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A Robot System for Corn Planting in the Philippines

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A Thesis

Presented to the Faculty of the

Department of Electronics and Communications Engineering

Gokongwei College of Engineering

De La Salle University

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

13

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by

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16

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August, 2016



De La Salle University

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ORAL DEFENSE RECOMMENDATION SHEET

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25

This thesis, entitled **A Robot System for Corn Planting in the Philippines**, prepared and submitted by thesis group, DreamTeam, composed of:

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

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THESIS APPROVAL SHEET

35

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with group number DreamTeam 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.

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62

ABSTRACT

63 Corn planting in the Philippines has been the second most important crop in the Philippines.
64 Researches about agricultural technology have been progressive in improving the quality
65 and production of crops. This research introduces a robot system for corn planting in the
66 Philippines based from an international study on Automated Rice Planting Robot. This
67 research implemented computer vision to its navigation and control mechanisms. With
68 its portability, the study aims to provide a convenient way to plant corn seeds in ideally
69 replacing human labor in corn production. Through modeling the system with RaspberryPi
70 and its camera module, it managed to plant a corn row (as a scaled representation of an
71 actual corn field) with reliable approximations in manual labor. Hence, this robot system
72 managed to perform as expected in terms of applying embedded systems in the field of
73 agriculture; as far as the reach of modern Filipino technology.

74

Index Terms—Robot, System, RaspberryPi, Agriculture, Philippines.



75 TABLE OF CONTENTS

76	Oral Defense Recommendation Sheet	ii
77	Thesis Approval Sheet	iii
78	Acknowledgment	v
79	Abstract	vi
80	Table of Contents	vii
81	Chapter 1 INTRODUCTION	1
82	1.1 Background of the Study	2
83	1.2 Prior Studies	3
84	1.3 Problem Statement	5
85	1.4 Objectives	6
86	1.4.1 General Objective(s)	6
87	1.4.2 Specific Objectives	6
88	1.5 Significance of the Study	6
89	1.6 Assumptions, Scope and Delimitation	8
90	1.7 Description and Methodology	8
91	1.8 Estimated Work Schedule and Budget	10
92	Chapter 2 LITERATURE REVIEW	12
93	2.1 Vision-Based Guidance for Robot Navigation in Agriculture	13
94	2.2 Video Streaming In Autonomous Mobile Robot Using Wi-Fi	14
95	2.3 Camera-Based Clear Path Detection	15
96	2.4 An Efficient Crop Row Detection Method for Agriculture Robots	16
97	2.5 A technical review on navigation systems of agricultural autonomous off-road vehicles	18
98	2.6 Agricultural automatic guidance research in North America	19
99	2.7 Automatic guidance for agricultural vehicles in Europe	20
100	2.8 Autonomous Agriculture Vehicles in Japan	21
101	2.9 Variable Field-of-view Machine Vision-Based Row Guidance of Agricultural Robot	22
102	2.10 Navigation System for Agricultural Machines	22



105	Chapter 3 THEORETICAL CONSIDERATIONS	23
106	3.1 Corn	24
107	3.2 Corn Production	24
108	3.3 Agricultural Technology	25
109	3.4 Agricultural Robots	26
110	3.5 Philippine Agriculture	26
111	Chapter 4 DESIGN CONSIDERATIONS	28
112	4.1 Raspberry Pi 3 Model B	29
113	4.2 Raspberry Pi Camera Module	32
114	4.3 Virtual Network Computing	32
115	4.4 IP Address	33
116	4.5 Design Reference	34
117	4.6 Design and Dimensions	34
118	4.7 Components	36
119	Chapter 5 METHODOLOGY	39
120	5.1 Implementation	40
121	5.2 Evaluation	41
122	5.3 Summary	42
123	Chapter 6 RESULTS AND DISCUSSION	43
124	6.1 Summary	44
125	Chapter 7 CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIREC-	
126	TIVES	48
127	7.1 Concluding Remarks	49
128	7.2 Contributions	49
129	7.3 Recommendations	49
130	7.4 Future Prospects	50
131	References	51
132	Appendix A ANSWERS TO QUESTIONS TO THIS THESIS	53
133	A1 How important is the problem to practice?	55
134	A2 How will you know if the solution/s that you will achieve would be better	
135	than existing ones?	55
136	A2.1 How will you measure the improvement/s?	55
137	A2.1.1 What is/are your basis/bases for the improvement/s? . . .	55
138	A2.1.2 Why did you choose that/those basis/bases?	55



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139	A2.1.3 How significant are your measure/s of the improvement/s?	55
140	A3 What is the difference of the solution/s from existing ones?	56
141	A3.1 How is it different from previous and existing ones?	56
142	A4 What are the assumptions made (that are behind for your proposed solution to work)?	56
143	A4.1 Will your proposed solution/s be sensitive to these assumptions? . .	56
144	A4.2 Can your proposed solution/s be applied to more general cases when some of the assumptions are eliminated? If so, how?	57
145	A5 What is the necessity of your approach / proposed solution/s?	57
146	A5.1 What will be the limits of applicability of your proposed solution/s?	57
147	A5.2 What will be the message of the proposed solution to technical people? How about to non-technical managers and business men?	57
148	A6 How will you know if your proposed solution/s is/are correct?	58
149	A6.1 Will your results warrant the level of mathematics used (i.e., will the end justify the means)?	58
150	A7 Is/are there an/_ alternative way/s to get to the same solution/s?	58
151	A7.1 Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s?	58
152	A7.2 Is there an approximation that can arrive at the essentially the same proposed solution/s more easily?	58
153	A8 If you were the examiner of your proposal, how would you present the proposal in another way?	59
154	A8.1 What are the weaknesses of your proposal?	59
162	Appendix B VITA	60



163 **Chapter 1**

164 **INTRODUCTION**

165 **Contents**

166	1.1	Background of the Study	2
167	1.2	Prior Studies	3
168	1.3	Problem Statement	5
169	1.4	Objectives	6
170	1.4.1	General Objective(s)	6
171	1.4.2	Specific Objectives	6
172	1.5	Significance of the Study	6
173	1.6	Assumptions, Scope and Delimitation	8
174	1.7	Description and Methodology	8
175	1.8	Estimated Work Schedule and Budget	10



178 **1.1 Background of the Study**

179 Corn is second to rice as the most important crop in the Philippines, with one-third of
180 Filipino farmers, or 1.8 million, depending on maize as their major source of livelihood.
181 White corn is the most important substitute staple in periods of rice shortage, especially
182 for the people in rural areas. Yellow corn is the primary source of feed for the Philippines
183 animal industry, and is being increasingly used by the manufacturing sector [1]. Due to
184 rice shortage in the production of rice in the Philippines, farmers substitute corn as an
185 alternative to rice as their main source of livelihood.

186 The development of agricultural robots led some researchers to utilize image processing
187 for navigation. Digital image processing allows a much wider range of algorithms to be
188 applied to the input data and can avoid problems such as the build-up of noise and signal
189 distortion during processing. Today machine vision systems are applied in two dimensions (2-D)
190 or three dimensions (3-D). The 2-D vision systems use area scan or line scan cameras
191 as well as appropriate lighting to measure the visible characteristics of an object such as,
192 quality of surface appearance, edge based measurements and presence and location of
193 features. In agriculture, 2-D has applications in sorting based on color, shape and size.
194 In 3-D analysis basically there are two techniques applied: stereo vision and LED/laser
195 triangulation. Machine vision-based guidance showed acceptable performance at all speeds
196 and different paths by average errors below 3 cm. It was proposed that using both machine
197 vision and laser radar may provide a more robust guidance as well as obstacle detection
198 capability [2].

199 The adoption of improved technology for yellow corn production has resulted in
200 significant yield increases. Yellow corn accounted for 23% of total corn production 1985,



201 and for 58% by 2001. It should be noted that, however, that the national average yield of
202 1.82 tons per hectare for white and yellow corn (in 2001) is low when compared to corn
203 fields in other Asian countries [1].

204 **1.2 Prior Studies**

205 Pertinent to the needs of the country, the Philippines is centered and concentrated in con-
206 ducting researches on agricultural technology. As a country highly capable of producing
207 its own sources of food, there is no doubt that there is priority in funding these researches.
208 These, in turn, allow its agriculture to be as advanced as it requires for its growing pop-
209 ulation. Following the groups interest in integrating its recent forms of technology in
210 indigenous sectors of the society, the members conducted brief, prior studies about the
211 current advancements in agricultural technology of different origins. They purposed to find
212 foreign researches in order to extend the capabilities of local technology to be as equally
213 competent.

- 214 • A resource entitled "A Robot System for Paddy Field Farming in Japan" is set to
215 utilize a robot-operated farming technology guided from tillage to harvest in large-
216 scale agriculture. In such application, it is seen that in the cultivation of rice, wheat
217 and soybean (in Japan, as per the researchers' host country), there has been three
218 types of robot in development. First, a robot tractor, followed by a rice transplanter,
219 finally, combines harvester robots. Real-time Kinematic Global Positioning System
220 (RTK-GPS) and Inertia Measurement Unit (IMU), or Global Positioning System
221 (GPS) compass are utilized for navigation system. These robots have a Controller
222 Area Network (CAN) bus that all sensors and computers can be connected and



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223 interfaced in common among other robots such as tractors, rice transplanters and
224 combine harvesters. Hence, these could be officiated in autonomous operation in
225 paddy fields as well as discussing in this paper the ability of moving across fields for
226 effective operations and safe guidelines for robot systems [3].

