A Robot System for Corn Planting in the Philippines

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

by

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August, 2016

ORAL DEFENSE RECOMMENDATION SHEET

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

ABE, Paul Vince A.
AMADO, Dan Paulo E.
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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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August 19, 2016

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THESIS APPROVAL SHEET

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ABSTRACT

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

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Chapter 1
INTRODUCTION

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1.1 Background of the Study

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

The development or agricultural robot, led some researchers to utilize image processing for navigation. Digital image processing allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing. Today machine visions are applied in two dimensions (2-D) or three dimensions (3-D). The 2-D vision systems use area scan or line scan cameras as well as appropriate lighting to measure the visible characteristics of an object such as, quality of surface appearance, edge based measurements and presence and location of features. In agriculture, 2-D has applications in sorting based on color, shape and size. In 3-D analysis basically there are two techniques applied: stereo vision and LED/laser triangulation. Machine vision-based guidance showed acceptable performance at all speeds and different paths by average errors below 3 cm. It was proposed that using both machine vision and laser radar may provide a more robust guidance as well as obstacle detection capability [Mousazadech, 2013].

The adoption of improved technology for yellow corn production has resulted in significant yield increases. Yellow corn accounted for 23% of total corn production 1985, and for 58% by 2001. It should be noted that, however, that the national average yield of 1.82 tons per hectare for white and yellow corn (in 2001) is low when compared to corn fields in other Asian countries [Gozales and lapina, 2003].

1.2 Prior Studies

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

- A resource entitled ”A Robot System for Paddy Field Farming in Japan” is set to utilize a robot-operated farming technology guided from tillage to harvest in large-scale agriculture. In such application, it is seen that in the cultivation of rice, wheat and soybean (in Japan, as per the researchers’ host country), there has been three types of robot in development. First, a robot tractor, followed by a rice transplanter, finally, combines harvester robots. Real-time Kinematic Global Positioning System (RTK-GPS) and Inertia Measurement Unit (IMU), or Global Positioning System (GPS) compass are utilized for navigation system. These robots have a Controller Area Network (CAN) bus that all sensors and computers can be connected and interfaced in common among other robots such as tractors, rice transplanters and combine harvesters. Hence, these could be officiated in autonomous operation in paddy fields as well as discussing in this paper the ability of moving across fields for effective operations and safe guidelines for robot systems.

- Another is a resource entitled A Global Positioning System guided automated rice transplanter” that speaks about a new Global Positioning System (GPS) guided rice transplanter. This study is very coherent to the aforementioned research as this resource speaks more about the utilization of the GPS technology they used in implementing the three robots as tractor, rice transplanter and combine harvester. With these, such robot systems were GPS-guided with their respective position data and inertia measurement unit direction data. This new one (inherent to this resource) is guided with GPS position data with tilt correction during straight driving and guided with the data gathered from the IMU during each robot’s turning at the head land. An antenna prescribed to the GPS is set to 1.5 meters (as height) and 0.4 meters as its offset at the vehicle’s front axle. The actuator control command and data communication protocols adhere through the controller area network (CAN) bus. Hence, steering and transmission systems are controlled through electrical actuators with respect to the location in a given field.

- Lastly, a resource entitled Robot Farming System Using Multiple Tractors in Japan with the objective to develop a robot farming system using multiple robots. It discusses the application of multiple robots in Japan agriculture for rice, wheat, and soybean. The system that is discussed in this paper includes a rice planting robot, a seeding robot, a robot tractor, a combine robot harvester, and several tools attached on the robot tractor. The main objective of this paper is to help the farmers gain more profit thru farming. The paper focused on robot management system, low-cost system, robot farming safety, and real-time monitoring/documentation.

