A.I.V
Autonomous Irrigation Vehicle

Divide & Conquer

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Sponsored by: Guard Dog Valves

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1. Project Narrative Description

While performing marketing analysis of modern home irrigation systems, the group found that the majority of competitive products are using the classical method of transporting water through irrigation piping. The team's original idea was to innovate the yard's valve layout. Most common home irrigation systems have a valve that controls a section of sprinklers; for example, one valve controls the backyard while another valve controls the front yard as seen in figure 1. In order to innovate the team proposed a modern approach which would have an individual sprinkler head control as seen in figure 2. The control of the individual water flow would conserve water usage. After a couple of meetings with the sponsor the team suggested to possibly not use pipes, so in pursuance of revolutionizing the modern home irrigation system, the group proposes to use an autonomous mobile vehicle which carries a scalable quantity of water, as well as a hose attachment which would be used to irrigate the dry portions of the yard. Allocating the water with this kind of precision and efficiency would save the consumer money by cutting down the costs of water usage through accurate data.

Our autonomous vehicle will operate using vision intelligence and machine learning algorithms that utilize data received from a Light Detection and Rangingsensor (LIDAR). Visual intelligence enables the vehicle to identify obstacles in the surrounding environment and avoid collisions. Machine learning algorithms allow the vehicle to learn and make predictions based on data stored from previous experiences by recognizing patterns in the visual signals. These algorithms will allow the vehicle to adapt and traverse new environments.

The time and location of when and where the vehicle will water is dependent on a mesh network of soil moisture sensors. The mesh network will work with a central hub that is able to communicate with all of the moisture sensors within range to collect and return the collected data. The sensors within range of the central hub will relay the message to other neighboring sensors outside of the central hub's range, and so on to other neighbors, wherebythe central hub will eventually obtain all of the information available from all of the sensors on the mesh network. Depending on the type of grass and moisture desired, the vehicle will be dispatched to water the location deprived of moisture.

When the vehicle is not in use, it will be stationed at a home base until it is called upon to dispense water based on data from the sensors to water a designated area. The home base will feature a water reservoir and a charging station. The vehicle will be able to refill its watering tank from the water reservoir. The water reservoir will also be able to collect rainwater for reuse as well as have a garden hose attachment in case there is not a sufficient amount of water. For proof of concept, the team has decided to make a hybrid system which includes a small tank as mentioned above, but most of the water will come from a hose. The hose system will automatically retract into a spool providing an adequate amount of slack for the irrigation vehicle to traverse a yard.While at home base, the autonomous vehicle will be able to recharge its battery therebypowering its DC motors, the PCB it houses, and the sensors. Home base will also be powered by a solar panel to ensure a clean and renewable source of energy. Through these proposed means, irrigation methods will be revolutionized.

The mesh network portion of the project will be researched and designed by another Electrical/Computer engineering team which is part of the bigger sponsor. The home base, muscle and skeleton of the vehicle, and the water flow elements will be researched and designed by the Mechanical team which is also part of the bigger Guard Dog Valves sponsored team.