- 227 • Another is a resource entitled A Global Positioning System guided automated rice
228 transplanter” that speaks about a new Global Positioning System (GPS) guided
229 rice transplanter. This study is very coherent to the aforementioned research as
230 this resource speaks more about the utilization of the GPS technology they used in
231 implementing the three robots as tractor, rice transplanter and combine harvester.
232 With these, such robot systems were GPS-guided with their respective position data
233 and inertia measurement unit direction data. This new one (inherent to this resource)
234 is guided with GPS position data with tilt correction during straight driving and
235 guided with the data gathered from the IMU during each robot’s turning at the head
236 land. An antenna prescribed to the GPS is set to 1.5 meters (as height) and 0.4
237 meters as its offset at the vehicle’s front axle. The actuator control command and
238 data communication protocols adhere through the controller area network (CAN) bus.
239 Hence, steering and transmission systems are controlled through electrical actuators
240 with respect to the location in a given field [4].
- 241 • Lastly, a resource entitled Robot Farming System Using Multiple Tractors in Japan
242 with the objective to develop a robot farming system using multiple robots. It
243 discusses the application of multiple robots in Japan agriculture for rice, wheat, and
244 soybean. The system that is discussed in this paper includes a rice planting robot, a
245 seeding robot, a robot tractor, a combine robot harvester, and several tools attached



246 on the robot tractor. The main objective of this paper is to help the farmers gain
247 more profit thru farming. The paper focused on robot management system, low-cost
248 system, robot farming safety, and real-time monitoring/documentation [5].

249 **1.3 Problem Statement**

250 The Philippines is rich in fertile lands suitable for agricultural development. However,
251 due to the absence of advanced tools for farming, food shortage is becoming a problem.
252 Filipinos are importing crops from other countries such as Thailand and Vietnam in spite
253 of the capability of the Philippine land to cultivate crops.

254 Philippine farmers are not equipped with tools that could compete with the advanced
255 instruments used by foreign farmers. Most of the Philippine farmers rely on manual labor.
256 Difficult tasks such as sowing the field are done by the farmers yet their salary is still below
257 the minimum wage. The land may be rich and fertile for agriculture but the agricultural
258 sector, specifically the local farmers, are considered one of the poorest sector in the country.
259 In turn, the fields are neglected. According to National Geographic, Some 25 to 30 percent
260 of the terraces are abandoned and beginning to deteriorate, along with irrigation systems.
261 Investors and laborers are avoiding the agricultural industry due to the absence of advanced
262 systems used in planting crops. This greatly affects not only the necessity of each individual
263 but also the economy of the Philippines.



264 **1.4 Objectives**

265 **1.4.1 General Objective(s)**

266 To design and develop a system that would automate plantation of corn in corn fields in the
267 Philippines;

268 **1.4.2 Specific Objectives**

- 269 1. To implement computer vision through OpenCV in tracing the path sections of the
270 corn field as implemented to distant manual control;
- 271 2. To utilize the flood fill algorithm in designing the optimal route for the mobile robot
272 as it plant the rice;
- 273 3. To design an Raspberry Pi system in implementing computer vision as interface in
274 robotic application;
- 275 4. To design and develop a mobile robot designed to withstand corn field environmental
276 factors (e.g. soil, temperature, etc.);

277 **1.5 Significance of the Study**

278 Computer Engineering is the marriage of electronics and programming. Implementing
279 a programming-based instruction on an electronic hardware is a fundamental action in
280 the progression of this course. With the use of programming, hardware systems are
281 automated with a more defined set of instructions. With this, the study of a Robot System
282 for the Paddy Field in the Philippines would be an unwavering focus related to the field.



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283 The implementation of this robot system would reinforce automation with the aid of
284 computer vision. Moreover, the electronic and programming skills of the students would
285 be strengthened with this research. External elements such as the edge of the paddy field
286 increase the complexity of this longstanding research. Robot systems are no longer fairly
287 new. However, introducing computer vision that would direct a robot system that could
288 withstand environmental factors, specifically in paddy fields, would establish an innovation
289 for the field of Computer Engineering and for the country Philippines as well.

290 In social context, the employment of this robot system for corn field planting would
291 allow a decrease in production time of corn as it automates the planting of the crop.
292 Additionally, it would lessen the manual labor provided by the local farmers. Instead of
293 manually planting corn seeds, local farmers would save time and effort as the robot system
294 for corn field planting would be utilized. The workload for the farmers would be decreased
295 as the production is increased. It is anticipated that the use of this system would increase
296 the productivity of agricultural sector in the country. It would aide local farmers in ensuring
297 an increase in corn yield as plantation is automated. It will not only benefit the agricultural
298 area but also the economic status of the Philippines.

299 By engaging software-heavy technique such as computer vision into an electronic
300 device, this research would be principal in establishing further the discipline of Computer
301 Engineering. Considering programming as the automation mechanism of systems would
302 yield a better and more accurate result as the set of instructions is broadened. This
303 research is also essential in developing the programming and hardware skills of the students.
304 Simultaneously, this research is significant due to the demand of increasing the competency
305 of the agricultural sector of the Philippines.



306 **1.6 Assumptions, Scope and Delimitation**

307 Across the whole duration of the study, the group concentrated on the following:

- 308 • Focused on guiding a robot system thru computer vision across a small-area of a
rural corn field
- 309 • With added mechanism of planting seeds with make-shift, recycled canister-motor
combination
- 310 • Interfacing navigation Raspberry Pi with its own camera module
- 311 • Tested in 100 square-meter-area at Cagayan

314 With this, there were limitations set to the following extents:

- 315 • Localization of field study with the environmental factors seen at Abulug, Cagayan
- 316 • Robot functionalities set to plant seeds only; regardless of their germination
- 317 • Robot vision with at least a 720P-resolution camera under live feed
- 318 • Tested twenty iterations of planting seeds in one pass

319 **1.7 Description and Methodology**

320 The core of the mobile robot is the GizDuino X Version 2.0. It handles the operations
321 of the robot by processing input data from the camera and commanding the motors of
322 the wheels to mobilize the robot. Using edge detection software, in this case OpenCV,
323 the robot calculates for the distance, speed, and direction it has to go. The edge of the



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324 paddy works as the limit where the robot needs to go, and with the use of a rice planting
325 mechanism the robot fills the whole segment of the paddy area with rice seedlings placed on
326 a specialized container. Light emitting diodes are utilized by the robot for night operations.
327 Weatherproofing or waterproofing the robot should also be considered taking to account
328 that the paddy area is damp or wet during the plantation process and puts the robot at
329 risks of water damage. Unexpected rain and flood are also few of the risks that should be
330 considered for waterproofing the robot. It is expected that once the robot is set, it will do
331 its work with 0 to minimum human interaction or intervention, except during the refilling
332 of the seedlings in the container.

333 The process of the study was to suggest an automated system that would plant rice
334 seedlings on a rural paddy field. Apart from the projected upkeep from a commercial
335 paddy field, it was manageable for the group to train the proposed system at a relatively
336 lower upkeep; that is on a rural paddy field. The key method of testing was to implement
337 a navigation system for the robot. Achieved through edge detection, the group mounted
338 a camera that served as the robots guidance sensor for navigation. The algorithm was
339 implemented thru OpenCV and was translated into machine-level instruction using Arduino
340 to mandate basic directional movements of a robot: forwarding, backwarding and turning.

341 With a known, existing system that still utilized human interaction, (i.e. a Japanese
342 farmer pulling a planting machine that picked holes and chuted seedlings), this was the
343 framework of the study; but to not include human interaction in machine operation. Hence,
344 with this framework, the group aimed to compare if removing human interaction would
345 act as equally useful in full-automation. The variables at test were the accuracy and speed
346 of the automated plantation. These variables were applied in the performance of the
347 farmer and the robot. The rice farmer played a vital role in this study, because the studys



348 standards were based fully in his performance. Hence, the factors to be measured in the
349 two performances were

- 350 • Time taken to plant twenty seedlings on a single crop row (Farmer and Robot)
351 • Proper picking depth, measured in millimeters (Farmer and Robot)

352 The group designated their independent study as the farmers performance; leaving out
353 the robots performance as the dependent study. Therefore, to confirm gathered results about
354 the robot, the group calculated the dispersion and central tendencies of the data taken from
355 the dependent study to the independent study: from the time and depth variables. The group
356 decided this validation method as such due to the ideal purpose of the proposed system: it
357 should be able to replace farmers in field planting.

