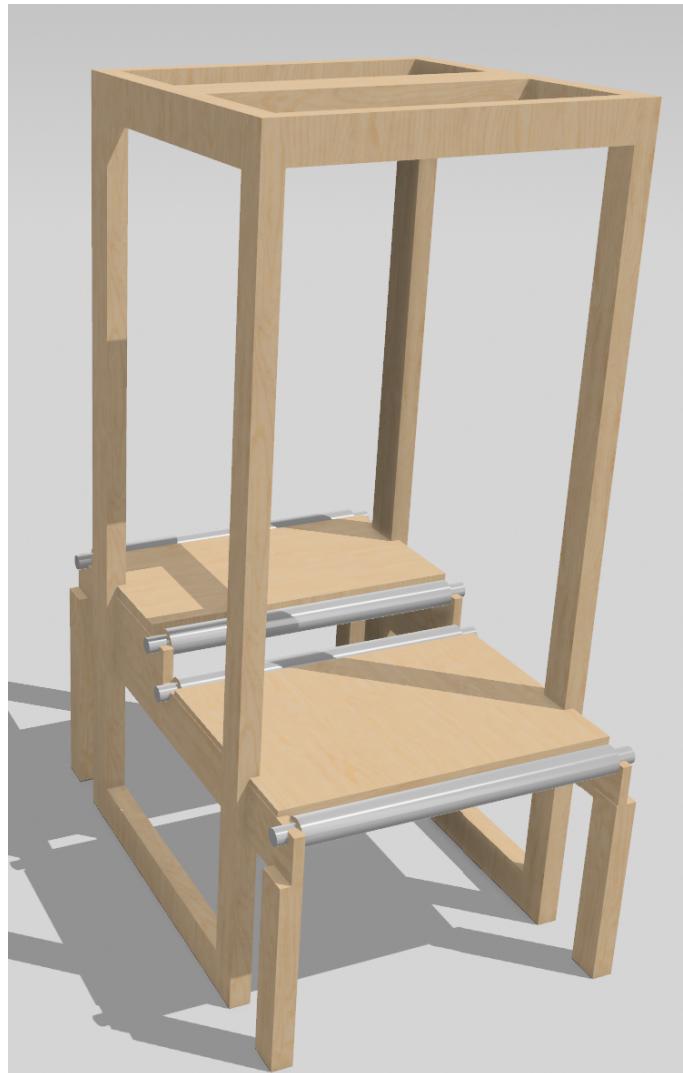


Fig. 4.3 Initial 3D Model of the Prototype



675 **4.3.2 Prototype Flowchart**

676 **4.3.3 Prototype 3D Model**

677 **4.3.4 Hardware Specifications**

678 **4.3.4.1 Raspberry Pi**



Fig. 4.4 Raspberry Pi 4 Model B

679 The Raspberry Pi 4 Model B is a compact, low-cost computer that serves as the system's  
680 main processing unit. It was chosen for its balance of performance and affordability, making  
681 it suitable for image processing tasks. Furthermore, it was selected for its compatibility  
682 with various peripherals through the GPIO pins and USB-A ports together with its ease of  
683 integration into the prototype.

684

685 **Specifications:**



# De La Salle University

- 686     • SoC: Broadcom BCM2711
- 687     • CPU: Quad-core ARM Cortex-A72 (64-bit)
- 688     • Clock Speed: 1.5 GHz (base, overclockable)
- 689     • RAM: 8GB LPDDR4-3200 SDRAM
- 690     • Wireless: Dual-band 2.4 GHz / 5 GHz Wi-Fi (802.11ac)
- 691     • Bluetooth: Bluetooth 5.0 (BLE support)
- 692     • Ethernet: Gigabit Ethernet (full throughput)
- 693     • USB: 2 x USB 3.0 ports and 2 x USB 2.0 ports
- 694     • Video Output: 2 x micro-HDMI ports (supports 4K @ 60Hz, dual 4K display capability)
- 695     • Audio: 3.5mm audio/video composite jack
- 696     • Storage: MicroSD card slot (supports booting via SD card or USB)
- 697     • GPIO: 40-pin GPIO header (backward-compatible with older models)
- 698     • Camera/Display: CSI (camera) and DSI (display) ports
- 699     • Power Input: USB-C (5V/3A recommended)
- 700     • Power Consumption: 3W idle, up to 7.5W under load
- 701

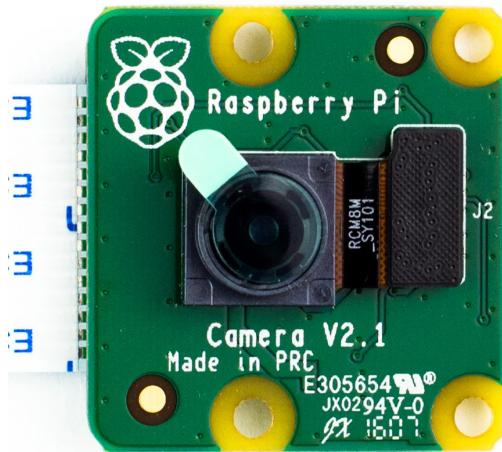


Fig. 4.5 Raspberry Pi Camera Module Version 2

702      **4.3.4.2 Raspberry Pi Camera**

703      The Raspberry Pi Camera Module Version 2 is a high-quality camera module designed for  
704      the Raspberry Pi platform. Likewise, it is capable of capturing still images at 8 megapixels,  
705      and supports video recording at 1080p @ 30fps, 720p @ 60fps, and 480p @ 90fps. More-  
706      over, it has a fixed-focus lens with a diagonal field of view of 62.2 degrees, and an optical  
707      format of 1/4 inch. Furthermore, it supports various Python libraries such as Picamera and  
708      OpenCV for image capture and processing. As such, it was selected for its compact size,  
709      ease of integration, and ability to capture high-resolution images.

710

711      **Specifications:**

- 712      • Sensor: Sony IMX219PQ 8-megapixel CMOS sensor.  
713      • Still Images Resolution: 8 MP (3280 x 2464 pixels).



- 714     • Video Resolution: Supports up to 1080p @ 30fps, 720p @ 60fps, and 480p @ 90fps.
- 715     • Focus: Fixed-focus lens (manual focus adjustment not supported without physical  
716         modification).
- 717     • Lens Size: 1/4-inch optical format.
- 718     • Field of View (FoV): Diagonal 62.2 degrees.
- 719     • Interface: Connected via 15-pin ribbon cable to the Raspberry Pi's CSI (Camera  
720         Serial Interface) port.
- 721     • APIs/Libraries: Supports Python libraries such as Picamera and OpenCV for image  
722         capture and processing.
- 723     • Dimensions: 25 mm x 24 mm x 9 mm.

