Midterm I Report

Team 10

Development of a Tree Climbing Snake Robot

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ABSTRACT

The removal of trees is a hazardous task for those involved. Human interaction can be reduced by using a remotely-operated tree-cutting robot. A snake inspired model was chosen since it has high mobility and required little interaction when setting up. Research has shown the existence of other snake robots that can be used for inspiration, also demonstrating the feasibility of this project. The research includes other types of robots to be able to compare and examine them with the snake-like model. After deciding for the snake robot, research was done about the different types of movement that can be achieved with this model, to allow for grounded and climbing movement. Research was done as well on the design to successfully build the robot. Part of this research includes different concepts that are necessary to the clamping and mobility of the robot. Some things to keep in mind during development will be the gripping mechanism, the environmental awareness and the power consumption of the robot. This report contains the analysis of the needs of the customer, and research on: other climbing robots, some snake robots and the types of movements that can be achieved with such robots. It also details several designs that are considered for prototyping.

1. Introduction

Currently it is very dangerous and expensive to remove trees that are on the verge of falling. If these trees are not taken care of, they can cause a great deal of damage to their surroundings, especially to residential and commercial property. This ends up being more expensive than removing the tree initially. These trees need to be professionally removed in order to minimize their potential hazards to their environments. However, the tree removal profession is still considered a very dangerous occupation. This can be fixed by removing people from the equation and replacing them with robots.

After researching tree climbing robots, it was concluded that a snake-like robot will be the most effective. The main reason was because snake robots can climb trees and crawl on the ground without direct human interaction. Many problems could be solved if a remote control tree removing snake robot was created.

Due to time constraints, this project will focus solely on the climbing aspect. Needless to say, this project will set the base for future iterations. To ensure high performance of future iterations, the robot will have to carry a payload to simulate any cutting mechanism that will be attached on any future designs.

2. Project Definition

2.1 Need Statement

The removal of trees is too technical and dangerous for the average person.

2.2 Background and Literature Review

The main objective is to develop a snake robot that can climb and cut down trees. The use of a snake robot is mostly due to customer desire. There are many types of climbing robots and some robots have been developed to prune trees. These robots were investigated as well as snake robots to see if a snake robot is really the right tool for the objective. It is important to analyze if the different robots that have been developed for the task being asked may be a better option and if some redesign or an alteration of the project scope may be needed.

2.2.1 Problem Overview

When trees get old they begin to rot, making them highly unstable. These trees poses a great threat to their surroundings and should be removed before causing significant damage. But removing trees should be done by professionals, especially the tall ones. Chopping down trees requires specific skills, precision and a good understanding of safety precautions. There is a specific process on the removal of trees. The worker will remove the branches as he or she climbs up to the top of the tree. Once at the top, worker will cut the top segment of the tree. They will then descend and cut off the top segment. They will repeat this step until the tree reaches a height of around 10 feet. Once at this height, they complete the job by simply cutting the tree at the base. However even with all these professionals, tree removing is still considered one of the most dangerous occupations. There are on average 200 [#] tree-related fatal injuries every year in the United States. We would like to minimize this number by replacing the climbing workers with a robotic snake.

2.2.2 Types of Climbing Robots

There are many methods and types of wall climbing robots. A popular way to navigate trees is using a wheeled robot [2]. These kinds of robots use two platforms each having two wheels that clamp around the trunk of the tree. The wheels can have spikes known as spines which increase the traction for climbing up the tree [2]. With the added spines the robot is able to climb trees and rough surfaces unlike some type of climbers that are more suitable for smooth surfaces. Other climbing robots consist of legged robots, such as bipedal and hexapod robots [2][3]. The ‘mini bipedal climber’ uses small claws to adhere to a surface [3]. Another robot, ‘Rise’, utilizes suction as a means of adherence to a surface [2]. Another method that was developed to climb walls was using a swarm type crawling, or anchor climbing [4]. It enables large payloads to be transported up and down walls. This is done so using parent and child units. The parent climber is attached to multiple child units that pull and assist the parent unit, all of which stay on a surface using magnetic adhesion [5]. This method is similar to a group of ants carrying large items. Other types of robots can climb up rounded surfaces using an inch worm technique of climbing [5]. The top and bottom of the device are clamps. As the bottom is clamped down on the surface the top can reach out and clamp down. This method of locomotion is extremely slow [5]. Many of the robots mentioned above typically climb on straight, even walls, aside from the wheeled robots and the pole-like climber mentioned. Some of these types of climbing are not practical for climbing trees. For instance, magnetic adhesion or suction are not useful when climbing trees. The speed at which the robot needs to traverse the tree needs to at least be moderate, meaning the inch-worm technique is not a useful climbing method for the purpose of the objective. An important aspect of the design is that it needs to be able to climb and move on flat ground. The wheeled robots need to be attached to the tree directly by the user, as it is unable to move from the ground to the tree on its own. A snake robot has the ability to shift from crawling on the ground to climbing up a tree at a reasonable speed. For these reasons, a snake-like robot is a viable option for becoming a tree cutting robot.