1.3 Problem Statement

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

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

1.4 Objectives

1.4.1 General Objective(s)

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

1.4.2 Specific Objectives

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

1.5 Significance of the Study

Computer Engineering is the marriage of electronics and programming. Implementing a programming-based instruction on an electronic hardware is a fundamental action in the progression of this course. With the use of programming, hardware systems are automated with a more defined set of instructions. With this, the study of a Robot System for the Paddy Field in the Philippines would be an unwavering focus related to the field. The implementation of this robot system would reinforce automation with the aid of computer vision. Moreover, the electronic and programming skills of the students would be strengthened with this research. External elements such as the edge of the paddy field increase the complexity of this longstanding research. Robot systems are no longer fairly new. However, introducing computer vision that would direct a robot system that could withstand environmental factors, specifically in paddy fields, would establish an innovation for the field of Computer Engineering and for the country Philippines as well.

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

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

1.6 Assumptions, Scope and Delimitations

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

- Focused on guiding a robot system thru computer vision across a small-area of a rural corn field

- With added mechanism of planting seeds with make-shift, recycled canister-motor combination

- Interfacing navigation RaspberryPi with its own camera module
- Tested in 100 square-meter-area at Cagayan

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

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

1.7 Description and Methodology

The core of the mobile robot is the GizDuino X Version 2.0. It handles the operations of the robot by processing input data from the camera and commanding the motors of the wheels to mobilize the robot. Using edge detection software, in this case OpenCV, the robot calculates for the distance, speed, and direction it has to go. The edge of the paddy works as the limit where the robot needs to go, and with the use of a rice planting mechanism the robot fills the whole segment of the paddy area with rice seedlings placed on a specialized container. Light emitting diodes are utilized by the robot for night operations. Weatherproofing or waterproofing the robot should also be considered taking to account that the paddy area is damp or wet during the plantation process and puts the robot at risks of water damage. Unexpected rain and flood are also few of the risks that should be considered for waterproofing the robot. It is expected that once the robot is set, it will do its work with 0 to minimum human interaction or intervention, except during the refilling of the seedlings in the container.

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

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

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

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

1.8 Estimated Work Schedule and Budget

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**

Chapter 2
LITERATURE REVIEW

Contents

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.

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
- Generating a frame template thru the summation of the columns found on the skewed images
- Assuming a lateral motion that was relative to the crop by comparing such template to an initial crop template

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

2.2 Video Streaming In Autonomous Mobile Robot Using Wi-Fi

Another paper entitled Video Streaming In Autonomous Mobile Robot Using Wi-Fi was used to consider the relevance of a capable telemetry system. Having an autonomous mobile robot required to cover a distance from one point to another with two or more wheels. To reach a destination, it was not always possible that a person could not reach. Through an Autonomous Arduino Yun for four-wheeled mobile robots, it gave capabilities to robots to actually move from one point to another by finding paths and avoiding obstacles thru Video Streaming. Achieved thru Wi-Fi Technology (as avoidance to using Bluetooth technology due to its lesser security and shortness of range), the best path was identified thru Aggrandized Genetic Algorithm (AGA) which was comparatively greater than other algorithms. Wi-Fi (IEEE 802.11 b/g/n) was used to achieve secure communications at long distances.

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

2.3 Camera-Based Clear Path Detection

The study entitled Camera-Based Clear Path Detection used to detect clarity of paths as driver assistance towards obstacle avoidance on roads. With the assumptions made of video camera calibration and vehicle information (vehicle speed and yaw angle) were known, the researchers generated perspective patches for feature extraction in the image. Then, an initial estimate of the probability of a clear path is determined thru a support vector machine (SVM). With this, they performed probabilistic patch smoothing based on spatial and temporal constraints to improve estimates.

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

2.4 An Efficient Crop Row Detection Method for Agriculture Robots

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

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

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

- Initializing quadrangles. From the very first image, the quadrangle positions and dimensions were given by other methods or as manually indicated in the paper.
- Pre-processing of image. While the vehicle moved, it was obtained of the grey scaling image via 2G-R-B colour space and binarizing the grey scaling image using Otsus threshold at every image fed.
- Check the hitting and mishitting conditions of the boundary boxes.
- Modify the position of boundary boxes.
- For the following image, keep the boundary box positions and dimensions and repeat from second bullet.