358 **1.8 Estimated Work Schedule and Budget**



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TABLE 1.1 BILL OF COMPONENTS

UNIT	COMPONENT	PRICE/UNIT
30	Connecting Wires/Cables	7.50
1	Delivery/Shipping Fee	100.00
1	E-Gizmo Services	250
1	G-Tank Chassis	2,599.00
1	Heatsink	50.00
1	L293D	121.00
5	L7805	12.00
1	Laptop	30,000.00
1	Mini Toggle Switch	100.00
1	Motor Driver Shield	450
1	Nokia 5110 LCD Module	340.00
1	Official Pi 3 Case	390.5
1	Official Pi 3 Power Supply	466.59
1	PBOT Wheel Set	244.00
1	Raspberry Pi 3 Model B	1,899.25
1	Raspberry Pi Camera Module	1,348.29
2	Samsung Battery	390.00
1	Samsung Battery Charger	350.00
1	Small Breadboard	68.00
TOTAL		39,841.63



359

Chapter 2

360

LITERATURE REVIEW

361

Contents

362

363	2.1	Vision-Based Guidance for Robot Navigation in Agriculture	13
364	2.2	Video Streaming In Autonomous Mobile Robot Using Wi-Fi	14
365	2.3	Camera-Based Clear Path Detection	15
366	2.4	An Efficient Crop Row Detection Method for Agriculture Robots	16
367	2.5	A technical review on navigation systems of agricultural autonomous off-road vehicles	18
368	2.6	Agricultural automatic guidance research in North America	19
369	2.7	Automatic guidance for agricultural vehicles in Europe	20
370	2.8	Autonomous Agriculture Vehicles in Japan	21
371	2.9	Variable Field-of-view Machine Vision-Based Row Guidance of Agricultural Robot	22
372	2.10	Navigation System for Agricultural Machines	22

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374

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2.1 Vision-Based Guidance for Robot Navigation in Agriculture

A paper entitled Vision-Based Guidance for Robot Navigation in Agriculture was based on a study conducted on Australia. Here, they had an implementation of a vision-based texture tracking method to guide autonomous vehicles in agricultural fields. While it imposed a challenging task to detect crop rows, existing methods require visual difference between what crop is against what soil is for visual segmentation. Their proposed method involves extracting and tracking the direction and offset that existed among parallel textures in a simulated overhead view of the scene. Also, they allowed neglecting of crop-specific details such as color, spacing and periodicity. The results explained the demonstration of the method in both day and night times to autonomously guide a robot across crop rows [6].

An abridged, proposed algorithm design was as follows

- Pre-processing the image to correct lens distortion and to downsample the image for better processing speed
- Using an Inertia Management Unit to detect the horizon
- Warping the stabilized image into an overhead view
- Estimating the vehicles heading with respect to the crop rows thru estimation of a dominant parallel texture in the overhead image
- Correcting heading in the overhead view via image-skewing from the estimated heading



- 396 • Generating a frame template thru the summation of the columns found on the skewed
397 images

- 398 • Assuming a lateral motion that was relative to the crop by comparing such template
399 to an initial crop template

400 Notably citing the Horizon Detection, the researchers began to track the horizon via
401 selecting an image region (free of obstruction from a clear horizon view) within three
402 standard deviations of estimated horizon position. In turn, the pixels were classified into as
403 sky or ground. Further, they also had the estimation of the row direction. Their method
404 was to sum skewed images from varying angles along the columns then calculating the
405 variance of the resulting vector. The skew angle with the greatest variance was the best
406 estimate to qualify as the heading angle. Finally mentioning the detection of rows, their
407 study contained the instance on which the field did not have any crop rows to track (e.g.
408 the ends of the field were bare patches). In these situations, they examined the output of the
409 summation of skewed images aforementioned. They set a standard of frame templates that
410 vary from +/- 30 degrees.

411 **2.2 Video Streaming In Autonomous Mobile Robot
412 Using Wi-Fi**

413 Another paper entitled Video Streaming In Autonomous Mobile Robot Using Wi-Fi was
414 used to consider the relevance of a capable telemetry system. Having an autonomous
415 mobile robot required to cover a distance from one point to another with two or more
416 wheels. To reach a destination, it was not always possible that a person could not reach.



417 Through an Autonomous Arduino Yun for four-wheeled mobile robots, it gave capabilities
418 to robots to actually move from one point to another by finding paths and avoiding obstacles
419 thru Video Streaming. Achieved thru Wi-Fi Technology (as avoidance to using Bluetooth
420 technology due to its lesser security and shortness of range), the best path was identified
421 thru Aggrandized Genetic Algorithm (AGA) which was comparatively greater than other
422 algorithms. Wi-Fi (IEEE 802.11 b/g/n) was used to achieve secure communications at long
423 distances [7].

424 Upon mentioning Arduino Yun, it was one of the many boards and kits that Arduino
425 sell to their users. Weighing 32 grams with lateral dimensions of 73 millimeters by 53
426 millimeters, Arduino Yun was usually used for Wi-Fi technology; due to its in-built Wi-Fi
427 (IEEE 802.11 b/g/n). Along with this, this board supported USB port, MicroSD card Slot,
428 three reset buttons, In-circuit Serial Programming header, 16MHz Crystal Oscillator, 20
429 Digital Input and Output Pins and 12 Analog Channels. Concentrating more on the aspect
430 of video streaming, the Arduino Yun was capable of capturing video data to an SD card.
431 Hence, in order to facilitate teleportation that indicated two types of operation where a
432 machine was set to a distance: automatic mode and manual mode. The former allowed the
433 Arduino board to send Wi-Fi standard control signals in high data rate and good quality,
434 uninterrupted video transmission. The latter allowed recorded data to be extracted from the
435 SD card.

436 2.3 Camera-Based Clear Path Detection

437 The study entitled Camera-Based Clear Path Detection used to detect clarity of paths as
438 driver assistance towards obstacle avoidance on roads. With the assumptions made of video



439 camera calibration and vehicle information (vehicle speed and yaw angle) were known,
440 the researchers generated perspective patches for feature extraction in the image. Then,
441 an initial estimate of the probability of a clear path is determined thru a support vector
442 machine (SVM). With this, they performed probabilistic patch smoothing based on spatial
443 and temporal constraints to improve estimates [8].

444 What was notable to this study was the perspective patch generation. Of which, the
445 traditional way of determining objects without considering perspective information are
446 fixed-grid patch and dynamic-size patch. Since objects were found to be perpendicular to
447 the cameras optical axis, the clear path lied on the ground and was parallel to the cameras
448 optical axis. Instead of defining patches in image coordinates, they referenced the patches
449 according to world coordinates that were lying on the ground.

450 **2.4 An Efficient Crop Row Detection Method for Agri-
451 culture Robots**

452 A paper entitled An Efficient Crop Row Detection Method for Agriculture Robots was
453 used to develop an efficient crop row detection method on a vision-based navigation for
454 agriculture robots. The researchers proposed no low-level features (such as edges and
455 middle lines found on images) were needed. Therefore, complex algorithms for edging and
456 matching (especially the Hough transform) were avoided. This enabled conservation of
457 computation loads. Further, a flexible quadrangle was defined to detect crop rows, where it
458 extended or shrank this quadrangle to localize the crop rows from captured frames. The
459 study demonstrated that this method was proven effective with high time efficiency and
460 detection accuracy [9].



461 Involving this study was the image pre-processing. Two methods, as existent in the
462 paper, pertained to this pre-processing: Full-color images to gray-level images and Bina-
463 rization. The former was used to create convenience. But, the issue of preventing loss of
464 information happened when colors were devoid. And, it was a very common practice to
465 convert full-color images to grayscale ones. In agriculture applications, crops and/or weeds
466 are taken into account. With the background soil as reference, plants that belong to the
467 green chromatic coordinate, was referred to outline such component while depressing that
468 of the soils. Therefore, it made it easier to isolate these from the background. Following,
469 binarization was key to object-recognition and tracing applications. Under grayscale condi-
470 tions, this method was highly used to isolate objects from the background. All the while, it
471 was critical to consider thresholds. These might had lead to significant impact on the binary
472 image quality and computation loads. A method was proposed to choose the threshold thru
473 minimizing the intra-class variance of black and white pixels; which was widely used in
474 image-processing called Otsus Threshold.

475 The highlight of the study was about the flexible quadrangle. The method implied
476 the localization of crop rows without the need of edging or line fitting. The left and right
477 boundarie of the quadrangle were split into four sections shown in the figure below. Each
478 boundary box had a width of one pixel. These boxes were modified of their positions during
479 the vehicles proceeding to assure that the quadrangle tightly locked the crop row through
480 Hough Transforms. In essence, the whole gist of their proposed method were as follows:

- 481 • Initializing quadrangles. From the very first image, the quadrangle positions and
482 dimensions were given by other methods or as manually indicated in the paper.
483 • Pre-processing of image. While the vehicle moved, it was obtained of the grey



484 scaling image via 2G-R-B colour space and binarizing the grey scaling image using
485 Otsus threshold at every image fed.

- 486 • Check the hitting and mishitting conditions of the boundary boxes.
487 • Modify the position of boundary boxes.
488 • For the following image, keep the boundary box positions and dimensions and repeat
489 from second bullet.

490 **2.5 A technical review on navigation systems of agri-
491 cultural autonomous off-road vehicles**

492 A paper from Iran entitled A technical review on navigation systems of agricultural au-
493 tonomous off-road vehicles was used to evaluate the navigation systems for autonomous
494 vehicles used for agriculture. The predicament on the paper was that the man-power on
495 agriculture were decreased as industries attracted these labor force away. As a solution,
496 researchers on this paper were to design navigation systems for autonomous off-road vehi-
497 cles. In order for the navigation system to work, multiple sensors were considered. Some
498 of it were Machine Vision, Real Time Kinetic-Global Positioning, Mechanical Sensors,
499 Inertial Sensors Geomagnetic Direction Sensor (GDS), Ultrasonic, Fiber Optic Gyroscope
500 (FOG), Laser Radar (LADAR), Light Detection And Ranging (LIDAR), Optical encoder,
501 Potentiometer, Radio Frequency receiver (RF receiver), Piezoelectric yaw rate sensor, Near
502 Infra-Red (NIR), and Acoustic sensor. These sensors are the initial element in controlling
503 the autonomous vehicle. Fig. 2.1 shows the Block Control Diagram of autonomous vehicles
504 [2].