Sectional Valves

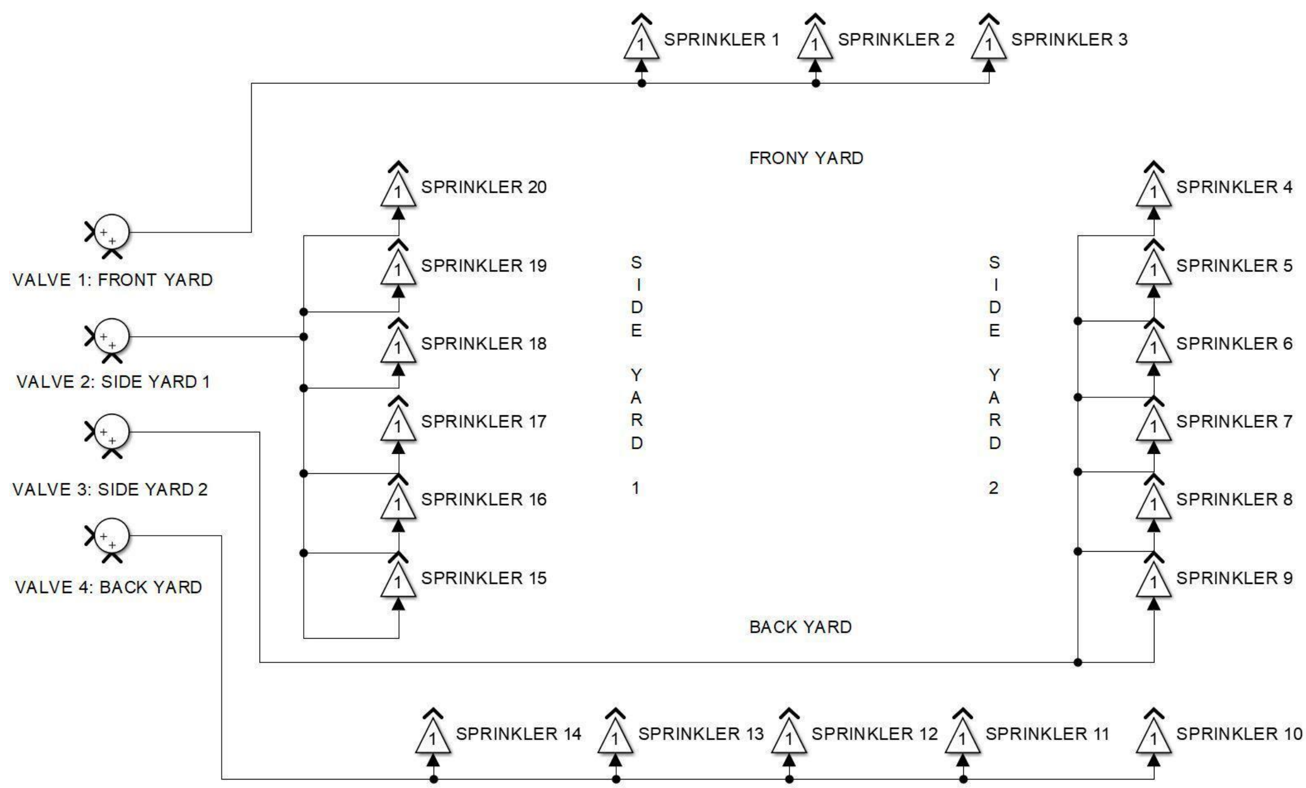


Figure 1

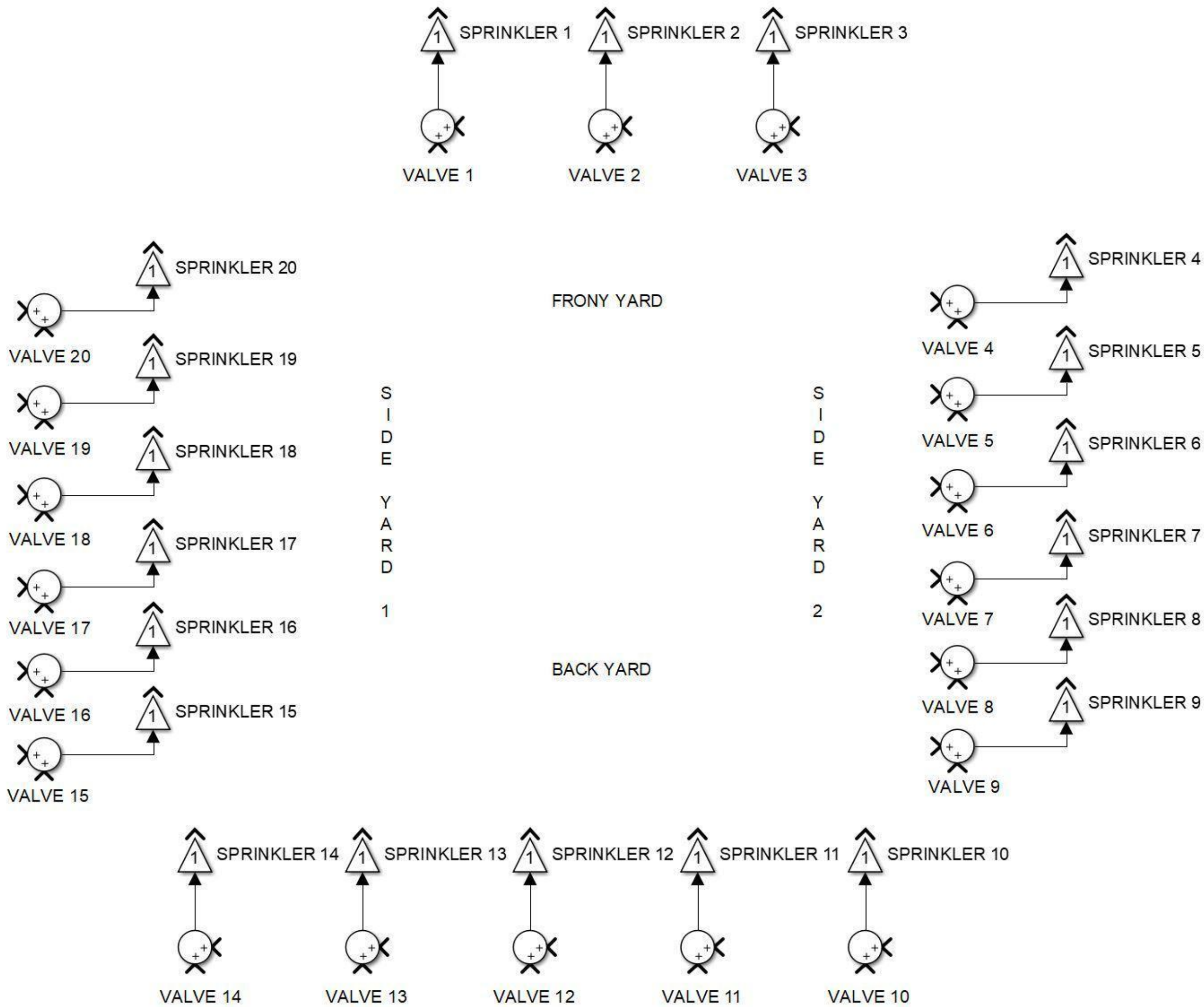


Figure 2

2. Requirements & Constraints

Time

As a group, we have set up personal deadlines for our group. By doing so, this allows our group to work efficiently and also account for any mishaps that may occur during development and research. Our group has also scheduled weekly meetings to confirm and reinforce a consistent rate of progression. With the group deciding to set a deadline before the designated deadline, the time constraints should be able to be handled with ease as well as minimize the consequences of random occurrences.

Specifications

In regards to the specifications of the given projects, there are a few sensors that will be utilized by the autonomous irrigation vehicle in order to traverse whatever terrain the vehicle is in as well as determining proper amount of water to be dispensed. Aside from sensors, the vehicle will have a PCB and microcontroller working in unison in order to communicate with the vehicle’s sensors as well as the moisture sensors installed in the ground. The vehicle’s battery life will have to be designed to output a sufficient amount of power that the vehicle will require whether traversing the terrain with a varying amount of water in the water tank or the varying rate of water flow while irrigating designated areas and plants.

Sensors such as LIDAR, power management, and water level will allow the vehicle to safely traverse its surrounding terrain, monitor battery charge and water tank’s level in order to determine whether or not to return to the home base to recharge and refill its battery and water tank. The LIDAR sensor will have range from 2cm up to 6m with a 360 degree view to detect and avoid obstacles in its surroundings. A battery management sensor will be installed in order to