2.2.3 Snake Robots

Gaits

A main focus for the project is for the robot to be able to climb trees and crawl on the ground. This is because the customer desires a remote controlled robot. This can be more easily done using the snake robot because different gaits for both of those motions have already been developed [6]. Gaits are the different way the robot can move and typically change based on the type of surface it is traversing. Crawling on a horizontal surface is much different than a climbing motion. Some of the more common type of horizontal gaits include: sidewinding, rolling and slithering [6]. By sending different sine waves to the robot it is able to alter its motions to the aforementioned gaits. For climbing, the rolling gait tends to be used by having the robotic snake wrap its body around the object tightly, clamping itself to the object and using its segments as wheels to roll upward. On the ground the rolling gait makes the body in a c shape and rolls individual links to allow for motion [6].

Designs

The motion of a physical snake is very fluid and smooth, in order to achieve motion similar to this, the snake robot needs many segments or modules that can move independently from one another. A few different designs that use modules are reconfigurable robots such as 'PolyBots' [7]. These types of robots can be reconfigured by adding or taking away modules to create new designs. They are not limited to just snake-like designs, but making them attachable and finding ways for the modules to communicate with one another can be difficult [7]. Another type of modular robot is a string type robot, these are the typical snake robots that are built [7]. They cannot be taken apart. Instead, they are a series of modules connected together. To allow for more variety of motion (allowing the use of multiple gaits), these modules can be oriented offset to each other by 90 degrees. Each module needs to have one degree of freedom, rotation about the z axis, and it has to be powered by motor individually [7]. More research on the different designs of snake like robots need to be done, but it is worth noting that the ones described have proven to be successful.

2.3 Goal Statement

The goal is to build a remotely operated snake-like-robot that will safely climb trees.

2.4 Objectives

The objectives for this project are detailed under Table 1. Objectives for the Design.

Table 1. Objectives for the Design.

Characteristic	Description
Good Grip	Length of snake robot must be at least 1.5 times the circumference of the tree
Good Range of Communication	Remote must be able to communicate with robotic snake at least 60 ft
Climbing Speed	Robotic snake must be able to climb tree at a reasonable speed (goal is 1 ft/min)
Durability	Must be made of a material strong enough to withstand damage
Climbing Power	Must be able to climb the tree with a 20 lb payload

2.5 Constraints

The constraints for this project are written under Table 2. Constraints for the Design with Descriptions

Table 2. Constraints for the Design with Descriptions

Constraint	Description
Remote Controlled	Snake robot is controlled by user on ground via a remote
Camera	Camera must give user feedback of the snake robot's environment
Power Source	It must operate on a rechargeable battery
Lightweight	Robot is light enough to overcome dynamic forces
Climbing Method	Robot must climb tree in a helical path

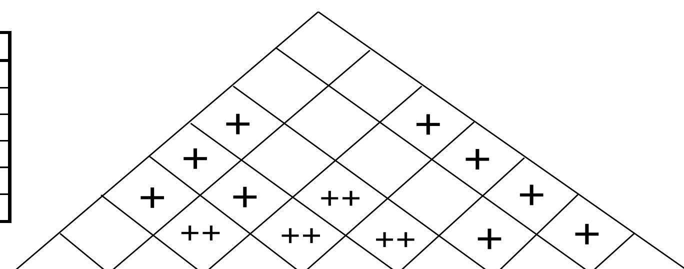
2.6 Project Scope

The purpose of this project is to design a helical climbing snake robot. In future iterations, the robot will be tasked to cut down trees. This is replicated in the design by having it carry a payload of 20lbs representing the cutting mechanism. The robotic snake is to be operated remotely by a user who may visualize the snake's perspective by utilizing a camera on the snake's head. The snake needs to obtain a good climbing speed in order to cut trees as quickly as possible. In literature, the maximum found was 3 feet per minute and the average was 1.5 feet per minute [8]. The robotic snake has to be durable in order to handle the stresses induced with climbing and gripping. The snake must be able to climb the tree and descend the tree for the extent of its battery life.

2.7 House of Quality

In order to tackle the multi-variable problem set forth by our sponsor the team implemented a House of Quality, see Figure 1. House of Quality for Project.. By design, the House of Quality is a methodological tool that consolidates the need of the customer and the need of the product. The customer requirements were obtained through consultations with the sponsor. Engineering characteristics were then developed by the team to provide specifications for the product. From the House of Quality it may be seen that the highest ranking Engineering Characteristics were in order of importance: gripping mechanism, environmental awareness and power consumption.

