Final Report

Team #11: Robo-Weeder

12/7/15

Submitted to: Dr. Nihkil Gupta (Faculty Advisor)
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Team 11
Robo-Weeder

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Team 11
Robo-Weeder

Abstract

The Robo-Weeder senior design project is sponsored by Jeff Phipps M.E., the owner of Orchard Pond Organics. Orchard Pond Organics is an 8 acre organic farm that has a pressing need for the assistance in weed control. The primary objective of the Robo-Weeder senior design project is to design and create a robotic system that will aid in this need by using a shearing mechanism to remove weeds in between the rows of planted vegetables. Team 11 has contacted and met with Mr. Jeff Phipps, the project sponsor, and discussed design objectives and constraints. The final chassis design has been approved by the sponsor as well as the faculty advisor and is currently under analysis by Team 11. Electrical components such as the primary microprocessor and the transmitter and receiver have been selected and are on order. Currently the mechanical engineering students are scaling down the final design as the constraint to use 8" augers has been removed, by approval of Dr. Nikhil Gupta. This will in turn dictate the motors that are selected for use on the robot for drive, steering and shearing functions.

1.

Introduction

As a continuation of the previous year's Robotic Weeding Harvester, Team 11 has been tasked with improving upon or redesigning the final design prototype that was generated. Team 11's project, appropriately named "Robo-Weeder" has a primary function of aiding in the removal of unwanted weeds that plague the seed beds of Jeff Phipps' organic farm, Orchard Pond Organics.

Organic farming techniques do not rely on the traditional farming practices of tilling the soil and the application of herbicides to control the growth of weeds. Instead, the weed control is done through a less invasive means leaving the soil undisturbed. Currently, most organic farmers have resulted to having to remove weeds by hand to achieve the desired effect. Although from an organic standpoint, hand removal of the weeds is ideal, however it's less than ideal when labor costs are considered.

Robo-Weeder will be to help facilitate the production of crops with high nutritional value. The Robo-Weeder will: be remotely operated, remove weeds through the application of a shearing force, have an interchangeable battery source as well as be equipped with video monitoring. The primary challenge that will be solved by team 11 is the amount of force to apply to the seedbed to achieve the desired amount of shear. The team dynamics include four mechanical engineers and two electrical engineers. The project is presented by the FAMU-FSU College of Engineering Department of Mechanical Engineering and is sponsored by Mr. Jeff Phipps, of the Orchard Pond Organics farm. The project is advised by Dr. Gupta and Dr. Hooker.

1.1 Goal Statement and Objectives

Thus far, the established goals for Team 11 is to:

- create a remotely operated machine
- eliminate unwanted plants by the root
- be splash proof
- have interchangeable weeding implements

1.2 Problem Statement

Orchard Pond Organics is a farm that has too many weeds and is in need of robotic assistance. The assistance will aid in the removal of weeds to reduce labor costs and improve the farm's production.

2.

Project Definition

2.1 Background Research

Current methods of farming use technologically advanced cultivating tools and genetically modified crops. This method is the currently the most used to maximize the possible yield of the crops with high nutritional value. However, these processes are not only destructive to the environment, but hurts crops by destroying microorganisms along with ground insects that would further contribute to the development of high yielding soil. Another flaw in conventional farming is that there is large scale production of one single crop on a parcel of land also known as monoculture. This cultivation method is main reason synthetic fertilizers and pesticides are used since there is a dramatic decrease in diversity of the crop on a land plot, eliminating the natural biological controls that would maintain pest levels, disease, and soil degradation .[1]

Another negative attribute of using pesticides, herbicides, and insecticides, is many 'pests' have already evolved and will continue to evolve to resist new developing chemicals. These pesticides, herbicides, insecticides, and fertilizers are derivatives of fossil fuels which are a limited natural resource. In addition to being a natural resource; fossil fuels also contribute to water contamination which is problematic because farms require the use of vast water irrigation systems. Currently irrigation systems extract water from reservoirs faster than they can be replenished, rapidly depleting this resource.

Due to the known fact that traditional farming leads to the serious consequences, organic farming has become a growing trend around the world. One might ask, "What exactly is an organic farm?" The answer is organic farming is done without using any chemically derived fertilizers, pesticides, herbicides, or is grown with genetically modified organisms (GMO) .[2] There are many different methods to subsidize the effect of not using traditional fertilizers, pesticides, and herbicides. Some insecticides may be used such as rotenone and pyrethrin, which are both organic compounds. Another method of organic farming is using cover crops such as clover, a legume, to reduce unwanted weeds. Legumes also put nitrogen back in the soil once they are tilled out of the earth. That being said, legumes are natural fertilizers and promote healthy soil as well as improvements of antioxidant levels or a highly nutritious crop .[3] To combat the effect of pest while not using pesticides, organic farms do away with monoculture and diversify the crops. This variation in crops allows certain crops immunity to pests that target a particular crop. The final method used by organic farmers is crop rotation which enhances the quality of the soil by placing vital nutrients back into the soil.

However, the downside of organic farming is the precise removal of undesired plants that grow near crops, and pest control. There are many different ways to combat these efforts but none of which work well with monoculture. Existing weeding machines are heavy, bulky and use gasoline engines which can adversely affect the crop yield.

The previous team spoke with Jeff Phipps head farmer where he expressed concerns of technology completely replacing the farmers and creating an environment of ignorance when it comes to producing crops. This year Team 11 is taking this concern into consideration and creating a machine that will assist the farmer in their duties.

2.2 House of Quality

An important tool that is at the disposal of the design team for the Robo-Weeder project, is the House of Quality. The House of Quality (HOQ) allows one to relate requirements that the customer has for the final product, or sponsor in the case of the Robo-Weeder project, to key engineering characteristics. It claimed the name House of Quality due to its graphical nature resembling a house.