monitor the autonomous vehicles level of battery charge. When the level of charge reaches a certain point, a signal will be transmitted to the vehicle indicating the vehicle to return to its home base. In order for the vehicle to determine where to dispense water, it will need a wireless WiFi antenna and transmitter to communicate with the measurement sensors that are on the mesh network. As the vehicle will be dispensing water to designated areas, its water level will drop so a water level sensor will also be implemented in the vehicles design. As with the battery management sensor, a signal at a certain threshold of water will indicate that the vehicle needs to return to the home base to refill its water tank.

In order for the vehicle to make the decisions of where to dispense water and when to return to home base, there will be a need for a printed circuit board and microcontroller to be installed on the vehicle. PCB and microcontroller will have to be designed in a manner that they are small enough for both of the components to fit comfortably on the autonomous vehicle. The PCB will function as an intermediary between the sensor data and data processing of the microcontroller. Signals that are generated by the on board sensors will be communicated with the microcontroller in order to determine where water will be dispense, if there are any obstacles in the vehicle’s path, and whether or not the vehicle needs to return to home base to refill its water tank or recharge its battery. The microcontroller will be handling all of the sensor data processing as well as movement and obstacle detection per its installed motors and LIDAR sensor, respectively. With the autonomous vehicle being capable of movement, there will need to be a certain velocity that the vehicle can safely traverse the terrain that it is in so as to minimize jerking motions.