Legend	
0	No correlation
3	Low correlation
6	Medium Correlation
9	High Correlation
+	Weak direct correlation
++	Strong direct correlation



Customer Requirements (CR)	Customer Importance (CI)	Engineering Characteristics (EC)						
		Wheel Type	Strength of Material	Weight	Gripping Mechanism	Power Consumption	Distance of Communication	Environmental Awareness
Rechargeable Batteries	5			3		9		
Easy To use	6	3		6	6		3	6
Resilient	5	6	9		6		6	9
Visibility	7					9	9	9
RC Friendly	7				3	6	9	3
Climbing	10	9	3	9	9	9	3	6
Safe	10	6	9	6	9		3	3
Score		198	165	201	267	240	234	255
Relative Weight		12.7	10.6	12.9	17.1	15.4	15.0	16.3
Rank		6	7	5	1	3	4	2

Figure 1. House of Quality for Project.

By looking at the 'roof' of the house of quality, the correlations between the ECs can be analyzed. Since the gripping mechanism will be an important part of the final design, it will be wise to look at how it affects the weight and power consumption. Since the gripping mechanism holds the robot against the tree, a strong compressive force act on the robotic snake, so a stronger material will be required as this force increases as well.

3. Design Contents

In this section, everything regarding the parts used for the designs will be discussed.

3.1 Wheels

The robot is going to need some mechanism to move, as the design calls for a helical climbing motion. Wheels were one of the simplest solution devised by the team. Attaching wheels to the robot allow for mobility with the attachment of a motor on the axle or rotation. The wheel system, although simple, can have a couple of variations.

3.1.1 Single Wheel

A single wheel is mounted with its axis or rotation planar to the center of gravity. This is done to prevent tilting of the system, similar to a motorcycle. It supports the structure on a single pivot point, applying great pressure on the point of contact with the surface. If a thin wheel is used, the system pivots easier than if a paint roller-like wheel was used. The benefits of having a single wheel is that it is more lightweight and cost efficient that having more. But, as explained before, rocking and tilting of the system is an issue, especially if the robotic snake is to be clamped with great force to the tree’s surface.

3.1.2 Dual-Parallel Wheels

Two wheels are mounted parallel to each other, equidistant from the center of gravity. By having the wheels set up this way, the system is constrained from rolling. That is, unless there was some external force that would cause the robotic snake to lose balance. Even though it provides better stability, it increases the torque requirements to overcome the inertial moment of the wheels, as well as the overall weight of the structure.

3.2 Actuator

There are several ways in which a system can be actuated to produce a desired motion, whether it is climbing or clamping.

3.2.1Pneumatics

Pneumatic actuators are actuators that use air pressure to create different types of motion. The two main types of pneumatics are linear and rotary. The linear pneumatic works like a piston. The air is drawn from outside into a chamber behind the rod at the end. As the pressure in the chamber increases the rod extends outward. Some pros to using pneumatics are their environmentally safe working fluid. Air can be pulled from outside and when it needs to decompress it can be released back into the environment. This also allows it to be lightweight. Because it can pull the working fluid from the environment, it doesn't need a reservoir to store the working fluid. It has a fast reaction speed, so it can actuate quickly, but because it uses air the movements are also unsteady and jerky. The jerky movements of the pneumatic are because air is a compressible fluid, this makes the motions complicated to understand and the math much more challenging for future work. The other biggest problem with using pneumatics it the seals tend to break or get worn out easily and can be difficult to replace. Once the seal is worn the pneumatic cannot work efficiently or at all.

3.2.2Hydraulics

Hydraulics are very similar to pneumatics but use a different working fluid. Instead of using air hydraulics use some sort of incompressible liquid, most typically oil. The forces that hydraulics can exert are much higher than that of a pneumatic and could ensure strong enough compressive forces to hold the device to the tree. With the use of an incompressible fluid the math becomes much simpler, but the motions that result are smooth and controlled. This is beneficial because it makes it easier for the user to control the robot. Some cons to hydraulics is that it needs a reservoir for the oil to return to when it contracts and expands. This reservoir adds quite a bit of weight and hydraulics themselves are heavier than pneumatics. The other major setback is that hydraulics are much slower than pneumatics. This is an issue that needs to be kept in mind because the robot needs to be able to climb the tree quickly, which will rely on how quickly it can grip the tree.

3.2.3Electric

The electric actuators are actuators that use motors to move. The motors are powered by a voltage source meaning a battery. These type of actuators can be very powerful depending on the motor and are environmentally friendly. The hydraulics uses oil which can leak and cause damage to the sounding area, but the motors run on electricity so there is no oil to be spilt. Electric actuators are very common and are often used in robots, as a result they are easy to acquire and are less expensive than pneumatics and hydraulics. A downside to using electric actuator is that each motor needs its own power source. The pneumatics can be powered by one source and the air line can run to all the actuators. Electric motors cannot be done the same was as efficiently because the after passing through each motor there it going to be a voltage drop and less power to the next.