724     **4.3.4.3 DC Motor**

725     The 12 Volt DC Gear Motor is a compact, high-torque, and low-noise motor suitable for a  
726         wide range of applications, including robotics, automation, and industrial control systems.  
727     It features a spur gear design, which provides a high reduction ratio for increased torque  
728         output. The motor is designed for continuous operation and has a low power consumption  
729         under standard load conditions. Likewise, it is also capable of withstanding high temper-  
730         atures and has a high reliability. This motor was selected for its high torque output, low  
731         power consumption, and compact size, making it ideal for the conveyor system.

732  
733     **Specifications:**



Fig. 4.6 12 Volt DC Gear Motor

- 734 • Gearbox Type: Spur gear design
- 735 • Operating Voltage: 12V (operational range: 6-12V)
- 736 • No-load Current Consumption: 0.8A
- 737 • Rated Current Draw: 3A (under standard load)
- 738 • No-load Speed: 282 RPM (maximum)
- 739 • Operating Speed: 248 RPM (under rated load)
- 740 • Torque Output: 18 kg-cm (rated)
- 741 • Stall Torque: 60 kg-cm (maximum)
- 742 • Power Rating: 50W (maximum)
- 743 • Unit Weight: 350 grams



744

#### 4.3.4.4 MicroSD Card



Fig. 4.7 SanDisk Ultra MicroSD Card

745

The SanDisk Ultra MicroSD Card is a compact, high-capacity, and secure digital memory card that is suitable for a wide range of applications, including digital cameras, smartphones, and tablets. It features a high-speed data transfer rate, making it ideal for storing large files such as images and videos. This card was selected for its high capacity, secure data protection, and ease of use, making it ideal for the storage system for the prototype.

750

#### Specifications:

752

- Capacity: 256GB
- Type: MicroSDXC (Secure Digital eXtended Capacity)
- Form Factor: MicroSD (11mm x 15mm x 1mm)
- File System: Pre-formatted exFAT

753

754

755



756

#### 4.3.4.5 LED Lights



Fig. 4.8 LED Light Strip

757

For the Light Emitting Diode (LED), they were used to provide consistent lighting for image capture, ensuring accurate color representation and feature extraction. The LED lights were selected for their energy efficiency, long lifespan, and ability to produce a uniform light output.

761

#### Specifications:

763

- Power Input: 5V DC (USB-powered, compatible with laptops, power banks, or USB adapters).
- Waterproof Design: Suitable for indoor/outdoor use.
- LED Type: SMD 2835 (surface-mount diodes for high brightness and efficiency).

764

765

766



- 767 • Color Type: White (cool white)
- 768 • Length: 1m
- 769 • Beam Angle: 120°
- 770 • Operating Temperature: -25°C to 60°C.
- 771 • Storage Temperature: -40°C to 80°C.

772 **4.3.4.6 Power Supply**



Fig. 4.9 Bench Power Supply

773 The bench power supply is a versatile and adjustable power source used to provide  
774 stable voltage and current for various electronic projects. It is designed for testing applica-  
775 tions, allowing users to set specific voltage and current levels. This power supply was  
776 selected for its versatility, ease of use, and ability to provide accurate voltage and current



# De La Salle University

777 control for the prototype.

778

779 **Specifications:**

- 780 • Type: SMPS (Switch-Mode Power Supply)
- 781 • Input: 110V AC, 50/60Hz (U.S. Standard)
- 782 • Output Range: 0-30V DC / 0-5A DC
- 783 • Voltage Precision:  $\pm 0.010V$  (10 mV) resolution
- 784 • Current Precision:  $\pm 0.001A$  (1 mA) resolution
- 785 • Power Precision:  $\pm 0.1W$  resolution
- 786 • Weight: 5 lbs (2.27 kg)
- 787 • Dimensions: 11.1" x 4.92" x 6.14" (28.2 cm x 12.5 cm x 15.6 cm)
- 788 • Maximum Power: 195W
- 789 • Power Source: AC input only

790 **4.3.4.7 4 Channel Relay Module**

791 The 4 Channel Relay Module is a compact and versatile relay board that allows for the  
792 control of multiple devices using a single microcontroller. This module was selected for  
793 its compact size, ease of use, and ability to control multiple devices simultaneously. It is  
794 designed to be used with microcontrollers such as Arduino and Raspberry Pi, allowing for  
795 easy integration into the prototype.



Fig. 4.10 4 Channel Relay Module

796

797

### Specifications:

798

- Operating Voltage: 5V DC (compatible with Arduino, Raspberry Pi, and other microcontrollers).

799

800

- Number of Relays: 4 independent channels.

801

- Relay Type: Electromechanical (mechanical switching).

802

- Max AC Load: 10A @ 250V AC (resistive).

803

- Max DC Load: 10A @ 30V DC (resistive).

804

- Contact Type: SPDT (Single Pole Double Throw) - NO (Normally Open), NC (Normally Closed), COM (Common).

805

- Dimensions: 50mm x 70mm x 20mm

806



- 807     • Weight: 50-80 grams.
- 808     • Status LEDs: Individual LEDs for each relay (indicates ON/OFF state).
- 809     • Input Pins: 4 digital control pins (one per relay).
- 810     • Output Terminals: Screw terminals for connecting loads (NO/NC/COM).

811 **4.4 Software Considerations**

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

815 **4.4.1 PyTorch**

816 **4.4.2 OpenCV**

817 **4.4.3 Tkinter**

818 **4.4.4 CustomTkinter**

819 **4.5 Security and Reliability Considerations**

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



## 823    **4.6 Scalability and Efficiency Considerations**

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

## 827    **4.7 User Interface**

828    A User Interface (UI) is designed to display grading results, system status. Wireframes  
829    illustrate the layout, ensuring usability and accessibility for operators. Likewise, a Graphical  
830    User Interface (GUI) is also used to allow users to customize the system's grading priorities.