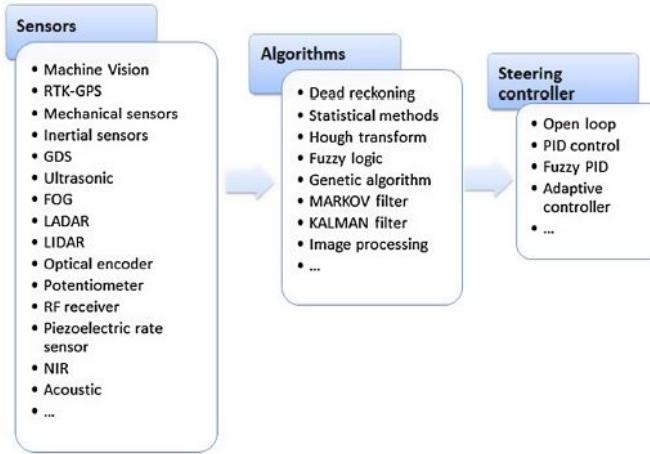


Fig. 2.1 Basic control diagram of autonomous vehicles.

2.6 Agricultural automatic guidance research in North America

In North America, the study Agricultural automatic guidance research in North America was published. It was established that Agricultural-related guidance research in North America has been review. Sensing Technologies were utilized and it was combined for automatic guidance. Automation depends on the ability of the researchers to maximize the performance of systems. Fig. 2.2 shows the basic elements of agricultural vehicle automation systems [10].

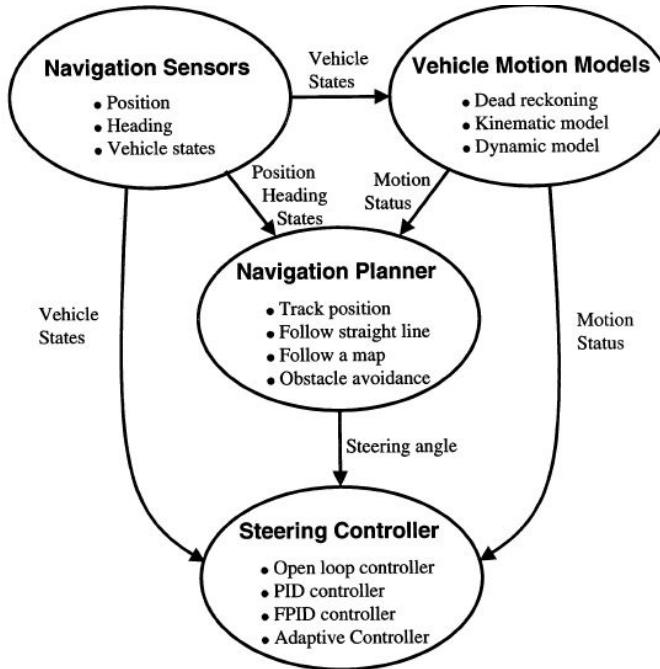


Fig. 2.2 Basic elements of agricultural vehicle automation systems

513 **2.7 Automatic guidance for agricultural vehicles in**
 514 **Europe**

515 A similar study was implemented in Germany with the title Automatic guidance for
 516 agricultural vehicles in Europe was published. This paper focused on the automatic
 517 guidance of automatic agricultural vehicles. Different types of sensor and machine vision
 518 were used to implement the study. In line with the machine vision fragment, the row
 519 arrangement of crops were significantly considered in the development of the vehicle that
 520 utilizes machine vision. Fig. 2.3 shows the images related to the field tests performed. The
 521 image was digitized and guidelines were added [11].



Fig. 2.3 Digitised image with guidelines.

2.8 Autonomous Agriculture Vehicles in Japan

One research is about the autonomous agriculture vehicles in Japan. This research has been developed in universities and government institutes, and by agricultural machinery manufacturers. The research was not able to push through the whole research in the universities due to funding limitations, because of this research in universities has concentrated on methodologies, such as navigation, sensing, and application of control theory. Development of a one dimensional image sensor, and application of neural networks and genetic algorithms, has taken place at Hokkaido University; vision guidance and fuzzy logic application at the University of Tokyo; an automatic follow-up vehicle has been developed at Kyoto University; and an automatic transport vehicle at Ehime University. At research institutes and manufacturers, with their greater financial freedom, more practical systems have been developed. A tilling robot and a driver-less air blast sprayer is being developed in the Bio-oriented Technology Research Advancement Institute (BRAIN); and an autonomous rice planter, a tillage robot and autonomous forage tractor in the research institute of the Ministry of Agriculture, Forestry, and Fishery (MAFF). Kubota Co. Ltd has developed autonomous rice planting and husbandry vehicles [12].



538 **2.9 Variable Field-of-view Machine Vision-Based Row
539 Guidance of Agricultural Robot**

540 Another research is about the variable field-of-view machine vision based row guidance
541 of agricultural robot. A new variable field-of-view machine vision method was developed
542 allowing an agricultural robot to navigate between rows in cornfields. The machine vision
543 hardware consisted of a camera with pitch and yaw motion control. Guidance lines were
544 detected using an image-processing algorithm, employing morphological features in a
545 far, near and lateral field of view, and the robot was guided along these lines using fuzzy
546 logic control. The vehicle that they tested successfully traveled through a distance of 30 m
547 towards the end of a crop row in three replications [13].

548 **2.10 Navigation System for Agricultural Machines**

549 Another article discusses the navigation system for agricultural machines. This article
550 presents a new kind of navigation system for agricultural machines. The focus is on
551 trajectory control where a Nonlinear Model Predictive path tracking for tractor and trailer
552 system is presented. The experiments of the proposed method are carried out by using real
553 agricultural machines in real environments. The goal of the research was to build a system,
554 which is able to have at least the same accuracy as a human driver. The sufficient accuracy
555 requirement was at most 10 cm lateral error at a speed of 12 km/h. The results presented in
556 the article show that the goal was met and NMPC is a feasible method for accurate path
557 tracking [14].



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Chapter 3

559

THEORETICAL CONSIDERATIONS

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Contents

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567

3.1	Corn	24
3.2	Corn Production	24
3.3	Agricultural Technology	25
3.4	Agricultural Robots	26
3.5	Philippine Agriculture	26



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3.1 Corn

569

Corn or Maize (*Zea mays L.*) is a grain crop that yields large kernels set in rows on a cob. It is highly important in the agriculture sector in many countries around the world.

571

Developed countries consume corn as a second-cycle product (e.g. in the form of meat, eggs and dairy products) while on developing countries, it is consumed directly. This crop serves as a staple diet for some 200 million people. Furthermore, this crop does not only serve as food; it can be processed into another form such as fuel (ethanol) and starch for other purposes. The many varieties of corn yield numerous products both for human and livestock consumption. [15] Figure 3.1 shows a picture of Maize.



Fig. 3.1 Pictorial Representation of Full-grown Natively-produced Corn [15]

577

3.2 Corn Production

578

Corn production consist of 10 growth stages. Initially, it starts from planting to seed emergence in Growth Stage 0. Then stages 1 to 4 counts the number of leaves that are completely unfolded. Succeeding stages describe the appearance of the corn cob and the



581 grain mass changes. The 9th stage describe the physiological maturity. Lastly, kernels are
582 dried in growth stage 10 and the corn is now fully grown.

583 Production of Corn requires specific environmental requirements for it to grow. This
584 crop is considered a warm weather crop; hence, it is grown in areas with temperature more
585 than 19 degrees Celsius. Germination of the seeds require a minimum of 10 degrees Celsius
586 temperature but an increase in the soil temperature up to a certain degree would allow a
587 faster growth for Maize. 32 degrees Celsius is the approximate critical temperature that
588 could dangerously affect the yielding of the corn. Another environmental factor required is
589 water. Each crop is estimated to have used 250 liters of water in the absence of moisture
590 stress at maturity. Last on the environmental requirement is the soil; it is the most crucial
591 factor that could greatly affect the production of corn. Suitable soil for corn is loam soil
592 – it must have morphological properties, good internal drainage, and optimal moisture
593 regime. [15]

594 **3.3 Agricultural Technology**

595 Agricultural Technologies are basically equipment used and developed for agricultural
596 purposes. Tools such as Plough, Yoke, Mallot, Sickle, etc. are considered Traditional tools.
597 More advanced tools include tractor, chisel plough, hydroponics, sprinkler system and
598 many others.