3.3 Gripping Mechanisms

There were three main types of gripping mechanisms that were considered. The first type was using electric actuators. This gripping mechanism would be used with a modular design. Each module would be controlled by a motor at the joint. The joints would alternate between pitch movements (up and down) and yaw movements (left and right). The motors would power the joints keeping the segments tightly wrapped. The other type of gripping mechanism that was considered for the modular design, was adding a strong wire inside the modules that run along the length of the snake robot. The wire would be rigidly attached to the head of the robot and the end near the tail would be pulled in tension. The tension would be supplied by a motor or spring or a combination of the two to tighten the wire. As the wire is tightened the robot will want to curl around. The more tension that is supplied the tighter the robot will become around the tree. The only limitation are the segments themselves which is the same limitation with the electric actuators. The third idea is to use a soft actuator. This design utilizes pneumatic actuation to clamp on the tree. The soft actuator is one segment that when pressurized will make a helical shape. The air compressor would be at the tail of the robot and would pressurized the entire segment. The segment would then form to the tree in the set helical shape.

4. Design Concepts

As of now the team has constructed two design concepts that are worth pursuing. The design concepts were generated from the Pugh matrix, which was developed from the morphological chart. Both may be found in the contents of this paper. The two designs were: the motorized modular aluminum snake robot and soft actuated fiber snake robot. The two main differences between them were the gripping mechanisms and the modularity, both which will be detailed below.

4.1 Design 1 – Motorized Modular Aluminum Robot Snake

The aluminum modular snake robot was the first design selected from the morphological chart. The aluminum body gives the body high strength as compared to other considered design materials such as the elastic body of the soft actuated robotic snake. The aluminum body is by consequence naturally heavy, however this may be reduced by hollowing out the material as much as possible. The only drawback from this approach is the reduction in strength by consequence. This design also features spiked wheels. This is due to their incredibly high friction coefficient as well as lack of concern for the residual health of the tree.

4.2 Design 2 – Soft Actuated Fiber Robot Snake

The soft actuated snake robot was the second design selected from the morphological chart. The soft actuated mechanism allows the robotic snake to take a helical form actuated by pneumatics. The materials implemented are also much lighter than the aluminum material. However, this in turn makes the material more prone to tears and unwanted deformations. This design also features spiked wheels. This for the same reasons as mentioned above. Both designs will be further detailed in the comparison below.

4.3 Design Comparison

In terms of gripping mechanisms the motorized modular aluminum snake robot design implements electrically actuated servo motors to apply a perpendicular force to the surface of the tree. The servo motors will be revolute and be implemented throughout the snake robot’s length to oppose gravity and avoid slipping. The main issue with this design is that the snake robot would require a large amount of motors which tend to be expensive. Furthermore, the motors will consume energy from the same source being used to drive the snake forward. This in turn may require larger or more batteries in series. This consequently will increase cost in batteries and the weight of the system. Figure 2. Helically Wrapped Modular Robotic Snake., shows a modular snake wrapping itself helically around a constant radius pole.

Figure 2. Helically Wrapped Modular Robotic Snake.

The second gripping mechanism is that of the soft actuated snake robot. The soft actuated gripping mechanism comes in a variety of geometries, and by implementing pneumatics it can bend in a variety of ways. It possesses the ability to bend and twist simultaneously. The bending motion tends to form a helical shape which is used to form the robot into the desired position. The twisting tends to turn the robotic snake along an axis that is aligned with the geometry's symmetric axis. To visualize the symmetric axis assume the object was fully stretched and thus appears to be a cylinder. The axis referred to as the symmetric axis is the axis along its height placed directly in the center of its circular cross section. The twisting and bending is formed by a pneumatic cylinder in the geometry of the object to be actuated. This pressure is placed off the center of mass causing the geometry to bend and twist. The gripping mechanism would thus depend on the pressure input by the pneumatic actuator. This means that a compressed air is necessary for operation. Having a compressor will increase the overall weight of the system. On a positive note, this component is completely independent of the electrically actuated driving mechanism. An alternate method would be to use tanks to store pressurized air. The downfall that made the second design less attractive than the previous is the fact that soft actuators are complex to build. Furthermore, they rely on elastic materials to achieve its variance in helical parameters. This in turn means the materials is not as strong as the aluminum design mentioned above. It is crucial that the materials are strong as the cutting of tree will require great force to resist falling from as well as to have a stronger grip for the tree. Given the complexity of the build and the large force being exerted on the robot, the modular aluminum snake was the design chosen to move forward with. Figure 3 shows an example of a soft actuated object undergoing bending and twisting.

Figure 3. Example of Soft Actuated Object Undergoing Bending and Twisting.

A further distinction between the two designs is the modularity of each. The modular aluminum snake robot is inherently modular. The soft actuated snake robot on the other hand is a single segment. The modularity from the aluminum snake robot comes from its links that may be attached with as many as needed to wrap itself around the tree. The soft actuated snake robot is set to a fixed length. This consequently puts a strict limit on the diameter of the trees in which the soft actuated snake robot may climb.