2.5 A technical review on navigation systems of agricultural autonomous off-road vehicles

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

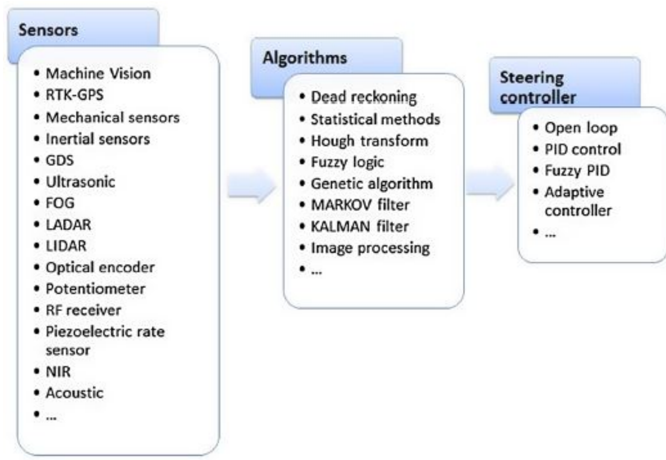

Fig. 2.1 Basic control diagram of autonomous vehicles.

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.

2.7 Automatic guidance for agricultural vehicles in Europe

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

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

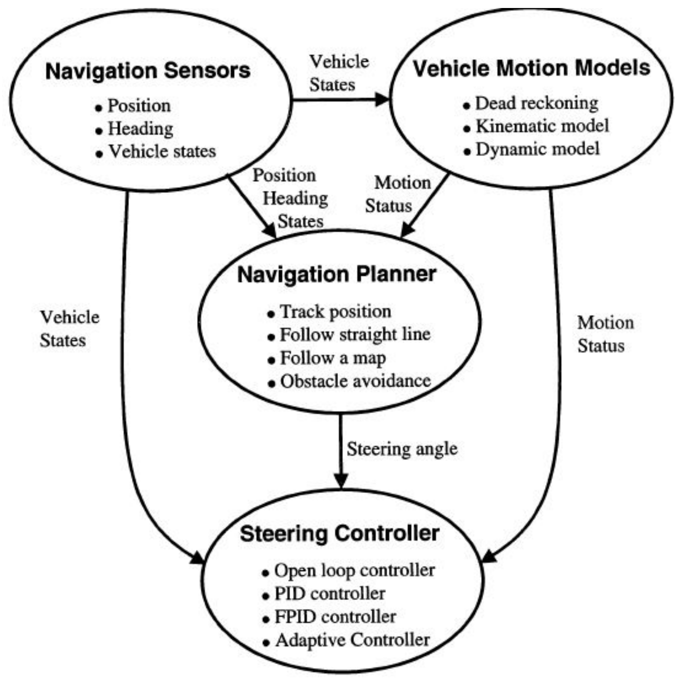

Fig. 2.2 Basic elements of agricultural vehicle automation systems

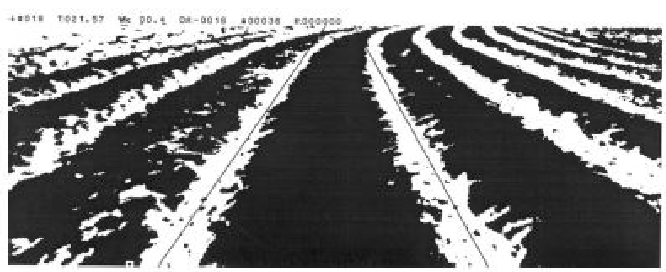

Fig. 2.3 Digitised image with guidelines.

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.

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

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

2.10 Navigation System for Agricultural Machines

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

Chapter 3
THEORETICAL CONSIDERATIONS

Contents

3.1 Corn

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. 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. [du Plessis, 2003] Figure 3.1 shows a picture of Maize.