## 831    **4.8 Constraints and Limitations**

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

## 835    **4.9 Technical Standards**

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



## 838    **4.10 Prototyping and Simulation**

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

## 842    **4.11 Design Validation**

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

## 846    **4.12 Summary**

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



850

## **Chapter 5**

851

# **METHODOLOGY**



TABLE 5.1 SUMMARY OF METHODS FOR REACHING THE OBJECTIVES

Objectives	Methods	Locations
GO: To develop a user-priority-based grading and sorting system for Carabao mangoes, using machine learning and computer vision techniques to assess ripeness, size, and bruises.	<ol style="list-style-type: none"> <li>1. Hardware design: Build an image acquisition system with a conveyor belt, LED lights, and Raspberry Pi Camera</li> <li>2. Software design: Coded a Raspberry Pi application to grade and sort the Carabao mangoes</li> </ol>	Sec. 5.2 on p. 50
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	<ol style="list-style-type: none"> <li>1. Hardware implementation: Design and build an image acquisition system prototype</li> </ol>	Sec. 5.3 on p. 50
SO2: To get the precision, recall, F1 score, confusion matrix, and train and test accuracy metrics for classifying the ripeness and bruises with an accuracy score of at least 90%.	<ol style="list-style-type: none"> <li>1. Performance testing: Train and test the machine learning algorithm for classifying bruises and ripeness</li> <li>2. Data collection: Gather our own Carabao mango dataset together with an online dataset</li> </ol>	Sec. 5.5 on p. 52

*Continued on next page*



*Continued from previous page*

Objectives	Methods	Locations
SO3: To create a microcontroller-based system to operate the image acquisition system, control the conveyor belt, and process the mango images through machine learning.	<ol style="list-style-type: none"> <li>1. Algorithm development: To develop a code for the image acquisition system</li> <li>2. Hardware design: To design a schematic for the microcontroller based system</li> </ol>	Sec. 5.3 on p. 50
SO4: To grade mangoes based on user priorities for size, ripeness, and bruises.	<ol style="list-style-type: none"> <li>1. Formula development: Formulated an equation based on the inputted user priority and the predicted mango classification</li> </ol>	Sec. 5.7 on p. 53
SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes.	<ol style="list-style-type: none"> <li>1. Performance testing: Train and test the machine learning algorithm for classifying bruises</li> </ol>	Sec. 5.6.2 on p. 53
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"> <li>1. Performance testing: Train and test the machine learning algorithm for classifying ripeness</li> </ol>	Sec. 5.6.1 on p. 53
SO7: To classify mango bruises based on image data by employing machine learning algorithms.	<ol style="list-style-type: none"> <li>1. Accuracy testing: Get the percent accuracy testing for getting the length and width of the Carabao mango</li> </ol>	Sec. 5.6.3 on p. 53



## 852    **5.1 Introduction**

853    The methodology for this research outlines the development of the Carabao Mango sorter  
854    using machine learning and computer vision. The sorting system uses a conveyor belt  
855    system which delivers the mangoes into the image acquisition system. This system captures  
856    the image of the mangoes which will then be going through the various stages of image  
857    processing and classification into grades which will depend on the priority of the user.  
858    This methodology ensures that the grading of the mangoes will be accurate while being  
859    non-destructive.

## 860    **5.2 Research Approach**

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

## 867    **5.3 Hardware Design**

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



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

## 876 **5.4 Software Design**

877 For the programming language used for the prototype and training and testing the CNN  
878 model, Python was used for training and testing the CNN model and it was also used in the  
879 microcontroller to run the application containing the UI and CNN model. PyTorch was the  
880 main library used in using the EfficientNet model that is used in classifying the ripeness  
881 and bruises of the mango. Likewise, tkinter is the used library when designing the UI in  
882 Python.

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



## 891    **5.5 Data Collection Methods**

892    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.

## 902    **5.6 Testing and Evaluation Methods**

903    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

911                      testing in real-world conditions to ensure mangoes are accurately and efficiently sorted and graded.



913 To test system performance, various measures of performance are used to evaluate.  
914 As seen on equation 3.6, accuracy score is used to measure the percentage of correctly  
915 classified mangoes to ensure the system maintains high precision levels. Precision as seen  
916 on equation 3.3 and recall as seen on equation 3.4 are used to measure consistency of  
917 classification to determine if the system classifies different ripeness levels and defects  
918 correctly. Furthermore, the F1 score formula as seen on equation 3.5 is used to evaluate the  
919 performance of the model's classification.

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

926 **5.6.1 Ripeness Training and Testing**

927 **5.6.2 Bruises Training and Testing**

928 **5.6.3 Size Determination**

929 **5.7 Formula for User Priority**

930 **5.8 Ethical Considerations**

931 Ethical considerations ensure that the system is operated safely and responsibly. Data  
932 privacy is ensured by securely storing and anonymizing extracted images and classification



933 data so that unauthorized access becomes impossible. The system is also eco-friendly  
934 through non-destructive testing, saving mangoes while also ensuring that they are of good  
935 quality. Safety in operations is also ensured by protecting moving parts to prevent mechani-  
936 cal harm and incorporating fail-safes to securely stop operation in case of malfunction.  
937 Addressing these concerns, the system is not only accurate and efficient but also secure,  
938 eco-friendly, and safe for operators, thus a sustainable solution to automated mango sorting  
939 and grading.

## 940 **5.9 Summary**

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



949

## Chapter 6

950

# RESULTS AND DISCUSSIONS



TABLE 6.1 SUMMARY OF METHODS FOR ACHIEVING 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.	<p>Expected Results:</p> <ul style="list-style-type: none"> <li>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.</li> </ul> <p>Actual Results:</p> <ul style="list-style-type: none"> <li>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</li> <li>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</li> </ul>	Sec. 6.6 on p. 61
SO1: To make an image acquisition system with a conveyor belt for automatic sorting and grading mangoes.	<p>Expected Results:</p> <ul style="list-style-type: none"> <li>1. Successfully integrated a conveyor belt with the image acquisition in order to achieve efficient flow of automated sorting and grading of the mangoes.</li> <li>2. Successfully integrated LED strips to provide optimal lighting for image capturing of the mangoes.</li> <li>3. Successfully fixed the hardware components in place</li> </ul> <p>Actual Results:</p> <ul style="list-style-type: none"> <li>1. Successfully integrated a conveyor belt with the image acquisition in order to achieve efficient flow of automated sorting and grading of the mangoes.</li> <li>2. Successfully integrated LED strips to provide optimal lighting for image capturing of the mangoes.</li> <li>3. Need to fix the hardware components in place</li> </ul>	Sec. 6.4 on p. 61