Importance/Weight	Customer Requirements	Mass	Material	Durability	Stability	Strength of Components	# of Tires/Tracks	# of Motors	Operation Mode (Wired, Radio, etc...)	Battery System
4	Safe to Operate	4	20	20	40	20	4	4	4	4
1	Cost Efficient	5	10	5	5	5	10	10	5	5
5	Effective	5	25	50	5	25	25	5	25	25
5	Reliable	5	25	50	50	50	5	5	5	25
2	Simple to Operate	2	2	2	2	2	2	2	10	2
2	Interchangable Implements	20	10	10	20	10	2	2	2	2
3	Weight	30	30	30	30	30	30	30	3	15
2	Marketability	2	2	20	20	10	2	2	10	2
4	Irregular Terrains	4	4	20	40	4	40	4	4	4
Totals		77	128	207	212	156	120	64	68	84
Rank		7	4	2	1	3	5	9	8	6

Figure 1 : House of Quality constructed for the Robo-Weeder project.

In the above, Figure 1, the decision matrix has been removed to show the primary data within the HOQ. The key features shown include the customer requirements, the weight or importance of the requirement, the key engineering characteristics shown in blue and the decision matrix relating each section. The conclusion of the analysis yields a ranking of the engineering characteristics and advises the design team which characteristics could be the most important when designing the final product. For the Robo-Weeder project, the House of Quality advises Durability, Stability and Strength should be considered during the design process. It should be noted that a full scale House of quality with the “Roof Section” is located in Appendix A.

2.3 Soil Analysis

The main function of the Robo-Weeder project is to develop a robotic platform that is capable of removing weeds from seedbeds on an organic farm. The removal of the weeds is accomplished by applying a shear force to the surface of the soil in such a manner as to disrupt the root systems of the weeds.

In order for Team 11 to accomplish the objective of shearing the soil to remove weeds, it is important to understand the forces that need to be applied to the soil to achieve the desired soil shear. To understand these forces, team 11 consulted with the Civil Engineering department to better understand the field of Soil Mechanics. During the consultations, Team 11 spoke with Adjunct Professor Sal Arnaldo, P.E. as well as Professor and Chairman Kamal Tawfiq, Ph.D., P.E. who recommended soil testing to understand the exact forces needed during this project.

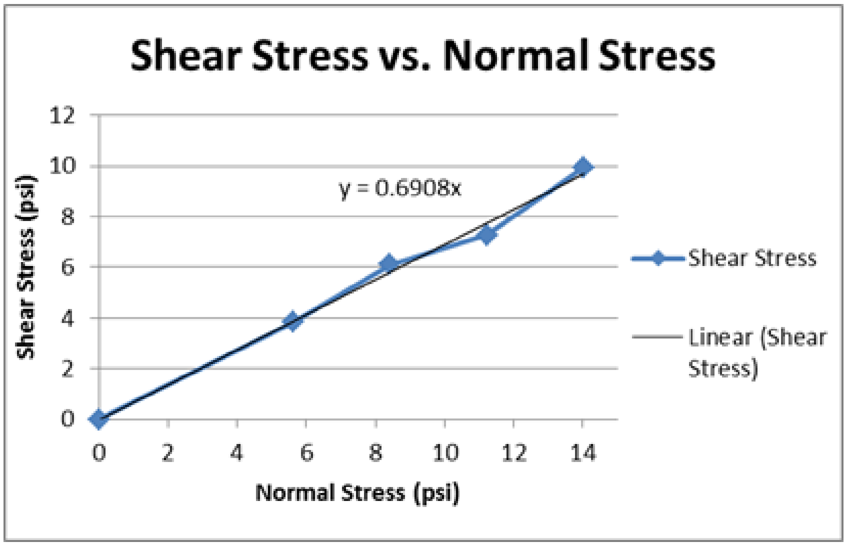

Figure 2: Shear Stress data collected from soil testing.

At the conclusion of the soil testing, Figure 3 above allows Team 11 to estimate the exact stresses needed to achieve soil shear. Team 11 can now estimate the footprint size as well as the weight of the robot to determine the normal stress on the soil. From the known normal stress, team 11 can use the relationship displayed by the linear trend line to estimate the shear stress that would need to be supplied by the Robo-Weeder.

2.4 Need Statement

The current sponsor for the Robo-weeder project, Jeff Phipps of Orchard Pond Organics, is a Mechanical Engineer and wants to develop a remotely operated platform that will aid farmers in general crop care, by removing weeds on his organic farm. The chassis desired must be robotic in nature, and must apply an adequate shear force to the roots of undesired plants without disturbing adjacent crops. The platform must be able to accommodate future cutting implements that the sponsor develops and must be safe, easily maintained and user friendly. In order to aid Mr. Phipps on his organic farm, an effective, reliable, and well-functioning remotely controlled platform must be created.

2.5 Project Constraints

The established constraints for the mechanism are as follows:

- Function in “No-Till” fashion
- Must be mobile
- Must be remotely operated
- Must use Auger style shearing mechanism
- Not disturb more than one inch in depth of soil
- Width shall not exceed 12 inches
- Must be tolerant to minimal water (splash proof).

- Must shear undesired plants on an acre of land per day

3.

Design Analysis

3.1 Mechanical Design Concepts

The Mechanical Design phase of the project has evolved as the team has progressed through the semester. With the aid of the background research the team is now able to accurately predict the forces needed to shear the soil accurately. Key aspects described in the following mechanical design section will include the steering assemblies, the auger shearing system and the Robo-Weeder's chassis. It is important to note, motor torques required to steer and propel the robot in the loose dirt as well as the motor torques required to ensure the shearing mechanism operates effectively are in the final phase of approval and have not been decided. These values will be solidified within the upcoming weeks and applied to determine the proper motors to ensure an accurate operation of the Robo-Weeder.