The similarities between them are straight forward. Both rely on electrically actuated servo motors to drive the system. Both also will feature spiked wheels. This becomes an obvious issue to the soft actuated mechanism if it were to puncture a hole in the elastic air-filled material. Both will be remote controlled and will feature rechargeable batteries to power the robotic snake. As seen and described above, the design that produces the least amount of future complications is the modular aluminum snake robot and thus is the design chosen to move forward with.

5. Design Selection

5.1 Morphological Chart

Table 3. Morphological Chart of the Snake Robot. below shows the morphological chart used to make the designs above. Every functional parameter has at least two possible ways in which it could be employed. The numbers displayed under the solutions are the rating given to that solution in comparison to each other. A plus 1 means that it would be the most optimal, since it follows the constraints or fulfils the requirement the best. A zero means that, though it is a good solution, a better alternative exists. A -1 means that either the integration of the system will be complicated or it is undesirable to have as part of the design.

Table 3. Morphological Chart of the Snake Robot.

Requirements	**Functional Parameters**	**Concepts or Solutions**		
Climb Trees	Wheels	Spiked Wheels (+1)	Rubber Wheels (0)	Continuous Track (-1)
	Clamping	Soft Actuator (+1)	Cable (+1)	Electric Motor (0)
	Construction Type	Single Segment (0)	Modular (1)	
Durable	Material	Reinforced Fibers (0)	Aluminum (1)	Steel (0)
Ease of use	Communication	Wireless (1)	Wired (0)	
	Transportation	Self-Moving (1)	Carried to tree (0)	
	Power input	Wired (0)	Disposable Battery (-1)	Rechargeable Battery (1)

5.2 Pugh Matrix

To fulfil the requirements stated in the previous section, it was ideal to choose only one solution. This was done for simplicity, since the integration of several solutions would not only be redundant, but also increase the complexity of the system. Table 4. Pugh Matrix for Selection of Design. below shows the Pugh Matrix that was used for design selection.

Table 4. Pugh Matrix for Selection of Design.

Concept	Base	Design 1	Design 2
Wheels	0	1	1
Clamping	0	1	1
Construction Type	0	1	0
Material	0	0	0
Communication	0	1	1
Transportation	0	0	0
Power Input	0	1	1
Score	0	5	4

Design 1, the Motorized Modular Aluminum Robotic Snake, was the one with the highest score. This means, that this design was the most optimal in fulfilling the requirements for this project and will be the one to be developed. It is worth mentioning that design 2 was behind by only one point, so perhaps part of the second design could be meshed with the first one and create a third, better design overall.

5.3 FMEA

After selection, it was important to understand how it could fail and what such failures mean for the overall design. A Failure Mode Effect Analysis was constructed on Table 5. FMEA for Snake Robot., below. It describes what happens to the robotic snake if a component were to fail. Of course, this process is preliminary and some further failures are yet to be determined. Additionally, if more components were to be added, this table would expand to accommodate.

Table 5. FMEA for Snake Robot.

No.	Functional Parameter	Failure Mode	Cause	Effect on Primary System
1	**Wheels**	Axles breaks or wheel deforms	Wear / Fatigue / Concentrated Stress	Snake robot becomes stranded / mobility severely reduced
2	**Clamping**	Clamping system breaks	Wear / Fatigue / Concentrated Stress	Robotic snake becomes loose and falls
3	**Material**	Material deforms or breaks	Wear / Fatigue / Concentrated Stress	Damage to immediate surrounding / internal systems
4	**Method Of Communication**	Damage on transceiver / interference	Water Damage / Short Circuit / Noise	Robotic snake is unable to be operated manually
5	**Power Input**	Power stops flowing	Battery Leakage / Cable Damage	Snake robot shuts down

6. Methodology / Management

6.1 Schedule and Resource Allocation

To manage the project development, a Gantt chart was designed. Because of its size, it was split into three separate pieces. Each piece details an important part during the development of the project.

The piece of the Gantt chart shown on Figure 4 details the project background. The project background highlights the sponsor/adviser meetings that will develop the scope of the project.