Continued on next page

## 6. Results and Discussions



# De La Salle University

*Continued from previous page*

Objectives	Methods	Locations
<p>SO2: To get the precision, recall, F1 score, confusion matrix, and train and test accuracy metrics for classifying the ripeness and bruises with an accuracy score of at least 90%.</p>	<p>Expected Results:</p> <ul style="list-style-type: none"> <li>1. Successfully achieved at least 90 percent accuracy, precision, recall, f1 score for ripeness classification of Carabao mangoes</li> <li>2. Successfully achieved at least 90 percent accuracy, precision, recall, f1 score for bruises classification of Carabao mangoes</li> </ul> <p>Actual Results:</p> <ul style="list-style-type: none"> <li>1. Successfully achieved at least 93% accuracy for ripeness classification of Carabao mangoes</li> <li>2. Successfully achieved at least 73% accuracy for bruise classification of Carabao Mangoes</li> </ul>	Sec. 6.1 on p. 60
<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>	<p>Expected Results:</p> <ul style="list-style-type: none"> <li>1. Successfully made a conveyor belt system to move the mangoes through the image acquisition system to the sorting system</li> <li>2. Successfully mounted the image acquisition system on the prototype</li> <li>3. Successfully made the frame for the conveyor belt and image acquisition system to sit on</li> </ul> <p>Actual Results:</p> <ul style="list-style-type: none"> <li>1. Successfully made a conveyor belt system to move the mangoes through the image acquisition system to the sorting system</li> <li>2. Temporarily mounted the image acquisition system on the prototype</li> <li>3. Successfully made the frame for the conveyor belt and image acquisition system to sit on</li> </ul>	Sec. 6.4 on p. 61

*Continued on next page*

## 6. Results and Discussions



# De La Salle University

*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"><li>1. Successfully grade mangoes based on the user priorities on the physical characteristics of the mango</li><li>2. Successfully verified with qualified individual the results</li><li>3. Successfully utilize the weighted equation to evaluate mango grade based on user priorities</li></ol> <p>Actual Results:</p> <ol style="list-style-type: none"><li>1. Successfully grade mangoes based on the user priorities on the physical characteristics of the mango</li><li>2. Successfully utilize the weighted equation to evaluate mango grade based on user priorities</li><li>3. Need to look for a qualified person to evaluate the graded mango for ground truth</li></ol>	Sec. 6.3 on p. 61

*Continued on next page*

## 6. Results and Discussions



# De La Salle University

*Continued from previous page*

Objectives	Methods	Locations
<p>SO5: To classify mango ripeness based on image data using machine learning algorithms such as kNN, k-mean, and Naïve Bayes.</p>	<p>Expected Results:</p> <ul style="list-style-type: none"> <li>1. Achieve at least 90% accuracy on performance metrics</li> <li>2. Obtain performance metrics for kNN, k-mean, and Naive Bayes methods for comparison and show the superior performance of using CNN</li> <li>3. 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</li> </ul> <p>Actual Results:</p> <ul style="list-style-type: none"> <li>1. Successfully trained a CNN model using EfficientNet-b0 and Adam Optimizer to detect ripeness based on color</li> <li>2. Successfully achieved at least 90 percent accuracy, precision, recall, f1 score for ripeness classification of Carabao mangoes</li> </ul>	<p>Sec. 6.1.1 on p. 60</p>
<p>SO6: To classify mango size based on image data by getting its length and width using OpenCV, geometry, and image processing techniques.</p>	<p>Expected Results:</p> <ul style="list-style-type: none"> <li>1. Successfully classified mango size using computer vision techniques</li> <li>2. Successfully tuned to have an accurate size with an 80 percent accuracy rating</li> </ul> <p>Actual Results:</p> <ul style="list-style-type: none"> <li>1. Successfully classified mango size using computer vision techniques</li> <li>2. Calculation of mango size is somewhat inaccurate and needs more fine tuning</li> </ul>	<p>Sec. 6.2 on p. 61</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> <ul style="list-style-type: none"> <li>1. Achieve at least 90% accuracy on performance metrics</li> <li>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</li> </ul> <p>Actual Results:</p> <ul style="list-style-type: none"> <li>1. Successfully trained a CNN model using EfficientNet-b0 and Adam Optimizer to bruises</li> <li>2. Successfully achieved at least 90 percent accuracy, precision, recall, f1 score for bruise classification of Carabao mangoes</li> </ul>	Sec. 6.1.2 on p. 61

951

## 6.1 Training and Testing Results of the Model

952

### 6.1.1 Ripeness Classification Results

953

Add the F1-Score and etc here



954 **6.1.2 Bruises Classification Results**

955 **6.2 Size Determination Results**

956 **6.3 User Priority Formula**

957  $B(P)$  and  $R(P)$  and  $S(P)$  are the User Priority-Based Grading for bruises, ripeness,  
958 and size of the Carabao mango. Furthermore,  $b(p)$  and  $r(p)$  and  $s(p)$  are the machine  
959 learning's predictions for bruises, ripeness, and size of the Carabao mango. The formula  
960 for the user priority is given by:

$$\text{User Priority} = b(P)B(P) + r(P)R(P) + s(P)S(P) \quad (6.1)$$

962 **6.4 Physical Prototype**

963 Add pictures of the hardware prototype here with description

964 **6.5 Software Application**

965 Show the raspberry pi app UI and demonstrate it here

966 **6.6 Summary**

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



968

## Chapter 7

969

# **CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIRECTIVES**

970



## 971      **7.1 Concluding Remarks**

972      In this Thesis, ...

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

## 976      **7.2 Contributions**

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

- 980      • the ;
- 981      • the ;
- 982      • the ;

## 983      **7.3 Recommendations**

984      The researchers recommend...

## 985      **7.4 Future Prospects**

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



988      1. the ....

989      2. the ....

990      3. the ....