Fig. 3.1 Pictorial Representation of A Natively-produced Corn

3.2 Corn Production

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

Production of Corn requires specific environmental requirements for it to grow. This crop is considered a warm weather crop; hence, it is grown in areas with temperature more than 19 degrees Celsius. Germination of the seeds require a minimum of 10 degrees Celsius temperature but an increase in the soil temperature up to a certain degree would allow a faster growth for Maize. 32 degrees Celsius is the approximate critical temperature that could dangerously affect the yielding of the corn. Another environmental factor required is

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water. Each crop is estimated to have used 250 liters of water in the absence of moisture stress at maturity. Last on the environmental requirement is the soil; it is the most crucial factor that could greatly affect the production of corn. Suitable soil for corn is loam soil – it must have morphological properties, good internal drainage, and optimal moisture regime. [du Plessis, 2003]

3.3 Agricultural Technology

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

Agricultural Technologies allowed considerable progression in crop production. Many public and private sector organizations develop these with the aim to address the various biotic and abiotic constraints. With the advancement in tools, America is able to implement Modern Agriculture, a wide type of production. It is an agriculture system wherein farmers use higher end technology and information to control most components of the system. In contrast with the traditional farmers who personally work with resources at hand, modern farmers are dependent on linkages–access to resources, technology, management, and many others. Productivity has increased as machines and computers have eliminated laborious parts of the job. [Motes,]

3.4 Agricultural Robots

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

3.5 Philippine Agriculture

The Philippines is rich in agricultural lands, where about one-third of the land area of 30 million hectares is classified as is. In the year 2013, about 30% of the Filipino workforce has been employed in this sector. [Wor,]. The major contributors to agriculture's gross value is known to be food crops, specifically rice and corn. The croplands of the Philippines are presently under sever environmental stress such as decresing man-land ratio has led

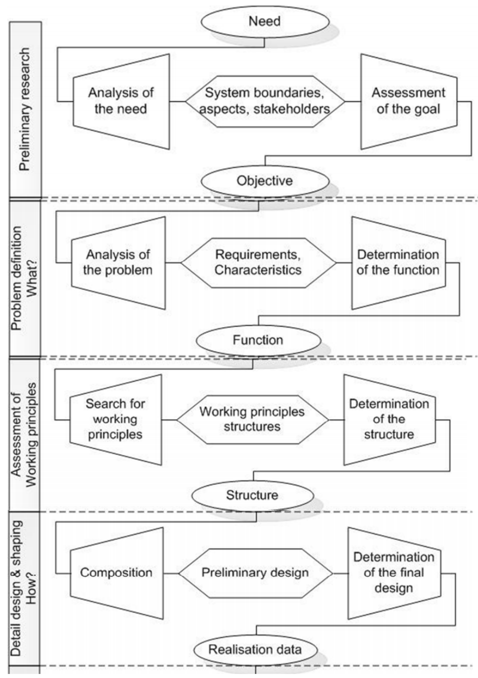

Fig. 3.2 Flowchart of Agricultural Robot Design

the landless to occupy and cultivate ecologically unstable marginal lands. Other problems have emerged as well in the sector of agriculture. Urgency for food security, employment generation to meet the 10-point agenda of the government, and greater global competitiveness trigger the major concerns of the Philippine agricultural sector. In order to respond to this urgent needs of an increasing population while poverty also increases, the Philippine agricultural sector in general has embraced the credo of conventional agricultural practices. [?]

Chapter 4
DESIGN CONSIDERATIONS

Contents

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4.1 Raspberry Pi 3 Model B

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

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

- A 1.2GHz 64-bit quad-core ARMv8 CPU
- 802.11n Wireless LAN
- Bluetooth 4.1
- Bluetooth Low Energy (BLE)]
- 1GB RAM
- 4 USB ports
- 40 GPIO pins
- Full HDMI port
- Ethernet port
- Combined 3.5mm audio jack and composite video
- Camera interface (CSI)
- Display interface (DSI)
- Micro SD card slot (now push-pull rather than push-push)
- VideoCore IV 3D graphics core