In terms of power demand, the autonomous irrigation vehicle will be requiring a substantial amount of power in order to traverse the terrain with the water tank. Depending on how much water the tank will be carrying, will dictate how much power will be needed in order for the vehicle to travel with the given weight. As such, a battery unit with a sufficient amount of voltage and amperage will be needed. Furthermore, as the vehicle itself will be operating out in the open, the battery will either need to be housed to prevent damage from the elements, have a specific amount of water resistance, or have a high resilience to outdoor activity. The power generated by the battery will also need to be distributed accordingly in regards to the demands of the sensors, motors, and water dispensing mechanism.

In regards to dispensing water at the designated watering location, the autonomous vehicle will have an additional method of transporting water. The vehicle will have a water tank attached as well as a tethered hose. The purpose of the hose is to minimize power consumption of the vehicle’s on board power supply as the water tank can add additional weight which requires a higher power output. With the hose attached, the water tank can be scaled down in size to minimize the weight, size, and power consumption of the vehicle itself. With the help of the sensors and microcontroller, the vehicle will be able to detect if the hose has been entangled with an obstacle. If the case arises of an entangled hose, the vehicle will be able to self disconnect the hose and continue to water with its own water supply. Once the hose has been detached from the vehicle itself, it will begin to retract itself to the home base or where ever the base of the hose is located.

The original project was a sensor based smart technology which focused on controlling the flow of water to sprinkler heads. Each of the sprinkler head would have had a sensor attached to it which would take in readings for soil moisture, ambient temperature, and online weather data for rain. When the data is read and processed, a microcontroller would have processed the data and would have determined whether or not the designated sprinkler head would dispense water to the designated area. In order to power the sensors on each of the sprinkler heads, a small but efficient solar panel would have been implemented to have provided power to the unit. With each of the sprinkler head sensors collecting data from the sensors, a machine learning algorithm could have been implemented to autonomously optimize watering schedules. In order to for the system to optimize the watering schedules, each of the sensors would have to been connected or linked to each other in to what is called a mesh network. In the mesh network, each of the sensors would be communicating and relaying data with each other with would provide the algorithm with enough data to begin to learn how to optimize watering schedule. Along with the proposed mesh network of sensors, mobile device application would have been designed to accompany the propose sensor technology. With the application on the mobile device, it would have been able to give the end user the ability to alter and directly be able to water any designated area with the sprinkler that was in the area. By giving the user, or customer, the ability to directly control the watering schedule, the system could also learn and develop routines based on the user’s inputs for the watering schedule.Along with providing the customer with the opportunity to control, designate, and set watering schedules, the mobile device application would have also provided the customer with valuable data such as moisture levels of the soil of a specific region, errors that may have occurred, and provide the user with current an up to date watering routines.

3. Hardware Diagram

The hardware diagrams seen in Figure 3 starts with the power which will be provided by a battery that can withstand the outdoor elements. The battery will be connected to a power distribution board as seen in Figure 3. The power distribution board will be responsible for regulating the voltage and delivering the proper amount of power to the microcontroller and other elements that might not be powered through the microcontroller. Once power is provided to the microcontroller, which will act as the brains of the autonomous irrigation vehicle, the various sensors will be able to send and receive information from the microcontroller.

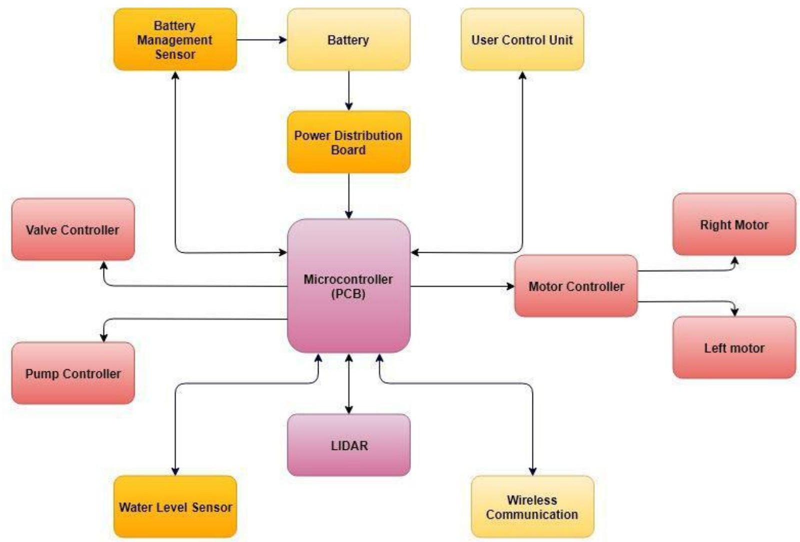
One sensor will be responsible for monitoring how much charge is left in the battery. The software will be programmed to use the battery management sensor as seen in Figure 3 so that the autonomous irrigation vehicle will always have enough charge in the battery to make it back to home base where it can refill its water tank and recharge its battery.