3.1.1 Chassis

The design of the chassis is a key concept that has to be designed to accommodate the weeding mechanism. This has been seen as a challenge due to the constraints given by the sponsor. For the chassis to incorporate the shearing assembly the original chassis must be redesigned. The original chassis design features a flat rectangular shape and can be seen in Figure ##. The material that was chosen to create the chassis is a square aluminum tubing. To incorporate the weeding mechanism it has been proposed by our advisor to remove the middle of the frame and extending it vertically just in the section where the weeding mechanism is located. This change will be incorporated in the coming future.

3.1.2 Steering Mechanism

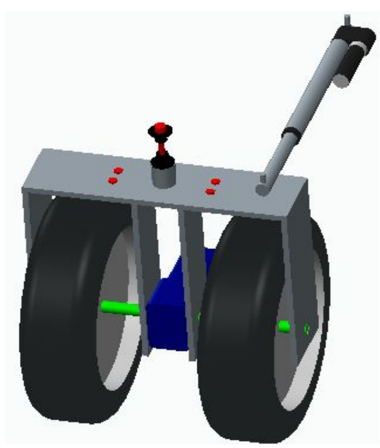

Figure 3: Steering Assembly with original linear actuator (width = 11 , height = 10)

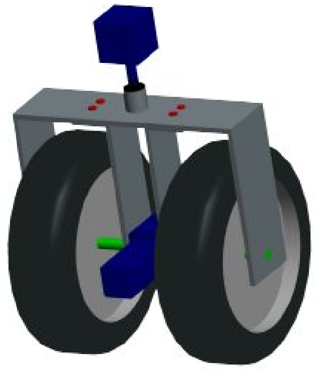

Figure 4: Steering assembly with new motor style steering attachment

The steering mechanism is also a key component to the operation of the ROV. Initially the steering mechanism was designed to incorporate a linear actuator; this can be seen in Figure 3. Due to the linear actuator having a slow extension speed alternate methods have been sought out. One method that was found to be feasible was a stepper motor which is has a high torque value as well as an accurate rotational clocking. While have a high torque value it also is relatively high velocity in terms of steering. Also the drive motor was originally proposed to mount to a double shafted output gearbox. This motor will be coupled to a central shaft where both wheels are driven by this shaft. This has shown to restrict the design of the ROV and connecting the motor to directly to the wheel with an offset gearbox. This will allow for a much simpler design and will be incorporated in the coming weeks.

3.1.3 Weeding Mechanism

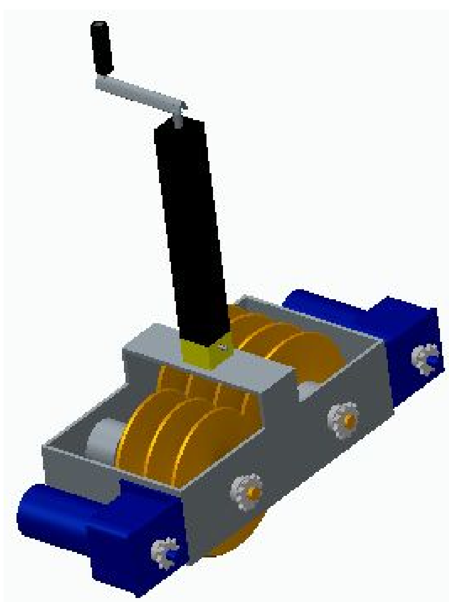

Figure 5: Shearing mechanism with housed auger shearing devices. (length = 40", height = 30", width = 11.5")

The weeding mechanism uses two four inch augers which turn in opposite directions to apply a shearing force to the top one inch of the soil. This weeding mechanism can be seen in Figure 5. Each auger is driven by separate motors with a gear ration of 1:1.2. This gave the required torque needed to sufficiently shear off the one inch of soil. The auger housing was designed to incorporating different size augers from four to five inches. The center support also serves as vertical lift for the weeding mechanism. The vertical lift aids in the allowing the augers to penetrate the soil one inch in depth. All of these components work together to allow the weeding component to meet the customer requirements.

3.4 Mechanical Design Evaluation

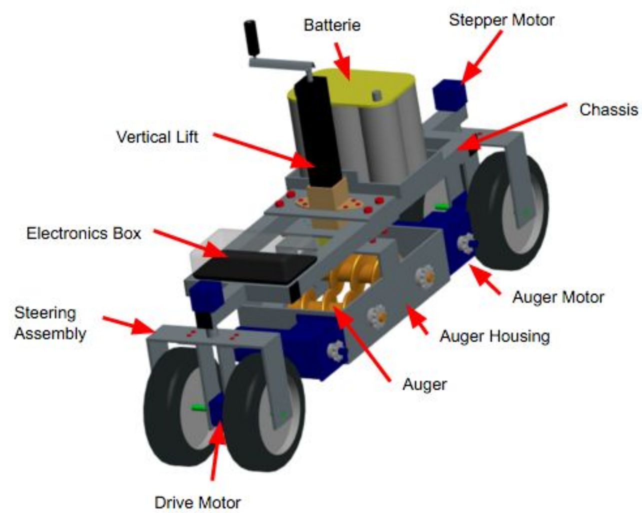

Figure 6: Full Robo-Weeder assembly with appropriate labels.

All of these system were combined together to get the final overall ROV. Each system has their own significance to the operation of the vehicle. To maximize the performance of the vehicle it has been seen that small changes to the design has to be made. Such changes include a vertical adjustment of the chassis over the section of the shearing device, swapping of the linear actuator for a stepper motor, changing the drive motor from a single motor to drive motors on each wheel. With these improvements to the overall design the ROV will be maximized to get the fullest potential.