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



994

## REFERENCES

- 995 Abbas, Q., Niazi, S., Iqbal, M., and Noureen, M. (2018). Mango Classification Using Texture &  
996 Shape Features. *IJCSNS International Journal of Computer Science and Network Security*, 18(8).
- 997 Abu, M., Olympio, N. S., and Darko, J. O. (2021). Determination of Harvest Maturity for Mango  
998 (*Mangifera indica*) Fruit by Non-Destructive Criteria. *Agricultural Sciences*,  
999 12(10):1103–1118.
- 1000 Adam, J. A. P., Dato, K. S., Impelido, M. C. D., Tobias, R. G., and Pilueta, N. U. (2022). Non-  
1001 destructive microcontroller-based carabao mango ripeness grader.
- 1002 Alejandro, A. B., Gonzales, J. P., Yap, J. P. C., and Linsangan, N. B. (2018). Grading and sorting of  
1003 Carabao mangoes using probabilistic neural network. page 020065, Bandung, Indonesia.
- 1004 Amna, M. W. A., Guiqiang, L., and Muhammad Zuhair AKRAM, M. F. (2023). Machine vision-  
1005 based automatic fruit quality detection and grading. *Frontiers of Agricultural Science and*  
1006 *Engineering*, 0(0):0.
- 1007 Britannica (n.d.). Mango history cultivation and facts.
- 1008 Centino, M. F., Castano, M. C. N., and Ebo, J. B. F. (2020). The Current Status of Philippine Mango  
1009 in the Global Value Chain.
- 1010 Chakraborty, S. K., Subeesh, A., Dubey, K., Jat, D., Chandel, N. S., Potdar, R., Rao, N. G., and  
1011 Kumar, D. (2023). Development of an optimally designed real time automatic citrus fruit grading-  
1012 sorting machine leveraging computer vision-based adaptive deep learning model. *Engineering*  
1013 *Applications of Artificial Intelligence*, 120:105826.
- 1014 Co., Z. F. I. (n.d.). What is fruit sorting.
- 1015 D'Adamo, G. (2018). The determinants of export quality in the euro area. *Quarterly Report on the*  
1016 *Euro Area (QREA)*, 17(1):23–31. Publisher: Directorate General Economic and Financial Affairs  
1017 (DG ECFIN), European Commission.
- 1018 DBpedia (n.d.). About: Carabao.
- 1019 Guillergan, G., Sabay, R., Madrigal, D., and Bual, J. (2024). Naive Bayes Classifier in Grading  
1020 Carabao Mangoes. *Technium: Romanian Journal of Applied Sciences and Technology*, 22:14–32.
- 1021 Guillermo, M. C. S., Naciongayo, D. S., and Galela, M. G. C. (2019). Determining ‘Carabao’  
1022 Mango Ripeness Stages Using Three Image Processing Algorithms.
- 1023 Lacap, A., Bayogan, E. R., Secretaria, L., Joyce, D., Ekman, J., and Goldwater, A. (2021). Bruise  
1024 Injury and Its Effect on ‘Carabao’ Mango Fruit Quality. *Philippine Journal of Science*, 150(6B).
- 1025 Patel, K. K., Khan, M. A., Kumar, Y., and Yadav, A. K. (2019). Novel Techniques in Post Harvest  
1026 Management of Mango- An Overview. *South Asian Journal of Food Technology and Environment*,  
1027 05(02):821–835.



# De La Salle University

- 1028 Rizwan Iqbal, H. M. and Hakim, A. (2022). Classification and Grading of Harvested Mangoes  
1029 Using Convolutional Neural Network. *International Journal of Fruit Science*, 22(1):95–109.
- 1030 Samaniego, L. A., De Jesus, L. C. M., Apostol, J. D., Betonio, D. C., Medalla, J. D. B., Peruda Jr,  
1031 S. R., Brucal, S. G. E., and Yong, E. D. (2023). Carabao mango export quality checker using  
1032 matlab image processing. *International Journal of Computing Sciences Research*, 7:2080–2094.
- 1033 Schulze, K., Nagle, M., Spreer, W., Mahayothee, B., and Müller, J. (2015). Development and  
1034 assessment of different modeling approaches for size-mass estimation of mango fruits (*Mangifera*  
1035 *indica* L., cv. ‘Nam Dokmai’). *Computers and Electronics in Agriculture*, 114:269–276.
- 1036 Supekar, A. D. and Wakode, M. (2020). Multi-Parameter Based Mango Grading Using Image  
1037 Processing and Machine Learning Techniques. *INFOCOMP Journal of Computer Science*,  
1038 19(2):175–187. Number: 2.
- 1039 Tomas, M. C., Celino, J. P. L., Escalambre, I. E., and Secreto, B. P. (2022). Detection of Overall  
1040 Fruit Maturity of Local Fruits Using Support Vector Machine through Image Processing. In *2022*  
1041 *12th International Conference on Software Technology and Engineering (ICSTE)*, pages 96–102.
- 1042 Veling, P. S. (2019). Mango Disease Detection by using Image Processing. *International Journal*  
1043 *for Research in Applied Science and Engineering Technology*, 7(4):3717–3726.
- 1044 Zheng, B. and Huang, T. (2021). Mango Grading System Based on Optimized Convolutional Neural  
1045 Network. *Mathematical Problems in Engineering*, 2021:1–11.

1046

Produced: March 30, 2025, 21:39



De La Salle University

1047

## **Appendix A STUDENT RESEARCH ETHICS CLEARANCE**

1048

A. Student Research Ethics Clearance



De La Salle University

1049

RESEARCH ETHICS CLEARANCE FORM <sup>1</sup> For Thesis Proposals	
<b>Names of Student Researcher(s):</b> BANAL, Kenan A. BAUTISTA, Francis Robert Miguel F. HERMOSURA, Don Humphrey L. SALAZAR, Daniel G	
<b>College:</b> GCOE	
<b>Department:</b> ECE	
<b>Course:</b> Computer Engineering	
<b>Expected Duration of the Project:</b> from: January 4 2025 to: January 4 2026	
<b>Ethical considerations</b>  (The <a href="#">Ethics Checklists</a> may be used as guides in determining areas for ethical concern/consideration)	
 <b>To the best of my knowledge, the ethical issues listed above have been addressed in the research.</b>   Dr. Reggie C. Gustilo	
<b>Name and Signature of Adviser/Mentor:</b> Date: February 5, 2025	
<b>Noted by:</b>   Dr. Argel Bandala	
<b>Name and Signature of the Department Chairperson:</b> Date: February 6, 2025	