599 Agricultural Technologies allowed considerable progression in crop production. Many
600 public and private sector organizations develop these with the aim to address the various
601 biotic and abiotic constraints. With the advancement in tools, America is able to implement
602 Modern Agriculture, a wide type of production. It is an agriculture system wherein farmers



603 use higher end technology and information to control most components of the system. In
604 contrast with the traditional farmers who personally work with resources at hand, modern
605 farmers are dependent on linkages—access to resources, technology, management, and many
606 others. Productivity has increased as machines and computers have eliminated laborious
607 parts of the job. [16]

608 **3.4 Agricultural Robots**

609 Agricultural robots are designed to be implemented on an unstructured environment. Hence,
610 these robots are expected to be dynamic, uncertain, complex, highly variable, and hostile. In
611 order to build an agricultural robot, multiple design principles are taken into consideration.
612 This includes product specification such as speed, system analysis such as the function,
613 concept development such as alternative methods, feasibility, and what not. Figure 3.2
614 shows the flowchart of the implementation of concepts on an agricultural robot. [17]

615 **3.5 Philippine Agriculture**

616 The Philippines is rich in agricultural lands, where about one-third of the land area of 30
617 million hectares is classified as is. In the year 2013, about 30% of the Filipino workforce
618 has been employed in this sector. [18]. The major contributors to agriculture's gross value
619 is known to be food crops, specifically rice and corn. The croplands of the Philippines
620 are presently under sever environmental stress such as decresing man-land ratio has led
621 the landless to occupy and cultivate ecologically unstable marginal lands. Other problems
622 have emerged as well in the sector of agriculture. Urgency for food security, employment

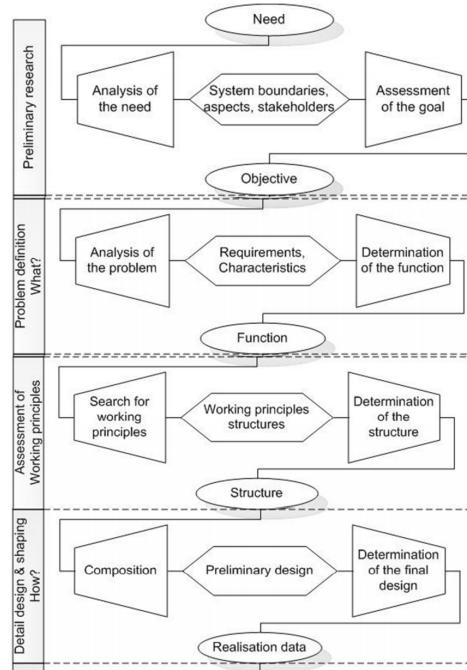


Fig. 3.2 Flowchart of Agricultural Robot Design [17]

623 generation to meet the 10-point agenda of the government, and greater global competitive-
 624 ness trigger the major concerns of the Philippine agricultural sector. In order to respond
 625 to this urgent needs of an increasing population while poverty also increases, the Philip-
 626 pine agricultural sector in general has embraced the credo of conventional agricultural
 627 practices. [?]



628

Chapter 4

629

DESIGN CONSIDERATIONS

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Contents

631

632

4.1	Raspberry Pi 3 Model B	29
4.2	Raspberry Pi Camera Module	32
4.3	Virtual Network Computing	32
4.4	IP Address	33
4.5	Design Reference	34
4.6	Design and Dimensions	34
4.7	Components	36

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640 **4.1 Raspberry Pi 3 Model B**

641 Raspberry Pi is a low-cost microcomputer originally designed to aide young people in
642 programming. It is advantageous in terms of size, portability, cost, programmability, and
643 connectivity. Raspberry Pi is mounted on a credit card-sized board and has multiple feature
644 ports such as USB 2.0, HDMI, Power, SD Card, and many more depending on the model.

645 On this research, Raspberry Pi 3 model B is used. Its features include:

- 646 • A 1.2GHz 64-bit quad-core ARMv8 CPU
- 647 • 802.11n Wireless LAN
- 648 • Bluetooth 4.1
- 649 • Bluetooth Low Energy (BLE)]
- 650 • 1GB RAM
- 651 • 4 USB ports
- 652 • 40 GPIO pins
- 653 • Full HDMI port
- 654 • Ethernet port
- 655 • Combined 3.5mm audio jack and composite video
- 656 • Camera interface (CSI)
- 657 • Display interface (DSI)
- 658 • Micro SD card slot (now push-pull rather than push-push)



659 • VideoCore IV 3D graphics core

660 Figures 4.1, 4.2, 4.3, 4.4 and 4.5 show the schematic diagrams essential to this research.

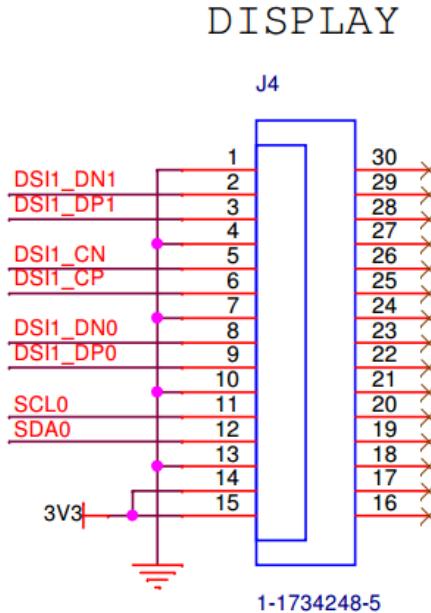


Fig. 4.1 Schematic of Display [19]

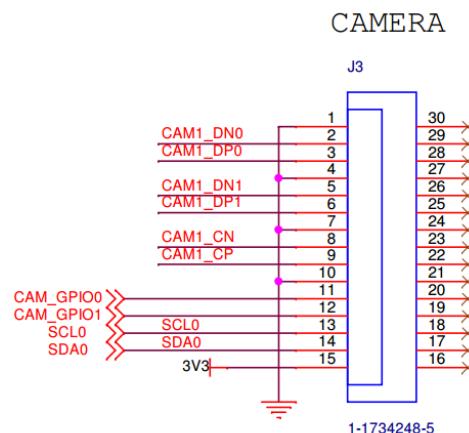


Fig. 4.2 Schematic of Camera Port [19]



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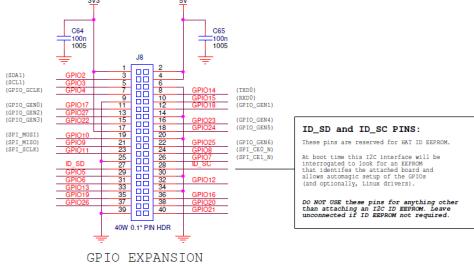


Fig. 4.3 Schematic of GPIO Expansion [19]

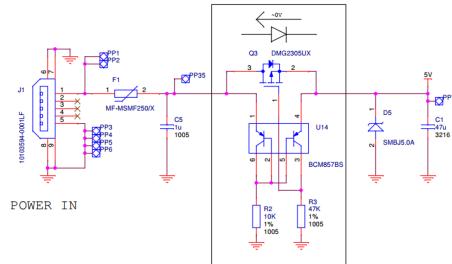


Fig. 4.4 Schematic of Power Input [19]

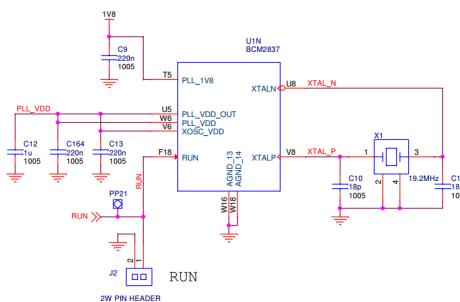


Fig. 4.5 Schematic of RUN [19]



661 4.2 Raspberry Pi Camera Module

662 The PiCamera is a camera module for Raspberry Pi that allows the users to capture still
663 photos and record videos in high definition. A camera port on the microcomputer is
664 available for this device. In this port, the camera is connected while Pi is still switched off
665 and once it is connected to the board, the devices are switched on. The camera software is
666 available on the Raspberry Pi Configuration Tool. Python3 is utilized in order to preview
667 the camera. Figure 4.6 shows the code to be executed in order to allow the preview of the
668 camera. [20]

```
from picamera import PiCamera
from time import sleep

camera = PiCamera()

camera.start_preview()
sleep(10)
camera.stop_preview()
```

Fig. 4.6 Code for Camera Preview

669 4.3 Virtual Network Computing

670 Virtual Network Computing (VNC) is a graphical sharing system on a desktop that allows
671 remote access and control of a desktop interface of one device from another. The events
672 from the controller such as keyboard and mouse are transmitted to the screen over the
673 network from the remote host. On the Raspberry Pi, it is necessary to install the TightVNC
674 package in order to utilize this system. To install this package, the code *sudo apt-get install*



675 *tightvncserver* is used. Running the TightVNC Server would prompt the user to input the
676 password *tightvncserver*. From the terminal, VNC is started. A session on VNC display
677 one with full HD resolution is written as *vncserver :1 -geometry 1920x1080 -depth 24*.
678 . In order to run the VNC server on the Pi, a command on a file is necessary. The shell
679 script *#!/bin/sh (next line) vncserver :1 -geometry 1920x1080 -depth 24 -dpi 96* is to be
680 created. By inputting the code *chmod +x vnc.sh*, the shell script with filename *vnc.sh* is
681 made executable. In order to run the file at any time, the code *.vnc.sh* is executed. The
682 procedure mentioned above is the initialization of VNC on the Pi module. With this, a
683 VNC client on the personal computer is needed in order to connect the computer to the
684 VNC server and have control of it. [21]

685 **4.4 IP Address**

686 Internet Protocol (IP) Address is an address that is used to identify a unique device over an
687 IP network. It is a core in network design as it is a Network Foundation service. It provides
688 the foundation of other network and user services and it allows the interaction of devices
689 within the network. [22] Raspberry Pi 3 model B is connected to a Local Area Network.
690 Hence, as any device connected to a LAN, Pi is assigned a unique IP address. IP address is
691 vital information in connecting the Pi to another machine using VNC. The code *hostname I*
692 reveals the IP Address of the Pi using the terminal.



Fig. 4.7 Design Reference for The Corn Planting Robot

693 4.5 Design Reference

694 Figure 4.7 shows the researchers' design reference for the corn planting robot. The design
695 was found online¹ which is uploaded by user named Luthfi Hasni. The design uses a PIC
696 or a Programmable Integrated Circuit to control the robot. It uses several sensors as its
697 navigation system. Besides from the 2 motors that controls the wheels of the robot, it has a
698 third motor that controls the boring of the soil and the sowing of the corn seeds at the same
699 time.