3.2 Electrical Design

The Electrical design concept is nearing its final design phase. The choices of parts to choose from and the potential for any modifications are nearing its final stages. Any efforts in finalizing the design will all depends on the choices of motors that will power the drive train, steering and the augers. The heart of the electrical design will be the microcontroller; any choices will be based on the capability of the microcontroller in terms of having enough pins for any expansion of the design. The choices for the motor-controller will be based on the voltage and amperage rating of the dc motor. This will ensure that each motor-controller will not overheat due to the excess load requirement of the dc motor and will be the design criteria that needs to be met, in able to avoid any design failure. The 12V power system for this design will have to provide the necessary system requirements in terms of the operating voltages and current, in addition to being able to maintain an acceptable amount of charge for a given length of operational use in between charging. The transmitter selected will need to perform all necessary functions such as driving, steering, as well as controlling the augers (turning them ON and OFF). As of now, the transmitter/receiver and microcontroller selections have been finalized.

3.2.1 Transmitter/Receiver

Figure 7: **RadioLink T6EHP-E 2.4G 6CH Transmitter w/ R7EH Receiver**

Table 1**:** RadioLink T6EHP-E 2.4G 6CH Transmitter w/ R7EH Receiver specification

Transmitter	RadioLink T6EHP-E
Frequency	2.4GHz 6 channel transmitter
Modulation	FHSS
Power supply	9.6V Ni-Cd battery or 12V alkaline battery
Current drain	250mA, 87mA (Energy Saving)
Range	400 m
Receiver	R6EH
Frequency	2.4 GHZ 6 channel receiver
Power supply	4.8V~6V
Current drain	9.5mA & 4.8V
Standard Channel Displays	

The radio transmitter that was selected is a typical Radio controlled transmitter that is typical of those in the aerial quadcopter transmitter application. It was determined that for the Robo-Weeder application, having six channels for a transmitter will serve the purpose of being able to provide all of the functions that is required for the Robo-Weeder to being operated. The RadioLink T6EHP-E transmitter has a range of 400 m that is suitable in the outdoor farming environment. It has a battery fail safe features which set the controls to a preset condition of idle (position) whenever the transmitter voltage drops down to 3.8V. Another safety feature comes in the form of when losing the transmitter signal, the controls will preset to an idle (position) condition. The radio receiver is more than capable of handling all the channels that will operate the Robo-Weeder, having six channels paired with the transmitter will allow for a better transmission and receiving capability.

3.2.2 Microcontroller

Figure 8: Arduino Uno

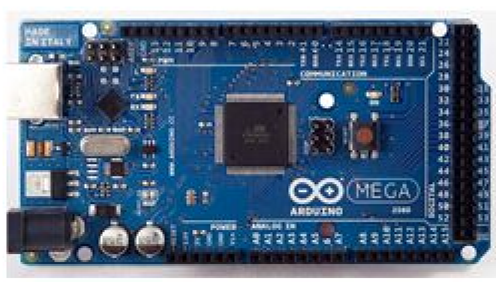

Figure 9: Arduino Mega 2560

Table 2: Microcontroller Specifications

Models	**Arduino UNO**	**Arduino Mega 2560 R3**
Price	$21.99	$45.95
Operating Voltage	5V	5V
Input Voltage (recommended)	7V to 12V	7-12V
Input Voltage (limits)	6V-20V	6V-20V

Digital I/O Pins	14 (6 PWM)	54 (14 PWM)
Analog Input Pins	6	16
DC Current per I/O Pin	40mA	40mA
Flash Memory	32KB	128KB
SRAM	2KB	8KB
Clock Speed	16MHZ	16MHZ
Processor	ATmega328	ATmega2560

The Arduino Mega (Table 2) will function as the “brain” of the electrical design. The Arduino Mega was selected due to the many pins it has on board, of which 24 of the 54 available pins will be used. For our design there will be, in total, 8 motors. In order to control these motors, 8 of the 24 utilized pins will be needed used as PWM signal outputs. The remaining 16 utilized pins will be used as logic signals with 2 logic signals assigned per PWM signal. The logic signals will provide either a High or Low signal which the Mega will output in order to perform the desired function. The extra pins on board will be necessary if additional features are added later on in order to further enhance the design if time permits.

The Arduino Uno (Table 2) was a new design implementation from the previous report. The primary purpose of the Arduino UNO is to provide better control of the robotic system. Three Arduino UNO’s will be implemented in our design, controlling a specific function. The three functions that they will control will be the drive feature, steering feature, as well as the auger regulation.