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



De La Salle University

1050

## **Appendix B ANSWERS TO QUESTIONS TO THIS THESIS**

1051

**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.

1052  
1053  
1054  
1055  
1056  
1057  
1058  
1059  
1060  
1061  
1062  
1063  
1064  
1065  
1066  
1067  
1068  
1069  
1070  
1071  
1072  
1073  
1074  
1075  
1076  
1077  
1078  
1079  
1080  
1081  
1082  
1083  
1084  
1085  
1086  
1087  
1088  
1089  
1090  
1091  
1092  
1093  
1094  
1095  
1096  
1097  
1098  
1099  
1100  
1101  
1102  
1103  
1104  
1105  
1106  
1107  
1108  
1109  
1110  
1111  
1112  
1113  
1114  
1115  
1116  
1117  
1118  
1119  
1120  
1121  
1122  
1123  
1124  
1125  
1126  
1127  
1128  
1129  
1130  
1131  
1132  
1133  
1134  
1135  
1136  
1137  
1138  
1139  
1140  
1141  
1142  
1143  
1144  
1145  
1146  
1147  
1148  
1149  
1150  
1151  
1152  
1153  
1154  
1155  
1156  
1157  
1158  
1159  
1160  
1161  
1162  
1163  
1164  
1165  
1166  
1167  
1168  
1169  
1170  
1171  
1172  
1173  
1174  
1175  
1176  
1177  
1178  
1179  
1180  
1181  
1182  
1183  
1184  
1185  
1186  
1187  
1188  
1189  
1190  
1191  
1192  
1193  
1194  
1195  
1196  
1197  
1198  
1199  
1200  
1201  
1202  
1203  
1204  
1205  
1206  
1207  
1208  
1209  
1210  
1211  
1212  
1213  
1214  
1215  
1216  
1217  
1218  
1219  
1220  
1221  
1222  
1223  
1224  
1225  
1226  
1227  
1228  
1229  
1230  
1231  
1232  
1233  
1234  
1235  
1236  
1237  
1238  
1239  
12310  
12311  
12312  
12313  
12314  
12315  
12316  
12317  
12318  
12319  
12320  
12321  
12322  
12323  
12324  
12325  
12326  
12327  
12328  
12329  
12330  
12331  
12332  
12333  
12334  
12335  
12336  
12337  
12338  
12339  
12340  
12341  
12342  
12343  
12344  
12345  
12346  
12347  
12348  
12349  
12350  
12351  
12352  
12353  
12354  
12355  
12356  
12357  
12358  
12359  
12360  
12361  
12362  
12363  
12364  
12365  
12366  
12367  
12368  
12369  
12370  
12371  
12372  
12373  
12374  
12375  
12376  
12377  
12378  
12379  
12380  
12381  
12382  
12383  
12384  
12385  
12386  
12387  
12388  
12389  
12390  
12391  
12392  
12393  
12394  
12395  
12396  
12397  
12398  
12399  
123910  
123911  
123912  
123913  
123914  
123915  
123916  
123917  
123918  
123919  
123920  
123921  
123922  
123923  
123924  
123925  
123926  
123927  
123928  
123929  
123930  
123931  
123932  
123933  
123934  
123935  
123936  
123937  
123938  
123939  
123940  
123941  
123942  
123943  
123944  
123945  
123946  
123947  
123948  
123949  
123950  
123951  
123952  
123953  
123954  
123955  
123956  
123957  
123958  
123959  
123960  
123961  
123962  
123963  
123964  
123965  
123966  
123967  
123968  
123969  
123970  
123971  
123972  
123973  
123974  
123975  
123976  
123977  
123978  
123979  
123980  
123981  
123982  
123983  
123984  
123985  
123986  
123987  
123988  
123989  
123990  
123991  
123992  
123993  
123994  
123995  
123996  
123997  
123998  
123999  
1239100  
1239101  
1239102  
1239103  
1239104  
1239105  
1239106  
1239107  
1239108  
1239109  
1239110  
1239111  
1239112  
1239113  
1239114  
1239115  
1239116  
1239117  
1239118  
1239119  
1239120  
1239121  
1239122  
1239123  
1239124  
1239125  
1239126  
1239127  
1239128  
1239129  
1239130  
1239131  
1239132  
1239133  
1239134  
1239135  
1239136  
1239137  
1239138  
1239139  
1239140  
1239141  
1239142  
1239143  
1239144  
1239145  
1239146  
1239147  
1239148  
1239149  
1239150  
1239151  
1239152  
1239153  
1239154  
1239155  
1239156  
1239157  
1239158  
1239159  
1239160  
1239161  
1239162  
1239163  
1239164  
1239165  
1239166  
1239167  
1239168  
1239169  
1239170  
1239171  
1239172  
1239173  
1239174  
1239175  
1239176  
1239177  
1239178  
1239179  
1239180  
1239181  
1239182  
1239183  
1239184  
1239185  
1239186  
1239187  
1239188  
1239189  
1239190  
1239191  
1239192  
1239193  
1239194  
1239195  
1239196  
1239197  
1239198  
1239199  
1239200  
1239201  
1239202  
1239203  
1239204  
1239205  
1239206  
1239207  
1239208  
1239209  
1239210  
1239211  
1239212  
1239213  
1239214  
1239215  
1239216  
1239217  
1239218  
1239219  
1239220  
1239221  
1239222  
1239223  
1239224  
1239225  
1239226  
1239227  
1239228  
1239229  
1239230  
1239231  
1239232  
1239233  
1239234  
1239235  
1239236  
1239237  
1239238  
1239239  
1239240  
1239241  
1239242  
1239243  
1239244  
1239245  
1239246  
1239247  
1239248  
1239249  
1239250  
1239251  
1239252  
1239253  
1239254  
1239255  
1239256  
1239257  
1239258  
1239259  
1239260  
1239261  
1239262  
1239263  
1239264  
1239265  
1239266  
1239267  
1239268  
1239269  
1239270  
1239271  
1239272  
1239273  
1239274  
1239275  
1239276  
1239277  
1239278  
1239279  
1239280  
1239281  
1239282  
1239283  
1239284  
1239285  
1239286  
1239287  
1239288  
1239289  
1239290  
1239291  
1239292  
1239293  
1239294  
1239295  
1239296  
1239297  
1239298  
1239299  
1239300  
1239301  
1239302  
1239303  
1239304  
1239305  
1239306  
1239307  
1239308  
1239309  
1239310  
1239311  
1239312  
1239313  
1239314  
1239315  
1239316  
1239317  
1239318  
1239319  
1239320  
1239321  
1239322  
1239323  
1239324  
1239325  
1239326  
1239327  
1239328  
1239329  
1239330  
1239331  
1239332  
1239333  
1239334  
1239335  
1239336  
1239337  
1239338  
1239339  
12393310  
12393311  
12393312  
12393313  
12393314  
12393315  
12393316  
12393317  
12393318  
12393319  
12393320  
12393321  
12393322  
12393323  
12393324  
12393325  
12393326  
12393327  
12393328  
12393329  
12393330  
12393331  
12393332  
12393333  
12393334  
12393335  
12393336  
12393337  
12393338  
12393339  
123933310  
123933311  
123933312  
123933313  
123933314  
123933315  
123933316  
123933317  
123933318  
123933319  
123933320  
123933321  
123933322  
123933323  
123933324  
123933325  
123933326  
123933327  
123933328  
123933329  
123933330  
123933331  
123933332  
123933333  
123933334  
123933335  
123933336  
123933337  
123933338  
123933339  
123933340  
123933341  
123933342  
123933343  
123933344  
123933345  
123933346  
123933347  