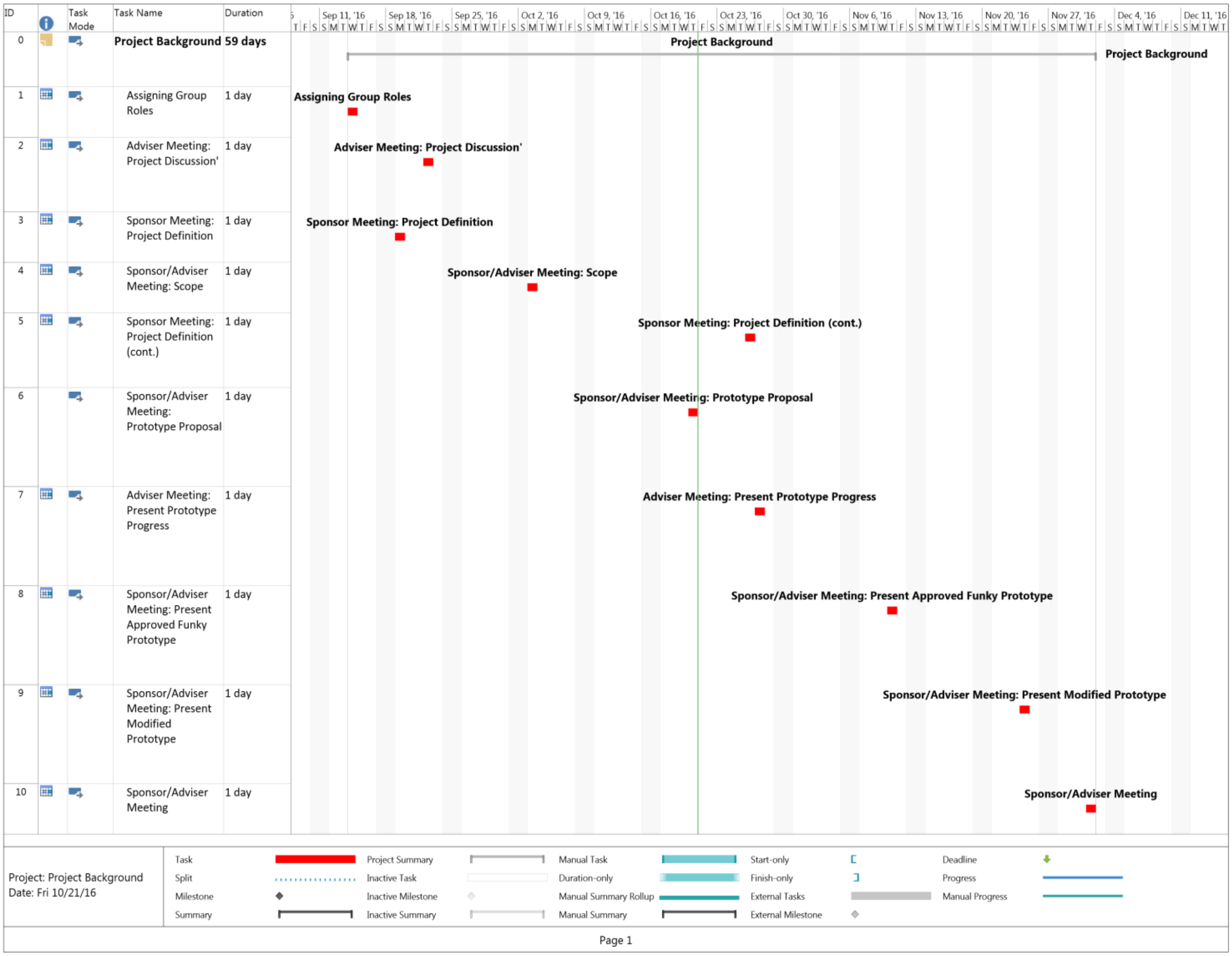


Figure 4. Project Background Plan.

The piece of the Gantt chart shown in Figure 5 details the background research. The background research occurs continually but is shown in the above chart in discrete segments on a task to task basis.