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

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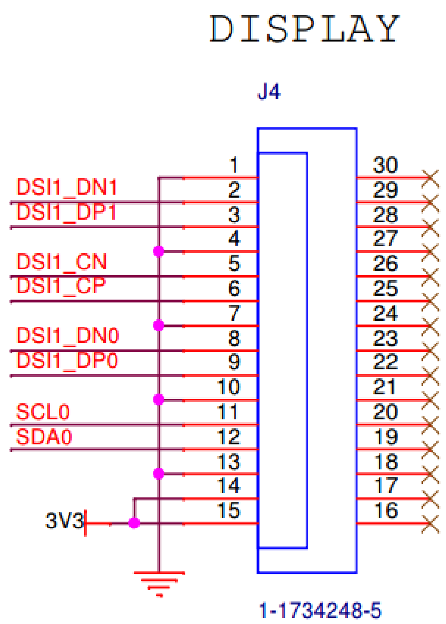

Fig. 4.1 Schematic of Display

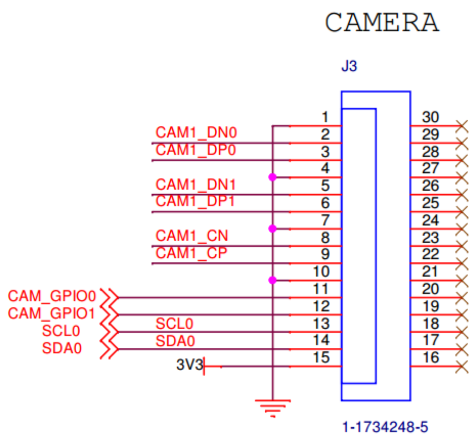

Fig. 4.2 Schematic of Camera Port

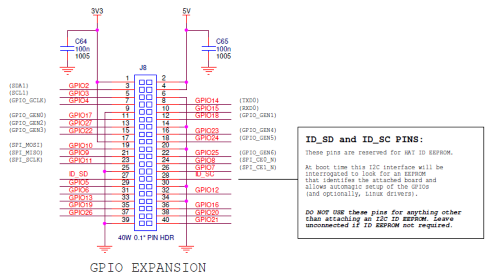

Fig. 4.3 Schematic of GPIO Expansion

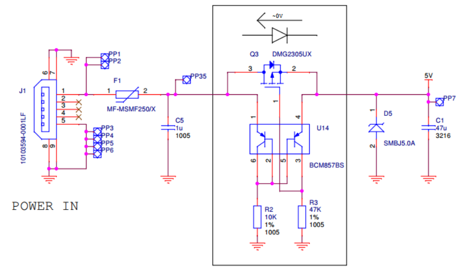

Fig. 4.4 Schematic of Power Input

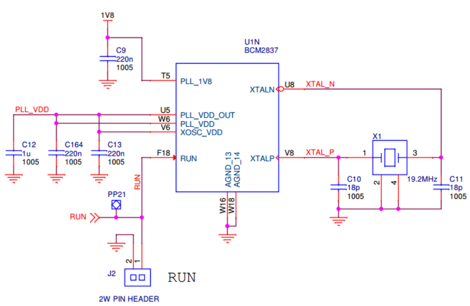

Fig. 4.5 Schematic of RUN

4.2 Raspberry Pi Camera Module

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

```
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

4.3 Virtual Network Computing

Virtual Network Computing (VNC) is a graphical sharing system on a desktop that allows remote access and control of a desktop interface of on device from another. The events from the controller such as keyboard and mouse are transmitted to the screen over the network from the remote host. On the Raspberry Pi, it is necessary to install the TightVNC package in order to utilize this system. To install this package, the code *sudo apt-get install tightvncserver* is used. Running the TightVNC Server would prompt the user to input the password *tightvncserver*. From the terminal, VNC is started. A session on VNC display one with full HD resolution is written as *vncserver :1 -geometry 1920x1080 -depth 24.* . In order to run the VNC server on the Pi, a command on a file is necessary. The shell script *!/bin/sh (next line) vncserver :1 -geometry 1920x1080 -depth 24 -dpi 96* is to be created. By inputting the code *chmod +x vnc.sh*, the shell script with filename vnc.sh is made executable. In order to run the file at any time, the code *./vnc.sh* is executed. The procedure mentioned above is the initialization of VNC on the Pi module. With this, a

VNC client on the personal computer is needed in order to connect the computer to the VNC server and have control of it. [RaspberryPiFoundation, b]

4.4 IP Address

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

4.5 Design Reference

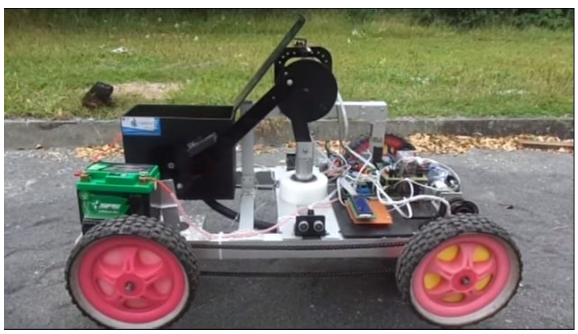

Fig. 4.7 Design Reference for The Corn Planting Robot

Figure 4.7 shows the researchers design reference for the corn planting robot. The design was found online (youtu.be/QooHpnYLj1w) which is uploaded by user named Luthfi Hasni. The design uses a PIC or a Programmable Integrated Circuit to control the robot. It uses several sensors as its navigation system. Besides from the 2 motors that controls the wheels of the robot, it has a third motor that controls the boring of the soil and the sowing of the cord seeds at the same time.