700 4.6 Design and Dimensions

701 Portability is one of the main considerations of the robots design. Figures 4.9 - 4.11 shows
702 the design and dimensions of the corn planting robot. The figures show that the researchers
703 robot is much smaller compared to the design reference. The robot has a length of 262 mm,
704 a width of 215 mm, and a height of 180 mm.

¹youtu.be/QooHpnYLj1w

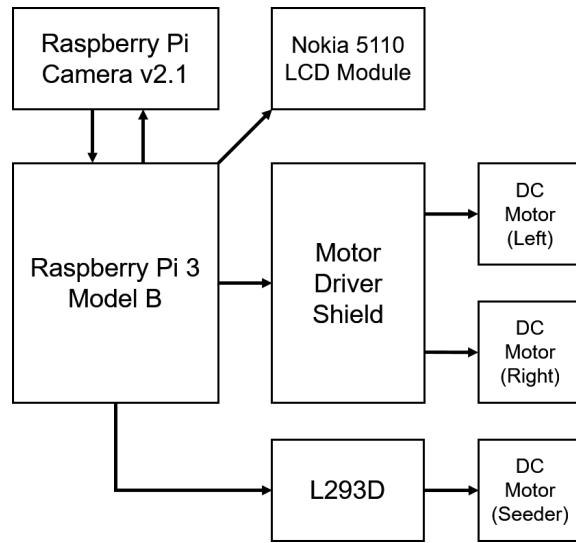


Fig. 4.8 System Design Diagram

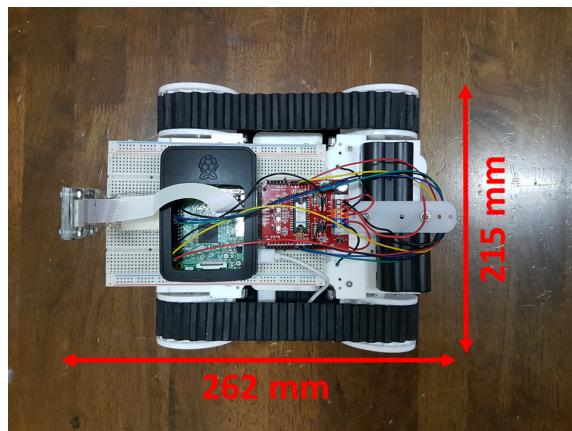


Fig. 4.9 Top View of the Corn Planting Robot and its Dimensions

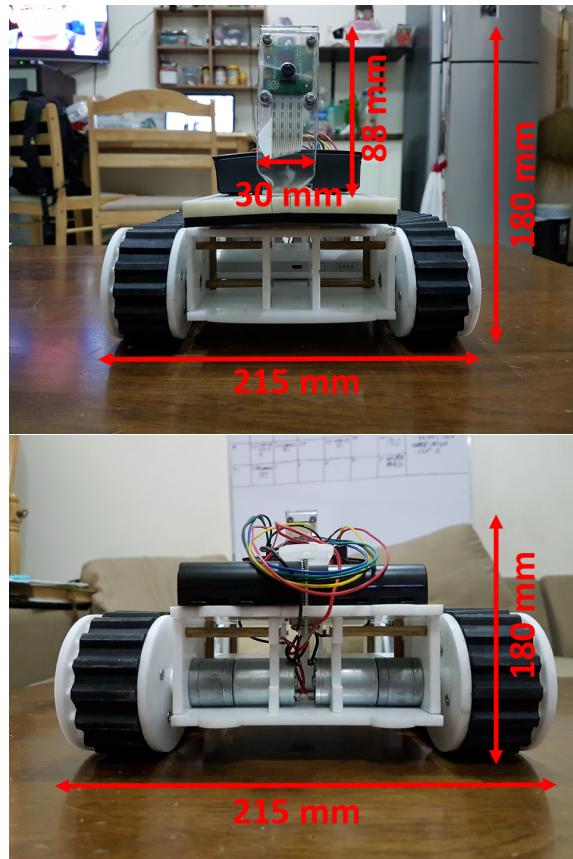


Fig. 4.10 Front and Back View of the Corn Planting Robot and its Dimensions

4.7 Components

As seen on Figure 4.12, part B is the continuous track of the robot. The researchers chose to use a continuous track for the robot since it is more suitable to be used on off-road environments on which corn is planted. The continuous track will help on the slip of the robot on the soil and help with the mobility of the robot. The robot uses a 6V DC geared motor which controls the continuous track (B) which makes the robot move. Two 7.4 V battery packs (D) that are connected in parallel are used to supply voltage to the motors. The motors and the battery packs (D) are then connected to the motor driver shield (E)



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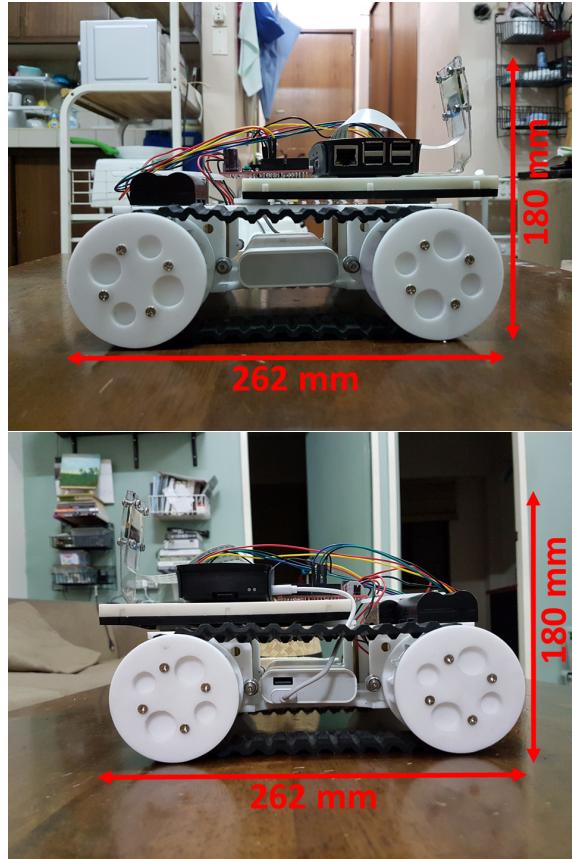


Fig. 4.11 Left and Right Side View of the Corn Planting Robot and its Dimensions

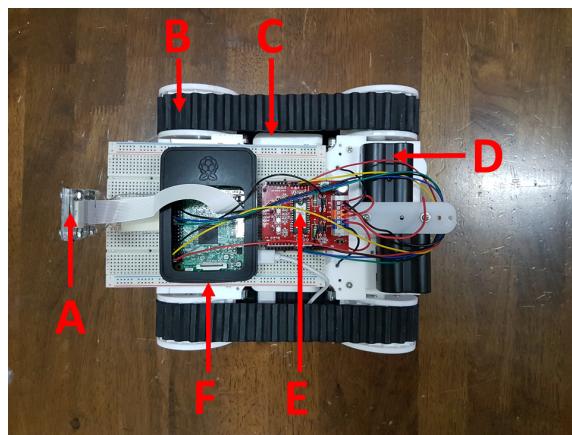


Fig. 4.12 Top View of the Corn Planting Robot with its Main Components Pointed Out



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713 which controls the direction of the motors individually thereby controls the movement
714 of the whole robot. The motor driver shield is connected to the Raspberry Pi 3 Model B
715 (F). The Raspberry Pi is the main processing unit of the robot. It is responsible for the
716 image processing, remote connection, and the control of the motor driver shield (E). For
717 the image processing, the researchers' used the Raspberry Pi Camera v2.1 (A). We used the
718 Raspberry Pi Camera for it allows the robot to utilize the GPU (Graphical Processing Unit)
719 of the Raspberry Pi, which makes the image processing faster and decrease the processing
720 load on the main processing unit. Lastly, the Raspberry Pi is then powered separately by a
721 power bank.

722 The researchers' decided to use the Raspberry Pi instead of PIC or Arduino and other
723 development boards due to its high processing ability, especially on image processing. PIC
724 and Arduino are more suitable for applications that uses analog sensors or is more focused
725 on hardware projects while the Raspberry Pi is more suitable for software processing. Since
726 the corn planting robot would use computer vision to navigate across the corn field, the
727 Raspberry Pi is more suitable for this kind of application. With a dedicated camera module
728 that is directly compatible and can be easily set up, and a GPU or a Graphical Processing
729 Unit, the Raspberry Pi can do image processing a lot faster which would allow the robot to
730 do real time image processing and navigate across the field at the same time.



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Chapter 5

732

METHODOLOGY

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Contents

734

735

5.1	Implementation	40
5.2	Evaluation	41
5.3	Summary	42

736

737

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5.1 Implementation

The project governed the interfacing of computer vision for a robot systems navigation. This proposed system was conditioned to navigate on dry land terrains at daytime. Further, certain considerations were taken as per testing. The land area for corn plantation had been downscaled to a 60-inches by 20-inches (by a factor of 1/65th length-wise and 1/197th width-wise) plant box for conduciveness of the study. Such downscaling managed to model one cornrow which was enough to attempt the forwarding control of the robot system. Made out of cardboard boxes lined with garbage bags (for water-proofing), the box frame was filled with loam soil: pre-plowed with two-inches deep as irrigation lines, and pre-holed, five-inches apart.

Proceeding, the mechanism produced for this study was an electrically-driven sower machine. Its cost-effectiveness (since it was made from a recycled canister with a motor screwed to its base) made it implementable to simulate a holed-disc dispensing unit. As the motor was activated manually by the user through a computer, the disc was properly timed to dispense appropriate amount seeds. The process mainly governed on asserting the seeding mechanism first before it proceeded forward.