3.2.3 Electrical System Design

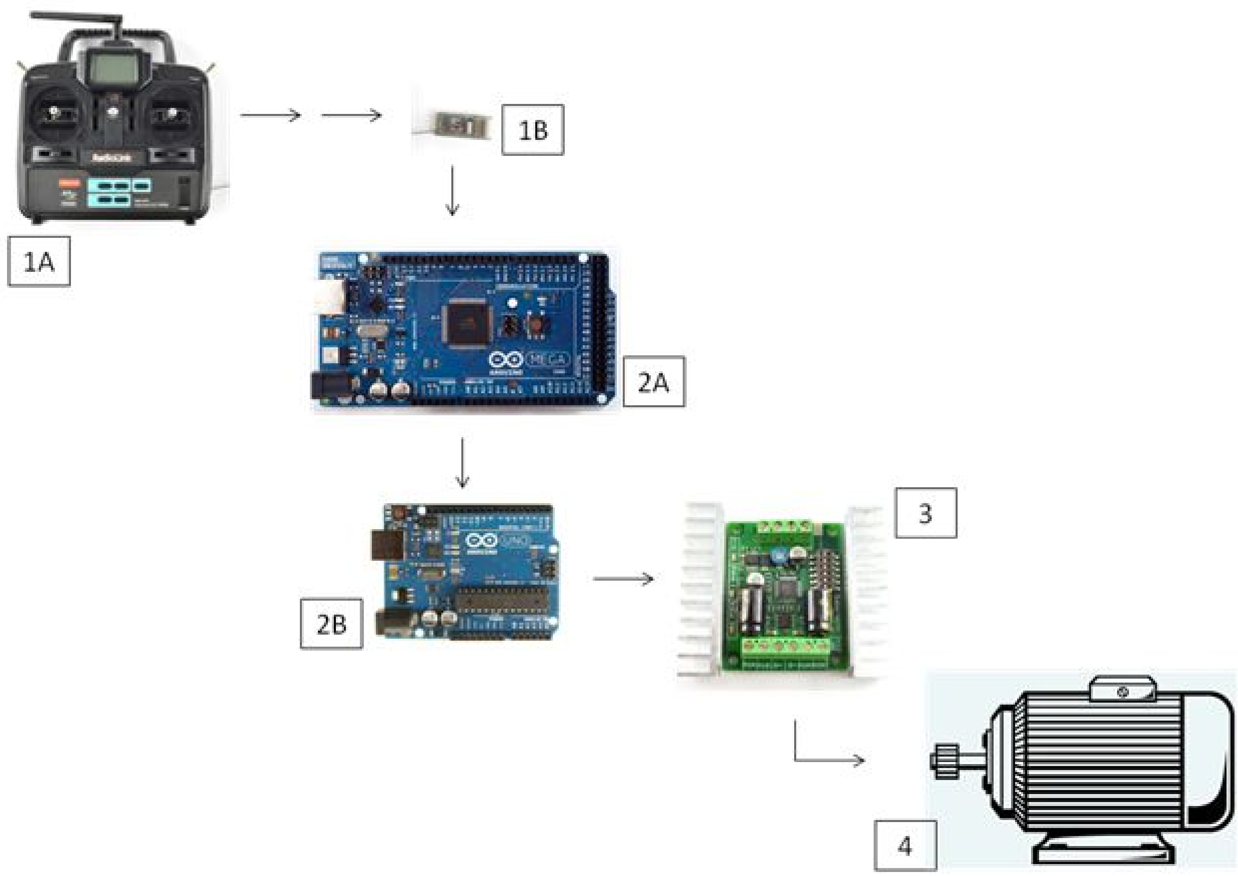

Figure 10: Flow chart illustrating the communication of the electrical components.

1. <u>Transmitter/Receiver</u>
   A. <u>RadioLink T6EHP-E 2.4G 6CH Transmitter w/ R7EH Receiver</u> –

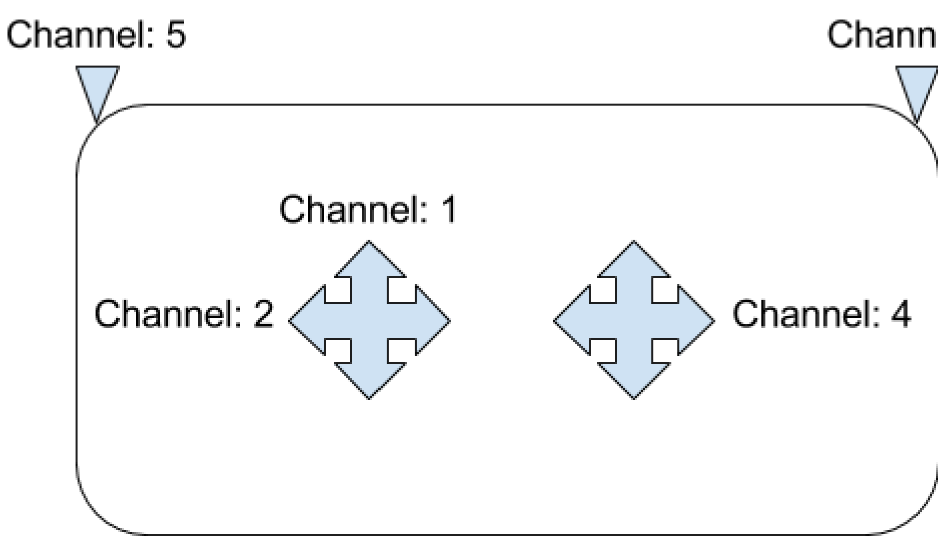

Figure 11: Transmitter joystick diagram

Table 3: Transmitter joystick configuration

Channel: 1	Forward/Reverse (front/rear) drive motor
Channel: 2	Front Steering
Channel: 4	Rear Steering
Channel: 5	Front Auger (Power ON/OFF)
Channel: 6	Rear Auger (Power ON/OFF)

The radio transmitter is paired with a receiver that allows it to transmit and receive at 2.4GHz frequency. The transmitter transmit six channels in the form of pulses (one channel per pulse) in a string like configuration (six pulse train), within each pulse rides another signal, a pulse width modulated signal (PWM) that is decoded by the receiver and sent to the proper channel. The microcontroller will receive this PWM signals and modifies it, the modified signal is then sent out to the designated motor-controller where that signal is used as an instruction to either increased or decreased the amount of voltages to control the DC motor, in addition to changing direction of travel (forward or reverse).

2. Microcontrollers

A. Arduino Mega 2560 – The Arduino Mega, as described before, is the "brain" of the Electrical system. The wireless signal that is sent from the transmitter to the receiver is interpreted here. Once the signal that has been sent is interpreted, an output will be sent to the corresponding Arduino Uno microcontroller to control that desired function.

B. Arduino Uno – The output function of the Arduino Mega will determine which Arduino Uno receives the signal. One Arduino UNO will control all four drive motors, another will control the two steering motors, and the third Arduino Uno will control the two auger motors. Separating each function into its own microcontroller will provide more control of the system, as well as provide a more beneficial way of testing the machine. The outputs for each UNO will use one PWM signal and two logic signals (high and low) per motor controlled. These outputs will be directly connected to a motor driver in order to control the motors.