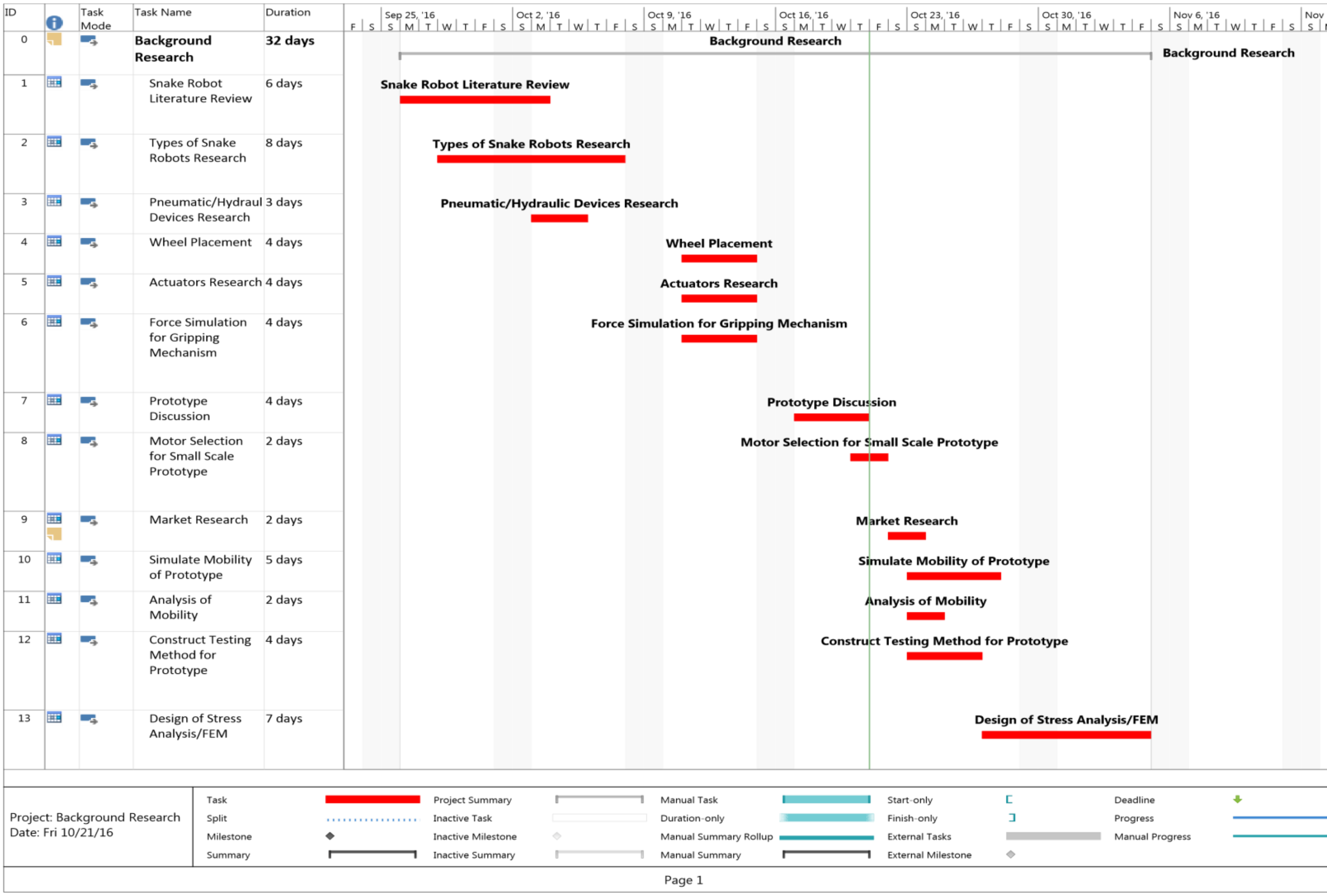


Figure 5. Background Research Gantt Chart.

The piece of the Gantt chart shown in Figure 6 details the prototypes portion of the chart. This portion details the prototyping of the project for the fall semester. Time in-between will be left for research, simulation, and optimization.