Mentioning that the land was pre-holed, the robot was now capable to be controlled by the user through a computer. The keyboard keys W (Forward), A (Left), S (Backward) and D (Right) were assigned to direct the basic movement of the system. The E key was made to function to halt the system. And, finally, to consolidate the basic movement of Seed Forward Seed Forward [...], the 3 key was assigned to operate this iteration. The whole system had been under the implementation of a Raspberry Pi 3 Model B SBC microprocessor unit with Raspberry Pi Camera V2 Video Module as its vision peripheral.



762 With these systems, interfaced and connected to a tank chassis with two motors rated
763 at 0.5A and 6V each; an additional one for the seeding mechanism rated at 0.25A and
764 5V; back wheels connected directly to the motor, leaving the front wheels as free wheels.
765 Supplied by two batteries (one per motor) rated at 5.7V with 5780mA current delivery
766 each.

767 **5.2 Evaluation**

768 The robot system was expected to plant 11 holes in 1.286 minutes per row. Since this
769 data were to include the seeding and the holing processes, the group attempted to modify
770 the system by removing the puncturing mechanism due to time constrains. With these
771 benchmarks scaled from a 100-meter-by-100-meter land area with eight persons to labor
772 the whole field, the system relatively delivered to emulate the benchmarked performance.
773 With three seeds to be planted per hole set for twenty trials (in ideal), the gathered data
774 managed to reach an observable consistency in detecting the possibility of jamming. This
775 was the very hampering concern of the whole study. Seeds were stuck inside the crevices
776 of the motor with the base of the canister. At this point, the group decided to remove the
777 factor of amount of seeds and just went with the success of having at least a seed put to a
778 hole. The factors affecting the prior trials had been the following:

- 779 • Misaligned seeding machine
- 780 • Stillness or non-rotation of the seeding machine
- 781 • Wrong dispensing of seeds (with less than 3 seeds)
- 782 • Positioning of the chassis in-line with the irrigation line



- 783 • Unlevelled land area where the belt wheel got jammed

784 **5.3 Summary**

785 In a nutshell, the whole study was a downscale simulation of a corn field plantation seen in
786 the Philippines. With a system made out of Raspberry Pi system and a homemade seeding
787 mechanism only, the system was set to plant three corn seeds in an 11-hole cornrows in
788 under a minute. Through the implementation of a computer vision with manual navigation
789 controls, the study delivered pleasing results.



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Chapter 6

791

RESULTS AND DISCUSSION

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Contents

793

6.1 Summary	44
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796

6.1 Summary

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The study focused heavily on the seeding and navigation mechanisms of the proposed robot system. Minding more on the former, the factors governing on testing the systems reliability were its row completion time and the number of successfully-filled holes done by itself. In order to quantify the success of filling row holes, a parameter called success rate was used to contrast the holes that were unfilled; which was the ratio of the successfully-filled holes and the total number of holes. The process was trialed 20 times.

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As for the navigation mechanism, the current extent of the robot system had managed to be wirelessly controlled through the RaspberryPi microprocessor. The interface for its control was implemented through a local area network that allowed a common point of connection between a laptop (which provided the controls for the system) and the microprocessor (which was being controlled). The alternation of actuating the seeding mechanism and the forwarding the robot was done in such particular manner.

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Figure 6.1 showed the Gantt chart relationship of the time taken by the robot to traverse a row and the number of successfully-filled holes. Visually, the highlighted trials signified the recurring problem of the system: the jamming of the seeding mechanism caused by the seeds being stuck in the crevices of the prototype. The trend was observed that jamming could be anticipated to occur when the number of successfully-filled holes began to decrease significantly; apart from the actual observation of hearing the motor to falter.

With this set of data, the relationship between the time and success rate was tested through measuring the central tendencies, variances, correlation and regression. For the success rate, it was shown that the mean met the median by a factor of approximately two percent. And, to show consistency of the system, the mode converged to reflecting 88.89%



Trial Count	Row Completion Time, seconds	Successfully Filled Holes									Success Rate
		1	2	3	4	5	6	7	8	9	
1	8.98										77.78%
2	8.76										44.44%
3	8.7										88.89%
4	8.62										88.89%
5	9.12										88.89%
6	8.73										77.78%
7	8.25										66.67%
8	8.64										77.78%
9	8.77										77.78%
10	8.81										88.89%
11	9.17										77.78%
12	8.96										55.56%
13	8.84										55.56%
14	8.66										44.44%
15	8.64										66.67%
16	8.75										88.89%
17	9.03										88.89%
18	8.95										77.78%
19	9.14										88.89%
20	9.09										88.89%

Fig. 6.1 Gantt Chart Analysis of Row Completion Time and Success Rate

819 success rate. With the variance of 2.17% and standard deviation of 14.74%, these went to
 820 show that the values considerably were close to the average; proving well of its reliability.

821 The row completion time showed greater performance. The three central tendencies
 822 were approximately converging to 8.8 seconds. For convenience, the inspection for the
 823 mode was done by rounding-off values of time in one decimal place. The variance and
 824 standard deviation of this parameter proved well of both the consistency and reliability of
 825 the system. With 0.05 seconds of variance and 0.22 seconds of standard deviation, 20 trials
 826 of the system described its performance with the approximations from all the benchmarks



Success Rate	
Mean	75.56%
Median	77.78%
Mode	88.89%
Variance	2.17%
Standard Deviation	14.74%
Row Completion Time, seconds	
Mean	8.831
Median	8.99
Mode	8.8
Variance	0.05
Standard Deviation	0.22
Correlation	
0.311744361	

Fig. 6.2 Statistical Analyses of Time and Success Rates

827 aforementioned.

828 From the figure 6.3, it illustrated the scatter plot diagram of the system results under
 829 20 trials. A trend line was modeled to estimate the regression analysis of the trial results.
 830 Reiterating the value of correlation (0.3117), it verified that there was a moderate, positive
 831 relationship of the time and the success rate. With the coefficient of determination (0.09718),
 832 it showed the probability of having independence between the success rate and the time
 833 and its difficulty to be predicted by the trend line.

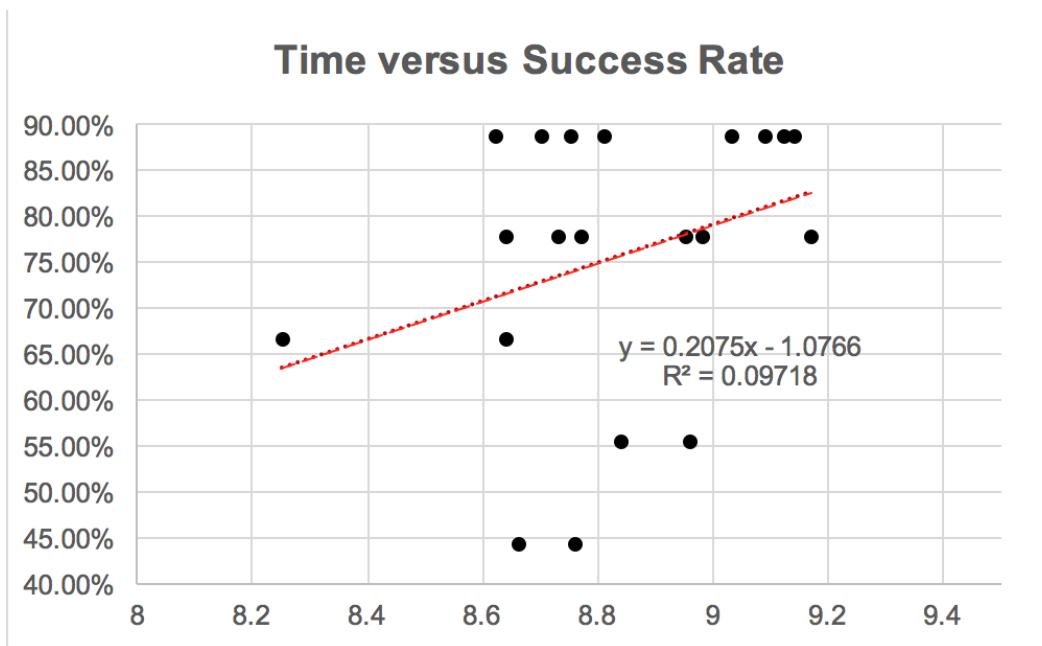


Fig. 6.3 Time versus Success



834 **Chapter 7**

835 **CONCLUSIONS, RECOMMENDATIONS,
836 AND FUTURE DIRECTIVES**

837 **Contents**

838 7.1 Concluding Remarks	49
839 7.2 Contributions	49
840 7.3 Recommendations	49
841 7.4 Future Prospects	50



844 **7.1 Concluding Remarks**

845 In this Thesis, the researchers developed a potential robot system for corn planting in the
846 Philippines. The researchers also implemented a computer vision to its navigation and
847 control mechanism. The robot system was implemented using the Raspberry Pi and its
848 camera module. Through data gathering and analysis, the researchers are able to show that
849 the corn planting robot system can potentially replace human labor in corn production due
850 to its superior speed in planting corn.

851 **7.2 Contributions**

852 The interrelated contributions and supplements that have been developed in this Thesis are
853 listed as follows.

- 854 • the seeding mechanism for planting various kinds of average size seeds;
855 • the remote controlled planting robot with real-time video streaming ;

856 **7.3 Recommendations**

857 A larger scale, multiple row corn planting robot system with a boring capability is recom-
858 mended for large producers of corn as a commercially viable production technique given
859 its superiority in terms of quality, production rate, and return of investment as compared to
860 the conventional corn planting approach.