4.6 Design and Dimensions

Portability is one of the main considerations of the robots design. Figures 4.9 - 4.11 shows the design and dimensions of the corn planting robot. The figures show that the researchers

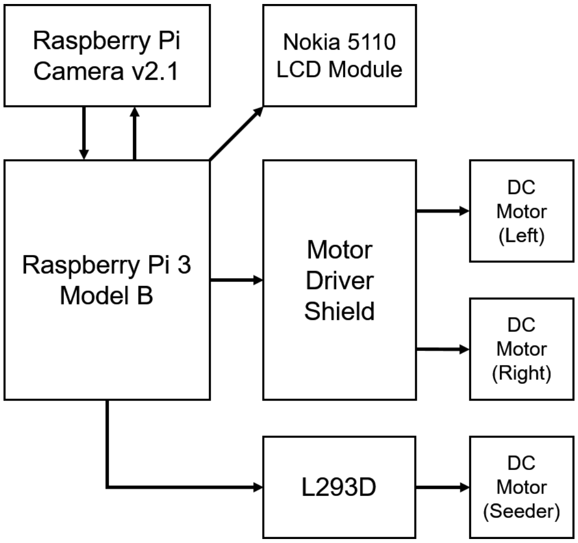

Fig. 4.8 System Design Diagram

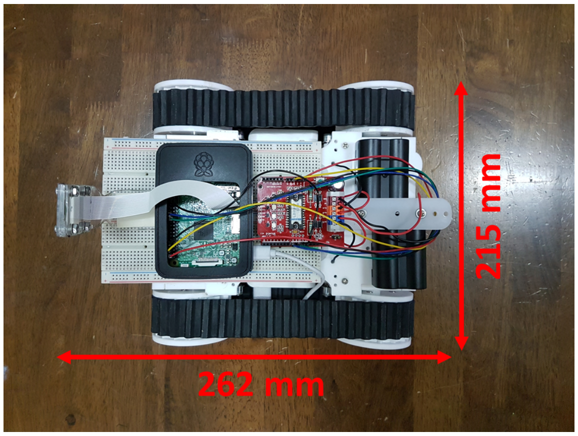

Fig. 4.9 Top View of the Corn Planting Robot and its Dimensions

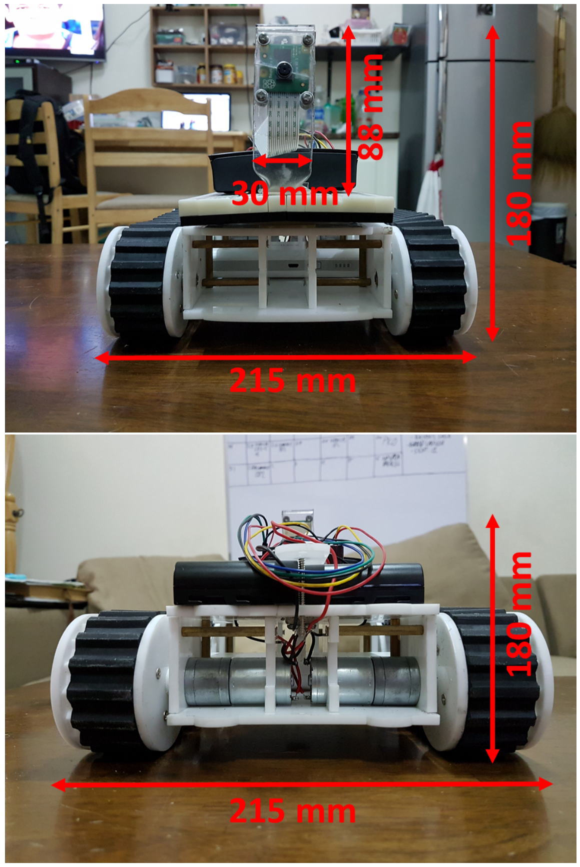

Fig. 4.10 Front and Back View of the Corn Planting Robot and its Dimensions

robot is much smaller compared to the design reference. The robot has a length of 262 mm, a width of 215 mm, and a height of 180 mm.

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 in 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 is connected in parallel is used to supply voltage to the motors. The motors and the battery packs (D) are then connected to the motor driver shield (E) which controls the direction of the motors individually thereby controls the movement of

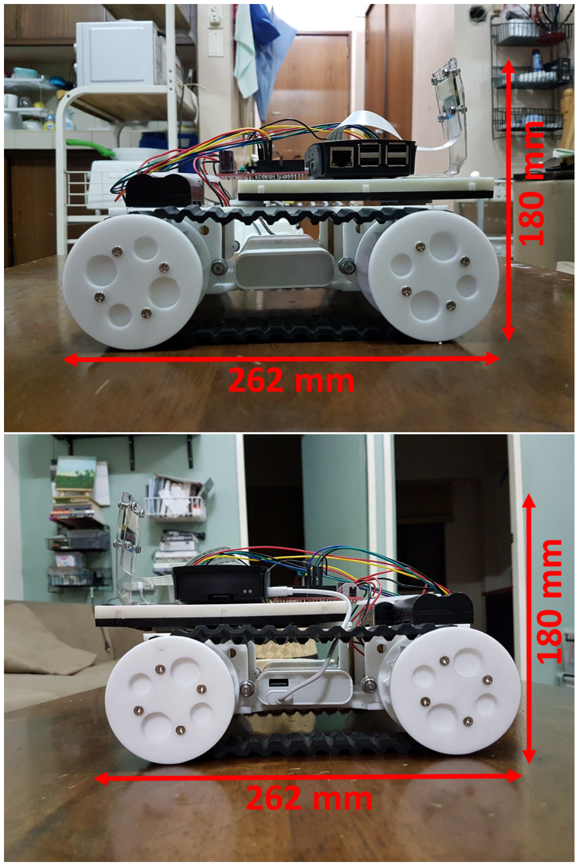

Fig. 4.11 Left and Right Side View of the Corn Planting Robot and its Dimensions

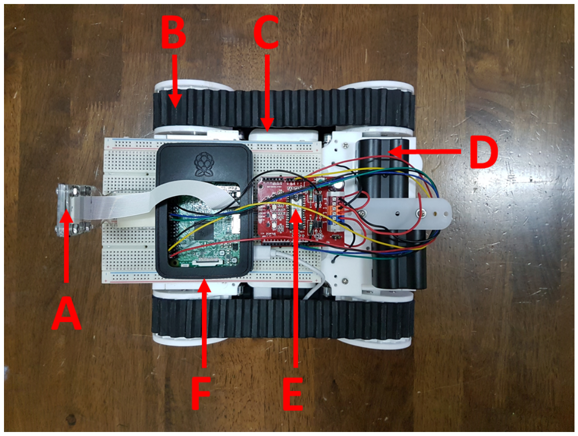

Fig. 4.12 Top View of the Corn Planting Robot with its Main Components Pointed Out

the whole robot. The motor driver shield is connected to the Raspberry Pi 3 Model B (F). The Raspberry Pi is the main processing unit of the robot. It is responsible for the image processing, remote connection, and the control of the motor driver shield (E). For the image processing, the researchers used the Raspberry Pi Camera v2.1 (A). We used the Raspberry Pi Camera for it allows the robot to utilize the GPU (Graphical Processing Unit) of the Raspberry Pi, which makes the image processing faster and decrease the processing load on the main processing unit. Lastly, the Raspberry Pi is then powered separately by a power bank.

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

Chapter 5
METHODOLOGY

Contents

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

5.2 Evaluation

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

- Misaligned seeding machine
- Stillness or non-rotation of the seeding machine
- Wrong dispensing of seeds (with less than 3 seeds)
- Positioning of the chassis in-line with the irrigation line
- Unlevelled land area where the belt wheel got jammed