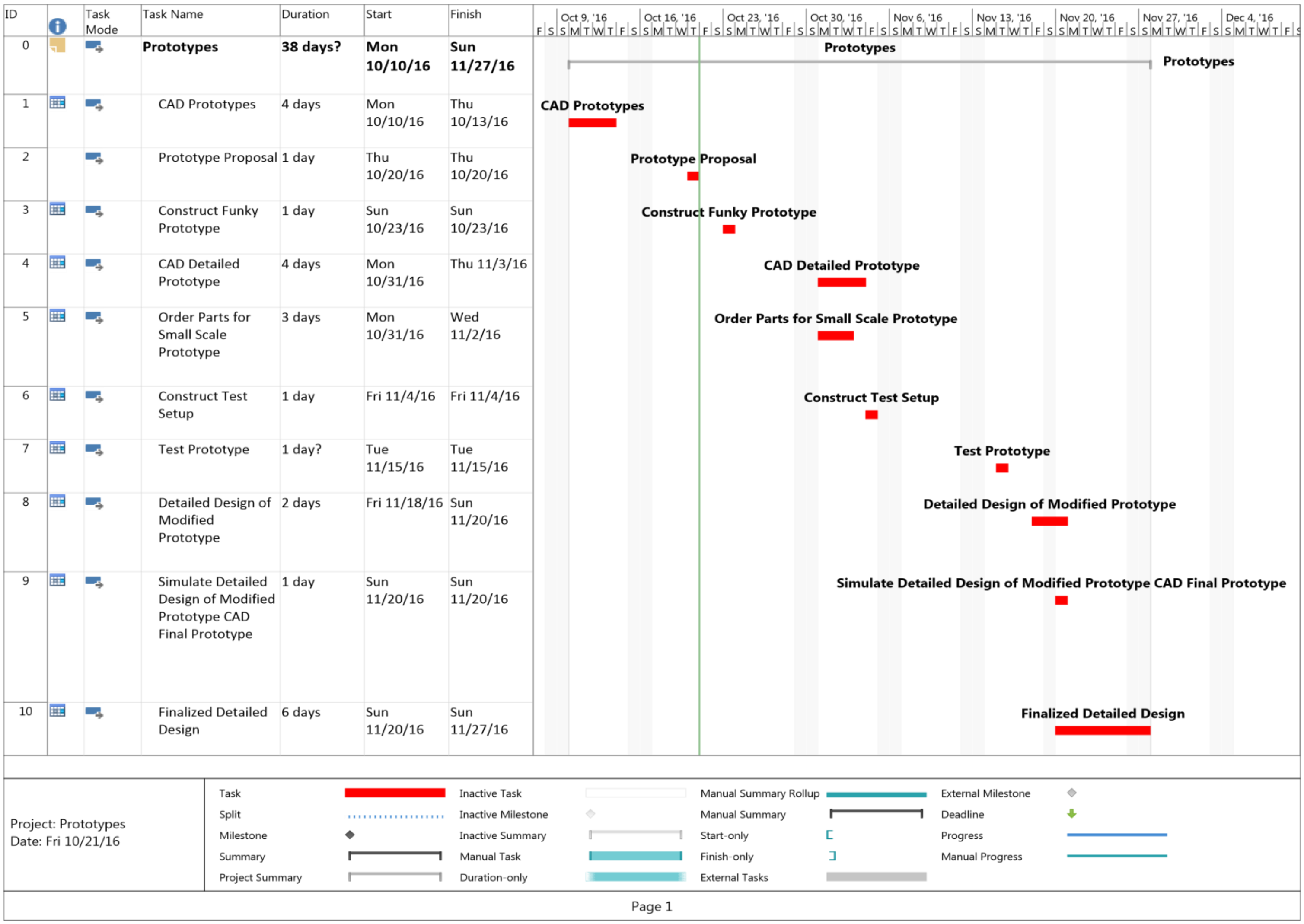


Figure 6. Prototype Development.

6.2 Challenges

Some of the challenges during development is the design of the snake robot. Since it will be clamped with great force onto a tree, the geometry of the design will be crucial to determine the force distribution. Early calculations show that the clamping force, the size adaptability, the stability among other things will vary with how the joint modules are connected. For instance, the closer the joint is to the tree, the greater the stability, but the harder it is to clamp down.

Time is a big challenge to overcome. A prototype has to be ready to assemble by late December, and rigorous testing is to follow.

6.3 Results

Some of the concepts for gripping were tested out and more research was done for the different designs that were being considered. A rough model of the modular snake robot was made out of cardboard to get a better understanding of the links and the motions necessary for mobility in a helical shape. The joins were all made to be single revolute joints, where one joint controls the wrapping motion while the next joint controls the upward motion. What the team learned from building this model was that pneumatic actuator would not be as useful for this type of design. Using motors at the joints would allow the robot to be much more compact than using pneumatics. And using rotary pneumatics instead of motors are much more expensive, while also having a higher chance of failure because of the constant pressure needed to keep it constricted. The downfall of using motors is that it would need to have a motor at each joint, which adds weight and cost to the design. The other concept that was tested was the soft actuator. Using a cardboard mold and liquid rubber, a bending actuator was created. The bending actuator was made in two parts, a flat bottom with a piece of paper to create the bending motion and top half with an air chamber. After a few tests of pressurizing the actuator it ruptured at the seam. Mainly this rupture occurred because of the sudden impulse of air that was sent to the actuator, but it wasn’t reliable or strong enough to withstand an impulse of air, and is suspected that it will not be able to be safe to operate around sharp objects that could puncture it.

7. Conclusion

A tree cutting robot is to be designed, with the goal of improving the safety associated with removing trees. Preliminary research suggests that a snake robot is a good choice to handle the task set forth by the sponsor. For snake robots different gaits have already been developed for both, climbing and crawling. While more research was necessary, it was found that the assembly of the snake robot may be handled by attaching the joints modularly with multiple segments connected to one another. In this set-up there is inherently a high amount of redundancies. This will provide flexibility, allowing for more fluid motion. From the information gathered, the main concerns during development will be the gripping mechanism, environmental awareness and power consumption. Preliminary design was done, and further refinement of the snake robot will come as prototyping and testing begins.

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Team 10 - Biography

The group leader of this project is Jorge Campa. He is pursuing a career in robotics and control systems. In his time at Florida State University he has been a teaching assistant in Dynamic Systems I and II. He has also served as an undergraduate research assistant at the High Performance Materials Institute.

Justin Morales is currently finishing his Bachelor's degree in mechanical engineering and plans on pursing his Master's after he graduates. He is the WebWizard for his team and is responsible for design and updating the senior design website.

Michelle Maggiore is serving as the lead Mechanical Engineer. She is interested in pursuing the field of robotics and is currently working at Florida State University's STRIDE lab.

Esteban Szalay is a Senior Mechanical Engineer student at Florida State University. By having an interest in teaching and robotics, he aids with the calculations for the design, as well as serving as a source of information.