123933348  
123933349  
123933350  
123933351  
123933352  
123933353  
123933354  
123933355  
123933356  
123933357  
123933358  
123933359  
123933360  
123933361  
123933362  
123933363  
123933364  
123933365  
123933366  
123933367  
123933368  
123933369  
123933370  
123933371  
123933372  
123933373  
123933374  
123933375  
123933376  
123933377  
123933378  
123933379  
123933380  
123933381  
123933382  
123933383  
123933384  
123933385  
123933386  
123933387  
123933388  
123933389  
123933390  
123933391  
123933392  
123933393  
123933394  
123933395  
123933396  
123933397  
123933398  
123933399  
1239333100  
1239333101  
1239333102  
1239333103  
1239333104  
1239333105  
1239333106  
1239333107  
1239333108  
1239333109  
1239333110  
1239333111  
1239333112  
1239333113  
1239333114  
1239333115  
1239333116  
1239333117  
1239333118  
1239333119  
1239333120  
1239333121  
1239333122  
1239333123  
1239333124  
1239333125  
1239333126  
1239333127  
1239333128  
1239333129  
1239333130  
1239333131  
1239333132  
1239333133  
1239333134  
1239333135  
1239333136  
1239333137  
1239333138  
1239333139  
1239333140  
1239333141  
1239333142  
1239333143  
1239333144  
1239333145  
1239333146  
1239333147  
1239333148  
1239333149  
1239333150  
1239333151  
1239333152  
1239333153  
1239333154  
1239333155  
1239333156  
1239333157  
1239333158  
1239333159  
1239333160  
1239333161  
1239333162  
1239333163  
1239333164  
1239333165  
1239333166  
1239333167  
1239333168  
1239333169  
1239333170  
1239333171  
1239333172  
1239333173  
1239333174  
1239333175  
1239333176  
1239333177  
1239333178  
1239333179  
1239333180  
1239333181  
1239333182  
1239333183  
1239333184  
1239333185  
1239333186  
1239333187  
1239333188  
1239333189  
1239333190  
1239333191  
1239333192  
1239333193  
1239333194  
1239333195  
1239333196  
1239333197  
1239333198  
1239333199  
1239333200  
1239333201  
1239333202  
1239333203  
1239333204  
1239333205  
1239333206  
1239333207  
1239333208  
1239333209  
1239333210  
1239333211  
1239333212  
1239333213  
1239333214  
1239333215  
1239333216  
1239333217  
1239333218  
1239333219  
1239333220  
1239333221  
1239333222  
1239333223  
1239333224  
1239333225  
1239333226  
1239333227  
1239333228  
1239333229  
1239333230  
1239333231  
1239333232  
1239333233  
1239333234  
1239333235  
1239333236  
1239333237  
1239333238  
1239333239  
1239333240  
1239333241  
1239333242  
1239333243  
1239333244  
1239333245  
1239333246  
1239333247  
1239333248  
1239333249  
1239333250  
1239333251  
1239333252  
1239333253  
1239333254  
1239333255  
1239333256  
1239333257  
1239333258  
1239333259  
1239333260  
1239333261  
1239333262  
1239333263  
1239333264  
1239333265  
1239333266  
1239333267  
1239333268  
1239333269  
1239333270  
1239333271  
1239333272  
1239333273  
1239333274  
1239333275  
1239333276  
1239333277  
1239333278  
1239333279  
1239333280  
1239333281  
1239333282  
1239333283  
1239333284  
1239333285  
1239333286  
1239333287  
1239333288  
1239333289  
1239333290  
1239333291  
1239333292  
1239333293  
1239333294  
1239333295  
1239333296  
1239333297  
1239333298  
1239333299  
1239333300  
1239333301  
1239333302  
1239333303  
1239333304  
1239333305  
1239333306  
1239333307  
1239333308  
1239333309  
1239333310  
1239333311  
1239333312  
1239333313  
1239333314  
1239333315  
1239333316  
1239333317  
1239333318  
1239333319  
1239333320  
1239333321  
1239333322  
1239333323  
1239333324  
1239333325  
1239333326  
1239333327  
1239333328  
1239333329  
1239333330  
1239333331  
1239333332  
1239333333  
1239333334  
1239333335  
1239333336  
1239333337  
1239333338  
1239333339  
1239333340  
1239333341  
1239333342  
1239333343  
1239333344  
1239333345  
1239333346  
1239333347  
1239333348  
1239333349  
1239333350  
1239333351  
1239333352  
1239333353  
1239333354  
1239333355  
1239333356  
1239333357  
1239333358  
1239333359  
1239333360  
1239333361  
1239333362  
1239333363  
1239333364  
1239333365  
1239333366  
1239333367  
1239333368  
1239333369  
1239333370  
1239333371  
1239333372  
1239333373  
1239333374  
1239333375  
1239333376  
1239333377  
1239333378  
1239333379  
1239333380  
1239333381  
1239333382  
1239333383  
1239333384  
1239333385  
1239333386  
1239333387  
1239333388  
1239333389  
1239333390  
1239333391  
1239333392  
1239333393  
1239333394  
1239333395  
1239333396  
1239333397  
1239333398  
1239333399  
1239333400  
1239333401  
1239333402  
1239333403  
1239333404  
1239333405  
1239333406  
1239333407  
1239333408  
1239333409  
1239333410  
1239333411  
1239333412  
1239333413  
1239333414  
1239333415  
1239333416  
1239333417  
1239333418  
1239333419  
1239333420  
1239333421  
1239333422  
1239333423  
1239333424  
1239333425  
1239333426  
1239333427  
1239333428  
1239333429  
1239333430  
1239333431  
1239333432  
1239333433  
1239333434  
1239333435  
1239333436  
1239333437  
1239333438  
1239333439  
1239333440  
1239333441  
1239333442  
1239333443  
1239333444  
1239333445  
1239333446  
1239333447  
1239333448  
1239333449  
1239333450  
1239333451  
1239333452  
1239333453  
1239333454  
1239333455  
1239333456  
1239333457  
1239333458  
1239333459  
1239333460  
1239333461  
1239333462  
1239333463  
1239333464  
1239333465  
1239333466  
1239333467  
1239333468  
1239333469  
1239333470  
1239333471  
1239333472  
1239333473  
1239333474  
1239333475  
1239333476  
1239333477  
1239333478  
1239333479  
1239333480  
1239333481  
1239333482  
1239333483  
1239333484  
1239333485  
1239333486  
1239333487  
1239333488  
1239333489  
1239333490  
1239333491  
1239333492  
1239333493  
1239333494  
1239333495  
1239333496  
1239333497  
1239333498  
1239333499  
1239333500  
1239333501  
1239333502  
1239333503  
1239333504  
1239333505  
1239333506  
1239333507  
1239333508  
1239333509  
1239333510  
1239333511  
1239333512  
1239333513  
1239333514  
1239333515  
1239333516  
1239333517  
1239333518  
1239333519  
1239333520  
1239333521  
1239333522  
1239333523  
1239333524  
1239333525  
1239333526  
1239333527  
1239333528  
1239333529  
1239333530  
1239