3. Motor Driver

A. Sabertooth Dual 12A Regenerative Motor Driver – This motor driver is a prospective component for the electrical design, pending confirmation of the final motor selection. The potential dc motors that have been looked at have a stall peak current of roughly 22A. This motor driver is capable of outputting 12A continuous with a peak value of 25A. The input voltage range of this motor driver is 6V-24V, which is what would be ideal for a 12V system. This motor driver provides a safety factor of 3A for the motors that have been deemed practical for the intended applications.

4. DC Motor

A. a) PG71 Planetary Gearbox with RS775 Motor and Encoder – This potential motor was originally looked at as a possible drive motor for the ROV. However, this same motor may also be used to power the augers that will be used. The stall current that these motors draw is 22A with a stall torque of about 200 in-lbs. This stall torque is more than what is needed, but will add to the safety factor. Another benefit to these motors over the previous ones that were looked at earlier in the semester is that they only weigh 2 lbs, nearly 7 times lighter.

3.3 Electrical Design Evaluations

The electrical system so far has been consistent in terms of continuously evaluating and testing the coding system and the layout of the microcontroller, as well as its configuration. The final evaluation is yet to be determined for the electrical system, pending the final selection of the DC motor that is nearing its final selection for the Robo-Weeder.

3.3.1 Microcontroller Design

The microcontroller design will be patterned in a hierarchical structure, having the ArduinoMega as the main controller and having the ArduinoUno operating below the ArduinoMega. It was taken into consideration the possibility of having a complex level of programming that could be uploaded to a single microcontroller versus having a simple less complicated programming that could be uploaded to multiple microcontrollers. By having an hierarchical structure, it facilitates an ease in troubleshooting which component of the Robo-Weeder had failed, if any such failure occurs. A single microcontroller operating with a complex level of programming will be much more complicated to diagnosed or troubleshoot in any kind of component failures.

3.3.2 Power System

The power system that Team 11 will implement to run this ROV will be a rechargeable battery system. The sponsor would like to be able to run the ROV for a period of time until the battery is drained, and then be able to easily replace the battery with a new, freshly charged one. It was decided that a 12V battery system will be used rather than a 24V system. The criteria to be looked at when selecting which type of battery to be used are the battery's run time, life-cycle, charge time, and weight. Initially, a lead-acid battery was the battery of choice for our 12V system. However, it was determined that multiple lithium-ion batteries will be implemented instead of the single lead-acid battery. This method will be costly, but the purpose of this is to minimize weight and size. The lead-acid battery had an approximate weight of 50 pounds compared to the two pound lithium-ion battery. The number of lithium batteries to be used as well as the necessary amp-hour rating will depend on the motor selection as well as the operation run-time goal.

4.
Risk Assessment

Throughout the duration of the Robo-Weeder senior design project, it is a necessity for team 11 to plan for risks and hazards that the team will encounter throughout the design and fabrication process. Several major risks that are being addressed during the fabrication process include electrical burns from Welding and serious injury from the machining process used to form the different elements of the final mechanical design.

After fabrication of the final prototype, team 11 will begin testing of the product. During the testing phase a completely different set of risks and hazards is presented to the team. The major risk present to the team is the chance for serious bodily harm through the rotating augers and electrical burn due to the electrical components and the power system. Other risks that are present during the design and testing phases are detailed more accurately in the attached risk assessment document.

5.
Environmental Safety Issues and Ethics

The environmental safety issue that we are mostly concerned with on the Robo-Weeder involves the lithium ion battery. The lithium ion battery can potentially experience phenomena known as thermal runaway. Although proper housing will be fabricated there is still great cause to investigate all possibilities of malfunction to avoid catastrophic effects.

5.1 Thermal Runaway

Thermal runaway is defined as an uncontrollable increase in temperature also known as a positive feedback. Essentially, heat causes an exothermic reaction that causes an increase in reaction rate that generates even more heat. Some heat can slowly escape the system however if the rate of heat generation is significantly greater than the heat that escapes, catastrophic explosions can occur as shown in the figure below.

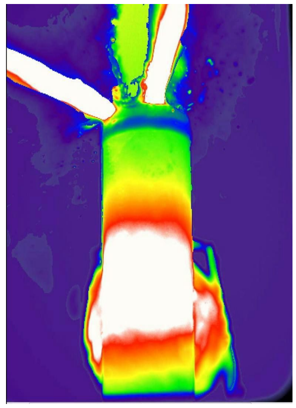

Figure 12: X-ray imaging of commercialized lithium ion battery experiencing thermal runaway at 250 degrees celsius.

During a thermal runaway explosion in a lithium ion battery, the contents within the can reach 250-1000 degrees Celsius. This will instantly damage the surrounding area with such a high magnitude that proper management protocol must be put in place.

Thermal Runaway Management

Over charging can cause significant degradation of both anode and cathode in the internal structure of the battery itself, resulting in the internal uncontrollable overheating of the battery pack. It is best not to overcharge the battery, in addition to having a safe and a well ventilated and cool storage space for the battery pack.

5.2 Proper Disposal

Once the Lithium Ion batteries have been used to the point of no possible recharge it can be recycled at the Division of Waste Management on 2600 Blair Stone Road, Tallahassee FL 32399

6.

Scheduling

6.1 Resource Allocation

During the Robo-Weeder project, the allocation of Team 11's resources is a very important part that will ensure the team is making the most of their time. The mechanical engineering member of Team 11 use their time to consult faculty with questions regarding mechanical aspects of the project, completing CAD drawings of each individual component as well as the entire Robo-Weeder and calculating motor requirements. The electrical engineering members are primarily using their time to speak with faculty regarding electrical concepts employed by the Robo-Weeder, as well as development of the code that will be used to program the microcontrollers.