Another monitoring sensor will be the water level sensor as seen in Figure 3. The purpose of this sensor is to monitor the amount of water in the tank so that the autonomous irrigation vehicle knows when to return to home base and refill its tank.

The autonomous irrigation vehicle will receive user input through a user control unit. It will be attached to the microcontroller so that the user can turn off, reset, and override the moisture sensors to send the autonomous irrigation vehicle to water any specific areas desired. The microcontroller will also have wireless communication capabilities and use WiFi to send and receive information from the mesh network of moisture sensors.

The vehicle vision component will be handled by the LIDAR as seen in Figure 3. It uses optical sensing to measure the distance to an object by illuminating it with light. The LIDAR works by using a rotating mirror to sweep the light beam 360 degrees, a receiver records the time taken by the light beam to return to calculate the distance to different objects. The motor controller as well as left and right motors will also be managed by the microcontroller to move the autonomous irrigation vehicle through the yard. The valve controller and pump controller will be turned on and off by the microcontroller to regulate the flow of water.

Hardware Diagram



Block Description	Block Satus
Battery Management Sensor	Research / Not Acquired
Battery	Research / Not Acquired
User Control Unit	Research / Not Acquired
Power Distribution Board	Research / Not Acquired
Microcontroller (PCB)	Research / Not Acquired
LIDAR	Research / Not Acquired
Wireless Communications	Research / Not Acquired
Water Level Sensor	Research / Not Acquired

Figure 3

The motor and water flow elements of the hardware diagram are being researched and designed by the mechanical engineering students of our sponsor group.

4. Software Flowchart

The autonomous vehicle begins at its charging/refilling home station. When it receives a signal from the mesh network to water a location or locations, it will load a map with all currently known terrain data with coordinates of each sensor node from the mesh network that requires watering in a hamiltonian graph. The shortest path to reach each node exactly once is calculated creating a list of coordinates to reach each target node that needs to be watered and factoring in known obstacles in the area, when the list of nodes is empty the vehicle returns to its home station. The vehicle will be attached to a retractable tether from its home station to provide water and power. If the vehicle detects that its tether gets caught on something, it disconnects it and uses power stored in an on board battery to head back to its home station to reconnect the tether and return to the node it was watering to finish watering its area or to the next node it was traveling to, depending on which it was previously doing.