1084 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1085 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1087 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 1088 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1089 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1090 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1091 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
 1092 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1093 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1094 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1095 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1097 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 1098 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1099 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1100 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1101 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
 1102 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1103 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1104 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1105 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1107 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 1108 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1109 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1110 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1111 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
 1112 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1113 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1114 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1115 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



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

1116 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1117 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1118 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1119 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1120 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1121 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1122 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1123 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1124 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1125 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1126 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1127 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1128 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1129 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1130 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1131 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1132 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1133 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1134 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1135 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1136 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1137 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1138 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1139 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1140 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1141 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1142 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



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

1148 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1149 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1150 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1151 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1152 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1153 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1154 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1155 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1156 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?**

1159 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1160 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1161 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1162 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1163 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1164 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1165 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1166 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1167 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1170 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1171 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1172 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1173 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1174 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1175 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1176 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1177 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1178 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



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

1183 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1184 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1185 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1186 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1187 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1188 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1189 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1190 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1191 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?**

1195 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1196 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1197 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1198 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1199 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1200 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1201 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1202 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1203 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1206 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1207 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1208 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1209 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1210 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1211 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1212 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.



1213 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1214 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1215 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 1216 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdier mi nec ante. Donec  
 1217 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1218 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1219 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
 1220 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1221 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1222 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1223 amet ipsum. Nunc quis urna dictum turpis accumsan semper.  
 1224  
 1225

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

1226 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 1227 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdier mi nec ante. Donec  
 1228 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1229 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1230 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
 1231 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1232 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1233 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1234 amet ipsum. Nunc quis urna dictum turpis accumsan semper.  
 1235  
 1236

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

1237 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.  
 1238 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdier mi nec ante. Donec  
 1239 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1240 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1241 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
 1242 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1243  
 1244



1245 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1246 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1247 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1250 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1251 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1252 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1253 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1254 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1255 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1256 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1257 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1258 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1263 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1264 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec  
 1265 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
 1266 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
 1267 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla  
 1268 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
 1269 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
 1270 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
 1271 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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

1272 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.  
 1273 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec



# De La Salle University

- 1276 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus  
1277 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.  
1278 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla  
1279 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue  
1280 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.  
1281 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit  
1282 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



De La Salle University

1283

## **Appendix C REVISIONS TO THE PROPOSAL**

1284

## C. Revisions to the Proposal



**De La Salle University**

1285

### 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](https://zoom.us/rec/share/mrn9zBtPz3bJ5laVcy2E8-iBno8A6fBRgOCacMrhmzLPCNO0IDxXBHiK_xzdicEb.MzbHGzrD7rL3tVgJ?startTIme=1731326444000)

Passcode: +7qL6DZE

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

C. Revisions to the Proposal



# De La Salle University

1286

## 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



1287

## PRO1 Panel Comments and Revisions – Appendix Z

### PRO1 Panel Comments and Revisions

Zoom Recording:

[https://zoom.us/rec/share/mrn9zBtPz3bJ5laVcy2E8-iBno8A6fBRgOCacMrhmzLPCNO0IDxXBHiK\\_xzdicEb.MzbHGzrD7rL3tVgJ?startTim=e=1731326444000](https://zoom.us/rec/share/mrn9zBtPz3bJ5laVcy2E8-iBno8A6fBRgOCacMrhmzLPCNO0IDxXBHiK_xzdicEb.MzbHGzrD7rL3tVgJ?startTim=e=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



1288

### 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.

## C. Revisions to the Proposal



# De La Salle University

1289

### 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:

  
\_\_\_\_\_  
**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

1290

## **Appendix D REVISIONS TO THE FINAL**

1291



- 1292      Make a table with the following columns for showing the summary of revisions to the  
 1293      proposal based on the comments of the panel of examiners.
- 1294      1. Examiner
- 1295      2. Comment
- 1296      3. Summary of how the comment has been addressed
- 1297      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	<p>1. First itemtext</p> <p>2. Second itemtext</p> <p>3. Last itemtext</p> <p>4. First itemtext</p> <p>5. Second itemtext</p> <p><b>First</b> itemtext</p> <p><b>Second</b> itemtext</p> <p><b>Last</b> itemtext</p> <p><b>First</b> itemtext</p> <p><b>Second</b> itemtext</p>	<p>1. First itemtext</p> <p>2. Second itemtext</p> <p>3. Last itemtext</p> <p>4. First itemtext</p> <p>5. Second itemtext</p>	<p>Sec. ?? on p. ??, Sec. ?? on p. ??, Fig. ?? on p. ??</p>

*Continued on next page*



# De La Salle University

*Continued from previous page*

<b>Examiner</b>	<b>Comment</b>	<b>Summary of how the comment has been addressed</b>	<b>Locations</b>
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  <b>First</b> itemtext  <b>Second</b> itemtext  <b>Last</b> itemtext  <b>First</b> itemtext  <b>Second</b> 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*



# De La Salle University

*Continued from previous page*

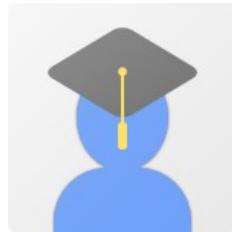
Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Alexander Co Abad	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. ?? on p. ??, Sec. ??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



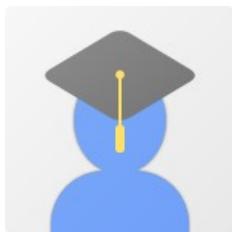
1298

## Appendix E VITA

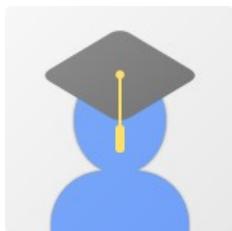
1299



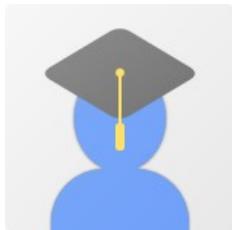
1300 Kenan A. Banal is currently taking up his B.Sc. Computer Engineering  
1301 studies. He is passionate about software and hardware systems such as Vivado, Arduino, C,  
1302 and Python.



1303 Francis Robert Miguel F. BAUTISTA is currently taking up his B.Sc.  
1304 Computer Engineering studies. He is passionate about software and hardware systems such  
1305 as Vivado, Arduino, C, and Python.



1306 Don Humphrey L. HERMOSURA is currently taking up his B.Sc.  
1307 Computer Engineering studies. He is passionate about software and hardware systems such  
1308 as Vivado, Arduino, C, and Python.



1309 Daniel G. SALAZAR is currently taking up his B.Sc. Computer  
1310 Engineering studies. He is passionate about software and hardware systems such as Vivado,  
1311 Arduino, C, and Python.



De La Salle University

1312

## **Appendix F ARTICLE PAPER(S)**

1313

# Article/Forum Paper Format

## (IEEE LaTeX format)

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

1314

**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, L<sup>A</sup>T<sub>E</sub>X, paper, template.

### I. INTRODUCTION

THIS demo file is intended to serve as a “starter file” for IEEE article papers produced under L<sup>A</sup>T<sub>E</sub>X 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 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.

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

1315



(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...