5.3 Summary

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

Chapter 6
RESULTS AND DISCUSSION

Contents

6.1 Summary

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.

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.

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

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%

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

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

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

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

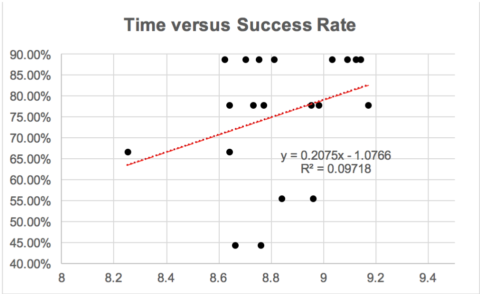

Fig. 6.3 Time versus Success

Chapter 7
CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIRECTIVES

Contents

7.1 Concluding Remarks

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

7.2 Contributions

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

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

7.3 Recommendations

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

This report also recommends further work to:

- Quantify the environmental factors seen at an actual cornfield
- Consider the amount of slip and skewing of the wheels during navigation
- Categorize the weight limit in relation to the optimal speed of the robot
- Develop an algorithm for further automation

7.4 Future Prospects

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

1. A Robot System for Rice Planting in the Philippines

2. Development of a Computer Vision Navigation System for Planting Corn in the Philippines
3. Multiple Camera Image Processing for Rice Planting Success Monitoring and Navigation
4. Rice Planting Hover Craft Robot for Paddy Field Farming
5. Aerial Soil Analysis for Potential Agricultural Farm Lands in the Philippines using Swarm Robots

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[RaspberryPiFoundation, b] RaspberryPiFoundation. Virtual network computing.

[RaspberryPiFoundation, c] RaspberryPiFoundation. What is raspberry pi?

Appendix A
ANSWERS TO QUESTIONS TO THIS THESIS

Contents

A1 How important is the problem to practice?

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.

A2 How will you know if the solution/s that you will achieve would be better than existing ones?

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.

A2.1 How will you measure the improvement/s?

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.

A2.1.1 What is/are your basis/bases for the improvement/s?

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.

A2.1.2 Why did you choose that/those basis/bases?

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.

A2.1.3 How significant are your measure/s of the improvement/s?

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.

A3 What is the difference of the solution/s from existing ones?

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

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

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

A4 What are the assumptions made (that are behind for your proposed solution to work)?

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

A4.1 Will your proposed solution/s be sensitive to these assumptions?

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.

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

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

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

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

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

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

A7.1 Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s?

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

A7.2 Is there an approximation that can arrive at the essentially the same proposed solution/s more easily?

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

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

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

A8.1 What are the weaknesses of your proposal?

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

Appendix B
VITA

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.

Dan Paulo E. Amado is currently pursuing Bachelor of Science Degree in Computer Engineering at De La Salle University-Manila. His role in the group is the Master Programmer. With his adept skills in computer programming, he functions as the brain of the project, as he provides the main idea along with its purpose it serves. His research interests include mountaineering, agriculture, and robotics.

Joanna Katherine U. Mirida is currently pursuing Bachelor of Science Degree in Computer Engineering at De La Salle University-Manila. With her keen sight for details, she provides constructive criticisms as to where the group will set rooms for further improvements and necessary corrections from established ideas. Her research interest include biomedical engineering, nanotechnology, and energy management systems.