Software Flowchart

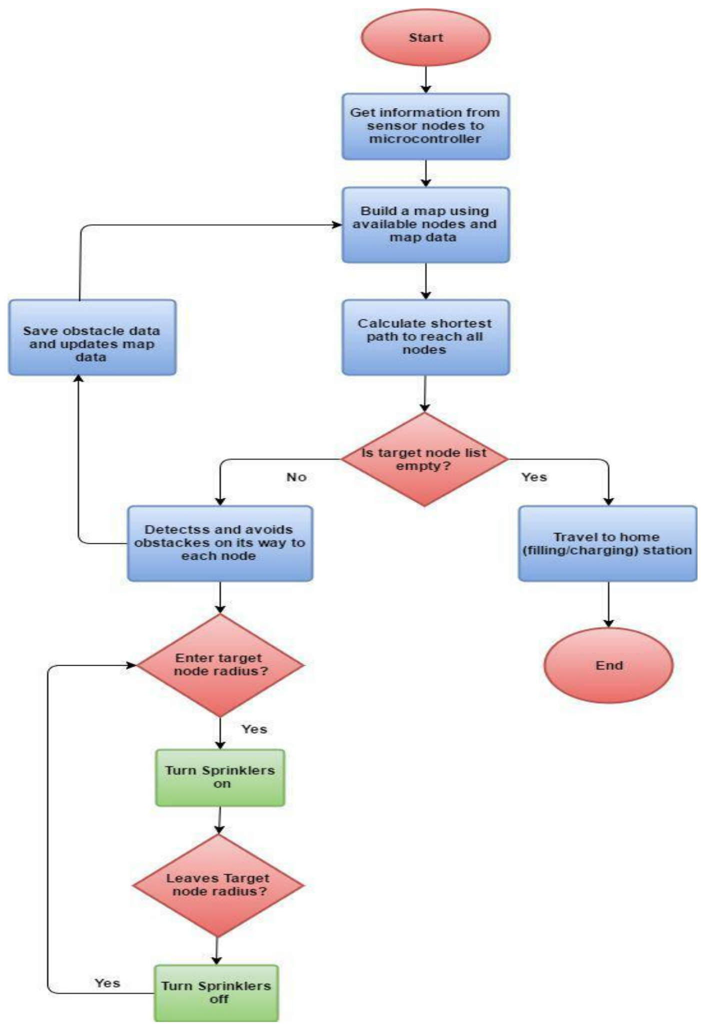


Figure 4

While the vehicle is traveling to each target node, it uses computer vision to detect obstacles such as ditches, steep slopes, rocks, trees, or anything that may impede the path or damage the autonomous vehicle. When a new obstacle is detected, it will update its map of obstacles and target nodes and recalculates a new path accordingly. It also constantly monitors for whenever the vehicle enters the range of the next target node on its path. When it does, it turns on its on board water dispensing system and circles once around the node watering the area. Once it completes its circle around the node it shuts off its watering system and heads to the next node on its path list.

This comes across as an example of the classical “Traveling Salesperson Problem” (TSP), which asks to find the shortest possible route to visit each “city” given a list of “cities” and the distance between each pair of “cities. This can be approached using a combination of an uniform cost search (UCS) and a greedy algorithm such as repetitive nearest neighbor algorithm (RNNA) or an A* search algorithm, a Markov Decision Process (MDP) could also work well for this too. With either A* search or MDP, heuristics and reward functions could be based on a water dispersion rate, an energy consumption rate, and time or distance costs for it in the future the vehicle becomes cordless with a water tank, but for the time being would start out with only time and distance while it uses the tether, with the tether RNNA may be sufficient enough.

RNNA is basically when you run a nearest neighbor algorithm using each node as a starting node. The nearest neighbor algorithm starts from a node and chooses the nearest unvisited node from the to move to next and repeats the process until all nodes have been visited. This will generate at least as many paths as there are nodes, more if at any point there are multiple neighbors who are equally close and the path needs to split. From all the paths generated, the shortest distance path, or the path with the lowest cost if dealing with other constraints, is chosen.

5. House of Quality

The House of quality shown in Table 5 represents inner relationship between the marketing requirement and engineering requirements as well as the correlation matrix shows how the engineering requirement impact each other. Each requirement is associated with positive or negative polarity.

The marking requirements are focused on what the customer need and expects. Cost is one of the main constraint in marking requirement. The cost constraint represents how much lower the customers want the price to be and it also has negative polarity which shows that the lower the cost, higher the demand for the product. Likewise, Power consumption is a measure of how much power the autonomous vehicle would consume to complete the target tasks. User friendliness is another crucial part of marketing requirement because it defines how easily the autonomous vehicle can be operated by end user. As well as the function of the vehicle should to easy to maintain. When customers buy new product (vehicle) first they check how reliable the product is.The reliability represents how well the autonomous robot will perform for this specific task.

Increasing the user friendliness and reliability of the product will make the product more desirable among buyers, so both requirements represented in positive polarity.