6.2 Gantt Chart

Throughout the Robo-Weeder project, team 11 has used a Gantt Chart to plot activities relevant to the project in an attempt to keep the team on track.

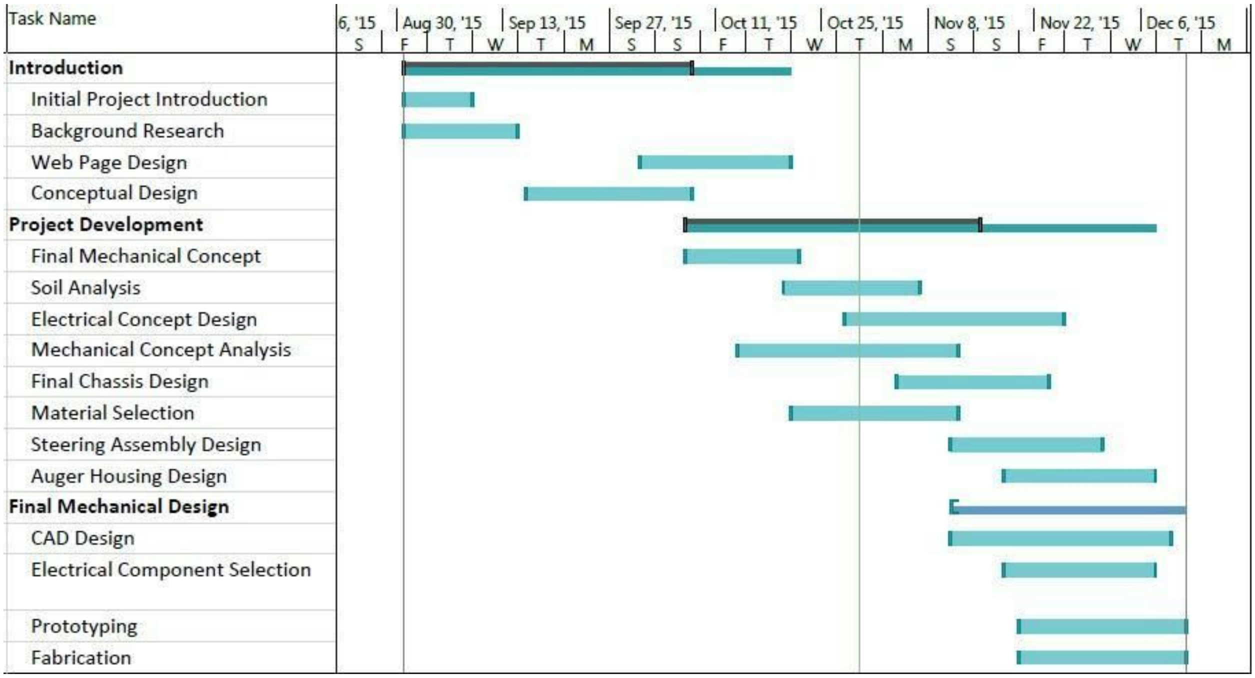

Figure 13: Gantt Chart constructed by team 11.

As seen above in figure X, team 11 is in the final Mechanical design phase of the project. During this phase of the project, detailed CAD drawings for the different assemblies on the Robo-Weeder are to be completed. Other tasks being conducted are the selection of electrical components such as DC electric motors to drive the different components located on the robot. Although the team is making progress, team 11 is slightly behind schedule.

7.

Procurement

7.1 Budget

The total budget for the Robo-Weeder senior design project is approximately $3,000 which is provided by our sponsor, Jeff Phipps. The spending forecast is shown below in figure X and aides the team in understanding which aspects of the design will induce the most cost.

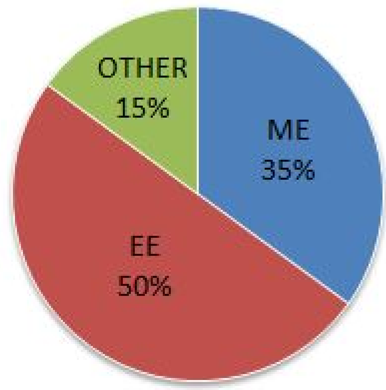

Figure 14: Projected Budget forecast by component type.

As seen in the budget forecast, team 11 has forecasted to spend approximately 50% of the funding on the electrical components. These electrical components include DC motors, batteries, microcontrollers, motor controllers and the receiver/transmitter combination. Team 11 has also forecasted an approximate amount of 35% of the total budget for the mechanical concepts. The foreseen items that will be covered under the mechanical portion of the budget include the auger shearing devices, raw materials for the construction of the chassis, wheel assemblies, auger housings, etc and finally the tires and wheels. The remaining 15% of the total budget will be used as flexible capital. This portion of the budget can be used to supplement any portion of the project's expenses.

7.2 Purchase Orders

Currently, Team 11 has ordered several of the known electrical components which will allow the team to begin crucial programming of the primary microcontroller and its communication with the user through the transmitter and receiver. These orders are presented in table X below. Other projected orders to be placed in the next few weeks include raw materials for the construction of the chassis and steering assemblies as well as the DC drive motors and batteries.

Table 4: Current Purchase Orders

Item	Quantity	Price
Arduino Mega Microcontroller	**1**	**$40**
Transmitter	**1**	**$50**

8.

Communications

During the course of the fall semester, Team 11 has used weekly meeting held on Wednesday evening to convey each individual's contributions to the project. Other methods of communication were also used by the team that would enable each member to quickly consult other team members if needed. These alternate methods included a group messaging service, email as well as phone calls. Effective communication early in the semester with the team's sponsor was used to identify the project's objectives and constraints. The team has also, held regular meetings with its faculty advisors to receive feedback regarding design considerations.