861 This report also recommends further work to:

- 862 • Quantify the environmental factors seen at an actual cornfield



- 863 • Consider the amount of slip and skewing of the wheels during navigation
864 • Categorize the weight limit in relation to the optimal speed of the robot
865 • Develop an algorithm for further automation

866 **7.4 Future Prospects**

867 There are several prospect related in this research that may be extended for further studies.
868 The suggested topics are listed in the following.

- 869 1. A Robot System for Rice Planting in the Philippines
- 870 2. Development of a Computer Vision Navigation System for Planting Corn in the
871 Philippines
- 872 3. Multiple Camera Image Processing for Rice Planting Success Monitoring and Navi-
873 gation
- 874 4. Rice Planting Hover Craft Robot for Paddy Field Farming
- 875 5. Aerial Soil Analysis for Potential Agricultural Farm Lands in the Philippines using
876 Swarm Robots



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Appendix A ANSWERS TO QUESTIONS TO THIS THESIS

Contents

A1	How important is the problem to practice?	55
A2	How will you know if the solution/s that you will achieve would be better than existing ones?	55
A2.1	How will you measure the improvement/s?	55
A2.1.1	What is/are your basis/bases for the improvement/s?	55
A2.1.2	Why did you choose that/those basis/bases?	55
A2.1.3	How significant are your measure/s of the improvement/s?	55
A3	What is the difference of the solution/s from existing ones?	56
A3.1	How is it different from previous and existing ones?	56
A4	What are the assumptions made (that are behind for your proposed solution to work)?	56
A4.1	Will your proposed solution/s be sensitive to these assumptions?	56
A4.2	Can your proposed solution/s be applied to more general cases when some of the assumptions are eliminated? If so, how?	57
A5	What is the necessity of your approach / proposed solution/s?	57
A5.1	What will be the limits of applicability of your proposed solution/s?	57
A5.2	What will be the message of the proposed solution to technical people? How about to non-technical managers and business men?	57
A6	How will you know if your proposed solution/s is/are correct?	58
A6.1	Will your results warrant the level of mathematics used (i.e., will the end justify the means)?	58
A7	Is/are there an/_ alternative way/s to get to the same solution/s?	58
A7.1	Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s?	58
A7.2	Is there an approximation that can arrive at the essentially the same proposed solution/s more easily?	58
A8	If you were the examiner of your proposal, how would you present the proposal in another way?	59
A8.1	What are the weaknesses of your proposal?	59



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Appendix B VITA

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948	A1 How important is the problem to practice?
949	Problems are the bases of the implementation of practices. Practices are implemented when it actually resolves a problem. Practices without problems to address are useless. Hence, problem is highly significant to the practice.
950	
951	
952	A2 How will you know if the solution/s that you will achieve would be better than existing ones?
953	
954	In order to recognize whether the solutions we achieved are better than existing ones, we need to compare and contrast the output of the prevailing solution with ours. Analysis of the Results and Discussions for both solutions is crucial in determining the dominant answer to the problem.
955	
956	
957	
958	A2.1 How will you measure the improvement/s?
959	In order to measure improvements, different tests are considered. In our research, the speed and the quantity of the seed-filled holes are measured. Afterwards, the measurements obtained are compared with the speed and reliability of manual planting. With this, the improvements are measured.
960	
961	
962	
963	A2.1.1 What is/are your basis/bases for the improvement/s?
964	Improvements are based on the increase in the productivity of a system. It is said that a system has improved when it is capable of yielding better result than prior solutions. In relation with our thesis, increase in speed and number of holes filled were the bases for improvements.
965	
966	
967	
968	A2.1.2 Why did you choose that/those basis/bases?
969	These bases are quantifiable such as it can be physically measured. From the physical measurement, comparison are easier on the end of the researchers. Hence, our group decided to choose these bases.
970	
971	
972	A2.1.3 How significant are your measure/s of the improvement/s?
973	These measures of improvement are highly significant in determining the implementation of the system after the research. When the measure of the improvements are favorable, it is likely that the system is recommended and applied.
974	
975	



976 **A3 What is the difference of the solution/s from ex-**
 977 **existing ones?**

978 This study was premature, if not introductory, in Philippine agricultural technology targeted
 979 specifically with corn production. Current studies did exist but they contributed more on
 980 weed removals. Hence, the difference of this study was to focus more on the seeding phase
 981 of corn production.

982 **A3.1 How is it different from previous and existing ones?**

983 Reiterating, this proposal was targeted on planting corn seeds in the corn production process.
 984 Since there were seldom researches about corn planting robots (not to mention that this
 985 was more defined in the field of rice planting), there was insufficiency of access to studies
 986 about this; presumably.

987 **A4 What are the assumptions made (that are be-**
 988 **hind for your proposed solution to work)?**

989 It is assumed that the soil for planting corn or the corn field itself is already set for the robot
 990 to place the seed on, which means, the soil is already bored or holed. It is also assumed
 991 that the robot would start correctly on first hole in order to have a successful sequence of
 992 seeding, which means, the holes are or assumed to be 5 inches apart from each other and
 993 has a diameter of approximately 2 inches, and a depth of 2 inches. The ground is assumed
 994 to be flat, and no presence of obstruction or ground level disturbances are present. Lastly,
 995 the robot itself is assumed to go on a straight path, and skewing and slipping of the wheels
 996 is not present.

997 **A4.1 Will your proposed solution/s be sensitive to these as-**
 998 **ssumptions?**

999 For this proposal, the system is highly sensitive to these assumptions.



A4.2 Can your proposed solution/s be applied to more general cases when some of the assumptions are eliminated? If so, how?

The system might still work if there are changes in the diameter and depth of the holes in the soil, but must be adjusted if the distance of the holes is inconsistent or not 5 inches apart from each other. In cases where the ground is not stable or flat, or the robots wheel skewed or slips, the system fails.

A5 What is the necessity of your approach / proposed solution/s?

The necessity of this solution was to integrate the advancement of technology in its wide reach and applicability to various fields. Inarguably, this had been the main purpose of technology.

A5.1 What will be the limits of applicability of your proposed solution/s?

Its limits would have to be the locally available technologies to implement this proposal, as well as the currency of the technologies planned to use (i.e. there might even be a more efficient and more optimized system or method in contrast with the proposed one).

A5.2 What will be the message of the proposed solution to technical people? How about to non-technical managers and business men?

Expectedly, this study might be too abstracted (since the systems used were modular) or too inefficient (due to the number of variables taken to study in this study). But, of greater potential to computer vision, these people might begin to stimulate theories of computer vision in this type of application specifically.

Since this study was focused more on the technological side of the industry, these businessmen might think more on gaining profit from these advancements. In return, they would have this marketed to consumers (which included non-technical managers) both international and local; with the hope of the former in aiding the local industry. But, specifically for non-technical managers, they might focus their attention to the potentiality of the proposal to the modernization of the traditional processes that they face; especially considering the current state of technology in the Philippines.



1031 **A6 How will you know if your proposed solution/s
1032 is/are correct?**

1033 The proposed solutions were observed in reference to pertinent benchmarks in the study
1034 focus. Hence, with the preliminaries of gathered information from the domain experts,
1035 these were met considerably with the outcomes of the study.

1036 **A6.1 Will your results warrant the level of mathematics used
1037 (i.e., will the end justify the means)?**

1038 Since this study was a proposal, the fundamental models of statistical analyses were used.
1039 And, with only two variables at study, it was but practical to resort to such simple models
1040 in order to present the most obvious and most digested relationship of the variables.

1041 **A7 Is/are there an/_ alternative way/s to get to the
1042 same solution/s?**

1043 There are various ways to make the solution work. The solution is not bounded open the
1044 system that is proposed on this paper.

1045 **A7.1 Can you come up with illustrating examples, or even bet-
1046 ter, counter examples to your proposed solution/s?**

1047 For example, the system can implement a different seeding mechanism to sow the seeds
1048 and can also integrate a boring mechanism it automatically bore the soil and sow the seed
1049 in a single action.

1050 **A7.2 Is there an approximation that can arrive at the essen-
1051 tially the same proposed solution/s more easily?**

1052 It can be approximated the example solution would work better than the proposed solution
1053 because of its ability to bore and seed at the same time, which means, the seeding success
1054 rate is next to 100



1055 **A8 If you were the examiner of your proposal, how**
1056 **would you present the proposal in another way?**

1057 In estimation, its method of presentation would be not just in the development of a robot
1058 system, but with the consideration of the economical pros and cons of lessening human
1059 interaction in corn production. In that way, this proposal is not just a presentation of an
1060 idea, but of self-critiquing, as well.

1061 **A8.1 What are the weaknesses of your proposal?**

1062 The weaknesses of this proposal were the timeframe given to execute the study and the
1063 projection of its extent against the limitation knowledgebase.



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Appendix B VITA

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Paul Vince A. Abe is currently pursuing Bachelor of Science Degree in Computer Engineering at De La Salle University-Manila. His role in the group is the Domain Expert. Along with his extensive ability in correlating needed topics in specifying both the strengths and projected weaknesses of the project, he contributes mainly in creating the knowledge pool of the group.

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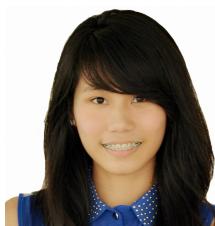
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