House of Quality

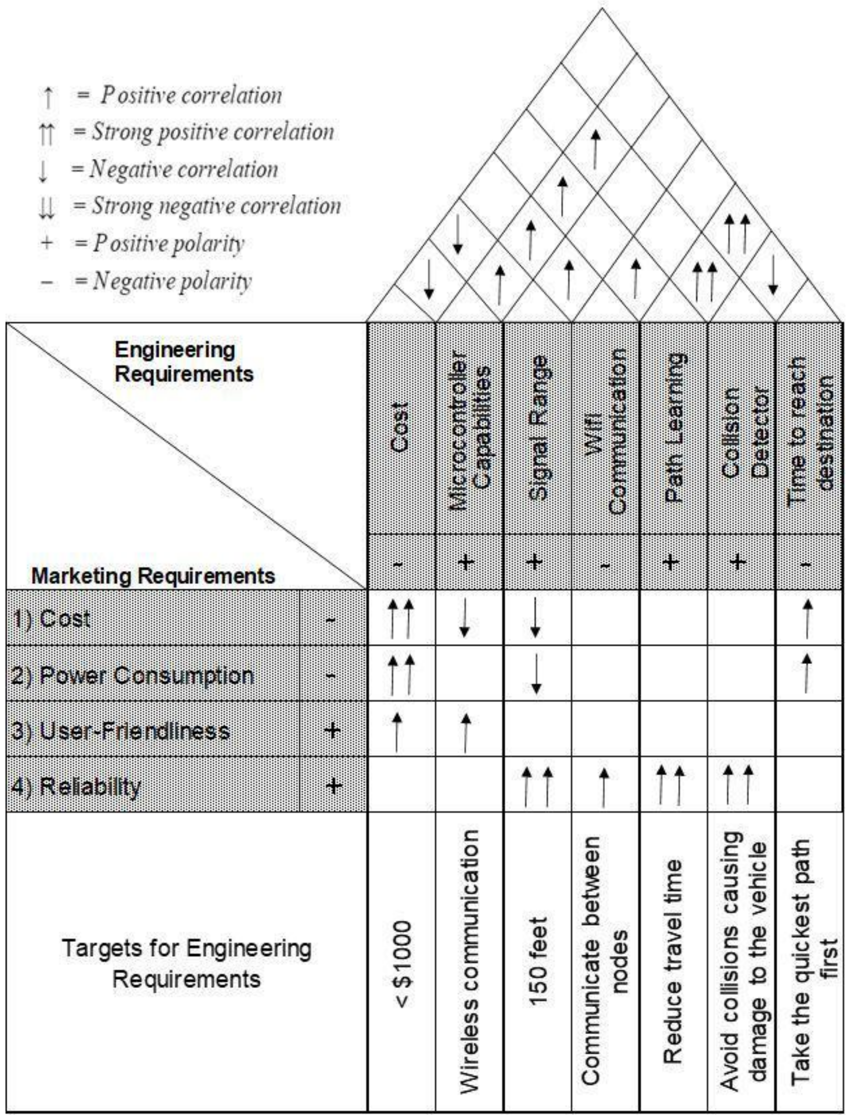


Figure 5

The engineering requirements represents how the engineers could design the product which will meet customer needs. As we talked about in marking requirement the lower the cost is better the demand. Thus, the cost is representing in negative polarity. Since Microcontroller is the brain of the robot, microcontroller enable engineers to interface mesh network and robot. Having a high capabilities microcontroller will allow engineers to reach the target more efficiently. Evidently the signal range is another significant part of engineering requirement. Each sensor node must communicate with microcontroller. Thus, the microcontroller capabilities and signal range are represented in positive polarity. Path learning will help the vehicle to reach the target node in the quickest way as well as it helps the autonomous vehicle to avoid the collision. Evidently Increase the collision detection and path learning will make the vehicle more desirable.

6. Financing

After careful consideration, our team has come to the conclusion of obtaining a couple of items in order for the autonomous vehicle to operate autonomously and safely. In order for the vehicle to operate as desired, the following items are required: A LIDAR, a battery to drive motors and other applications, a printed circuit board to have the vehicle operate with the LIDAR and other electronic components, a microcontroller to extract and read allocated data from LIDAR and mesh network of sensors, & solar panel to charge vehicle's battery after operation. Below is a budget system for the aforementioned items.

The LIDAR will be taking in data from the vehicle's surrounding area which will be used in conjunction with the vehicle vision and machine learning algorithms that will be incorporated to allow the vehicle to move autonomously. Solar panels will be installed at the home base which will allow the vehicle to recharge its battery as well as refill its water tank from the home base's reservoir tank. The 12V battery will provide the current based on the vehicle's power demand which is dependent on the amount of water the vehicle is carrying. The microcontroller will be used to control all operations of the vehicle. PCB provides communication between the LIDAR and microcontroller.