9.

Results and Discussion

Team 11 conducted a series of soil shear tests in conjunction with the civil engineering department. These tests allowed the team to project how much force would need to be applied in order to shear the soil and in turn destroy the root system of the weeds. Upon conclusion of the testing, a relationship between the normal force and the needed shear force was derived. It is estimated that the Robo-Weeder will weigh approximately 50 pounds but to account for any additional weight, the robot will be assumed to weigh 100 lbs. Also, the robot will house a shear area of approximately 28 square inches. These values yield a normal stress of approximately 3.57 psi. At this time, the relationship derived from the soil analysis can be applied which yields a needed shear stress of approximately 2.49 psi. The area that will be considered for the shear stress is approximately 2.46 inches squared which yields a force of 6.12 pounds.

Often times there are circumstances that arise that are not considered during the initial design of a prototype. These unforeseen circumstances are accounted for by using a safety factor which in turn forces an overdesign of the project. For the instance of the shearing mechanism, a safety factor of 2 was used when calculating the forces needed to shear the soil. This safety factor was used due to the large amount of uncertainty that is involved when working with soils. When applying a safety factor of 2, the needed force to shear the soil is elevated from approximately 6 pounds to 12 pounds. Team 11 will now use this value when finishing the design of the auger system and determining the motor torque.

10.

Conclusion

The Robo-Weeder project is a robotics project that aims at giving a 21st century solution to an age old farming problem. Jeff Phipps of Orchard Pond Organics is the team sponsor and has aided the team by supplying team 11 with the objectives and constraints for the project. The constraints that were outlined include incorporating a "no-till" design in which the Robo-Weeder doesn't disturb more than one inch of the top-soil, be remotely operated and be splash proof.

After the initial phases of the design process, team 11 conducted background research which included working with the sponsor to construct a House of Quality as well as completing analysis of the soil. The house of quality aided the team in identifying key engineering characteristics which need to be considered during the design process and the soil analysis allowed the team to understand the forces that the Robo-Weeder would need to apply to shear the soil.

The mechanical design portion of the Robo-Weeder consisted of the design of key components for the Robo-Weeder. These components included the design of the chassis, steering assemblies, and the auger housing. The final mechanical design has final dimensions of approximately 50” in length, 12” in width and 25” in height. The design will also house two 4” diameter augers that are each 8” in length. These augers will serve as the shearing mechanisms housed on the Robo-Weeder.

The electrical design portion of the Robo-Weeder Project consisted of the design of the Transmitter/Receiver combination that would serve as the communication between the robot and the user, the microcontrollers and the motor controllers. The final electrical design consists of the use of a six channel wireless transmitter made by RadioLink, one Arduino Mega microcontroller to serve as the primary signal processor which would then communicate to three Arduino Uno’s. Each of the three Uno’s would control a singular function on the Robo-Weeder. These functions include forward and reverse movement, front and rear steering and the control of the auger shearing system. The final phase in the electrical design is the selection of the motor controllers that will communicate directly with the motors housed on the robot.

At the conclusion of the first semester of the Robo-Weeder design project, Team 11 has learned valuable lessons. The first lesson is it is extremely important to make the most out of the available resources at the team’s disposal. During the first semester, the team maintained more open communication with the project’s sponsor instead of the team’s faculty advisor. Although the sponsor has an overall better understanding of what the final product should be, there is often a disconnect with what is actually feasible. This communication issue led to some early complications in the design phase and in turn has delayed the progress of some key portions of the project. Moving forward, team 11 has shifted its communications to more meetings with the faculty advisors allowing for a faster progression as well as a better understanding through the remainder of the design.

11.

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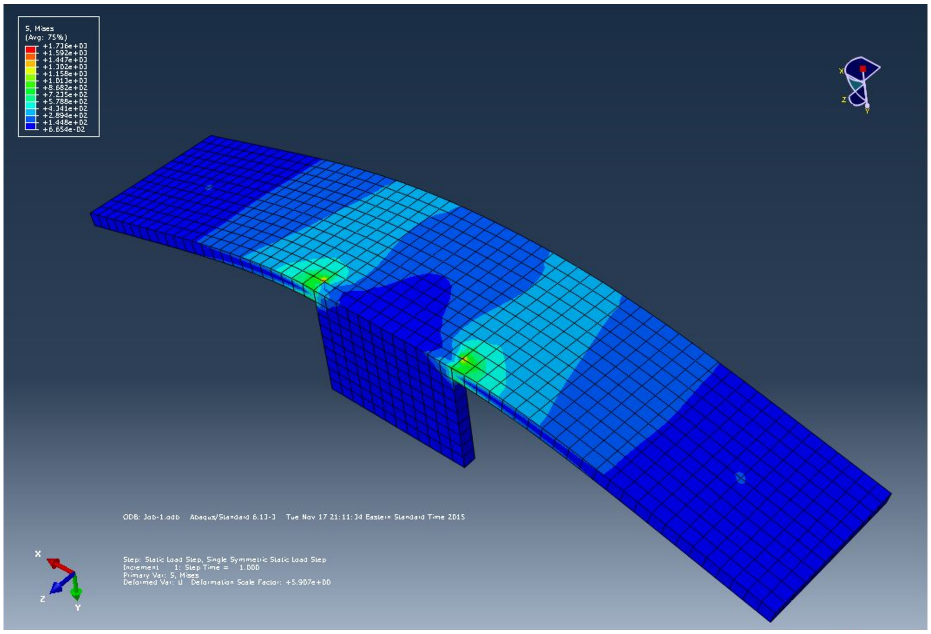
12 Appendix:



FEA analysis of previous conceptual design