Project Budget

Items	Price Per Unit (Low)	Price Per Unit (High)
LIDAR	$199.00	$349.00
Water Level	$5.75	$22.26
Battery Management Sensor	$19.95	$190.95
Battery	$36.67	$259.00
Microcontroller	$21.27	$35.00
PCB	$5.18	$10.00
Circuit Elements	$25.00	$50.00
Total	$575.73	$957.59

Table 1

Given the high costs of the items needed to obtain the desired results of the autonomous vehicle, even when going with the economical purchases, we as a team seek out sponsorship that can provide financial aid with item procurement. Without sponsorship, we as a team propose self financing with each member paying a distributed portion in order to obtain all items on the budget list. By splitting the costs between the team members, acquirement of the needed components becomes a feasible possibility.

7. Milestones

Listed below is a table laying out an approximate estimation of deadlines the team has set out for itself. The purpose of aiming for an approximate deadline prior the actual deadline gives the team time to make final overlooked errors, incorrect data, and deal with extraordinary circumstance that may occur. By taking into account of the final revision and random events that could arise, the group has spare time to make the proper adjustments that are needed.

Senior Design 1 Milestones

#	Task	Estimated Completion	Completion Date	Assignee
	Senior Design 1			
1	Project Selection	January 18, 2018	January 16, 2918	All Members
2	Assignment of Roles	January 31, 2018	January 24, 2018	All Members
	Documentation			
3	Initial Project Document - Divide & Conquer	February 9, 2018	January 28, 2	All Members
4	Updated Divide & Conquer Document	March 6, 2018	March 8, 2018	All Members
5	60pg Draft Senior Design 1 Documentation	March 23, 2018		All Members
6	100pg Senior Design 1 Documentation	April 13, 2018		All Members
7	Final Documentation	April 26, 2018		All Members
	Research			
8	List of peripherals & sensors to be used	February 7, 2018		All Members
9	Ideal Microcontroller Unit (MCU)	February 12, 2018		CpE Members
10	Machine Learning Algorithms	February 16, 2018		CpE Members
11	Circuit Schematics	March 9, 2018		EE Members
12	Methodology to Interface MCU with PCB & peripherals	March 16, 2018		CpE Members
13	Robot Vision Algorithms	March 16, 2018		All Members
14	Finalize Research & Acquisition of Items	April 20, 2018		All Members

Table 2

The Senior Design 1 Milestones outlines a set of estimated completion dates as previously aforementioned. The estimated completion dates for the Documentation section allow the team to correct any errors or faults that may occur. Research completion dates are listed as such as to allow the team to collect the proper amount of data in order to obtain the precise information while also remaining within a reasonable timeline to complete an item from the Documentation section.

With the given Milestones set from Table 2, the team has used the given dates to address and also estimate the completion dates of assignments, requirements, & presentations that will be due for the following semester, Senior Design 2. Such as the estimations were a few days prior to the actual given deadlines within Table 2, Table 3 will also be taking to the previous identical problems, there have been a few new elements that has been included such as proper testing of components, ensuring efficient coding as well as to begin prototyping.

Senior Design 2 Milestones

#	Task	Estimated Completion	Completion Date	Assignee
	Senior Design 2			
	Development			
15	Initial PCB Design	May 11, 2018		EE Members
16	Initial Vehicle Design	May 11, 2018		All Members
17	Testing of Acquired Items	May 18, 2018		EE Members
18	Build proposed Circuit Schematic on Breadboard	May 24, 2018		EE Members
19	Build & Test proposed design of PCB	June 8, 2018		EE Members
20	Program MCU w/ appropriate functions	June 8, 2018		CpE Members
21	Design PCB Revision 1	June 22, 2018		All Members
22	Interface MCU & PCB	June 29, 2018		All Members
23	Interfacing & debugging of MCU	June 29, 2018		All Members
24	Build Prototype Unit	July 6, 2018		All Members
25	Finalization of Prototype	July 19, 2018		All Members
	Presentation			
26	Peer Review Presentation	July 21, 2018		All Members
27	Final Report	July 26, 2018		All Members
28	Final Presentation	July 28, 2018		All Members

Table 3

The initial PCB and vehicle designs need to be completed by the the 11th of May, 2018, preferably by the end of April, 2018. Once the designs have been polished and carefully analyzed, acquisition of items will begin. With the items and components in hand, then begins building and putting together the circuit on a breadboard for further analysis and tests. As the circuit is being built, the programming of the selected MCU will have also begun along it. At a later date, proper interfacing of the PCB and MCU will be performed for efficient data acquisition. Final testings of both the PCB and MCU builds will then allow the group to construct a working prototype. Within a course of one week, a finalized prototype will have been constructed which will prompt the preparation for the Final Presentation.