Development of a Tree Climbing Snake Robot

Team 10

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Agenda

- Project Scope
  - Define Problem
  - Focus on solution
- Background Research
  - Existing robots and actuators
- Concept Generation
  - Creating and selecting a design
- Future Plans

What is the Problem?

- Old trees may fall at any moment
- Removing tall trees should be done by professionals
  - Requires specific skills and precision
  - 200 tree-related fatal injuries every year [1]
- Homeowner's insurance
  - $500-$1,000 for removing fallen trees
  - Healthy vs. Dead trees
- Car insurance
  - Only with Comprehensive insurance

Tree Removal Services

- Removing Process:
  - De-limbing on the way up
  - Cutting small segments on way down
  - Cut at base once at reasonable height
- Price ranges from $150-$1,500
  - Complexity
  - Height of tree
- Focus on pine trees
  - Average Diameter: 2.5 ft
  - Height: +100 ft
  - Age: 250 years

Project Definition

- Need Statement:
  - The removal of trees is too technical and dangerous for the average person.
- Goal Statement:
  - Build a remotely operated snake-like robot that will safely climb trees.
- Scope:
  - To climb a tree, in a helical manner, carrying a payload for future iterations.

Objectives

Table 1. Project Objectives with Descriptions

Characteristic	Description
Good Grip	Length of snake must be at least 1.5 times the circumference of the tree
Good Range of Communication	Remote must be able to communicate with snake up to 60 ft
Climbing Speed	Snake must be able to climb tree at a reasonable speed
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

Constraints

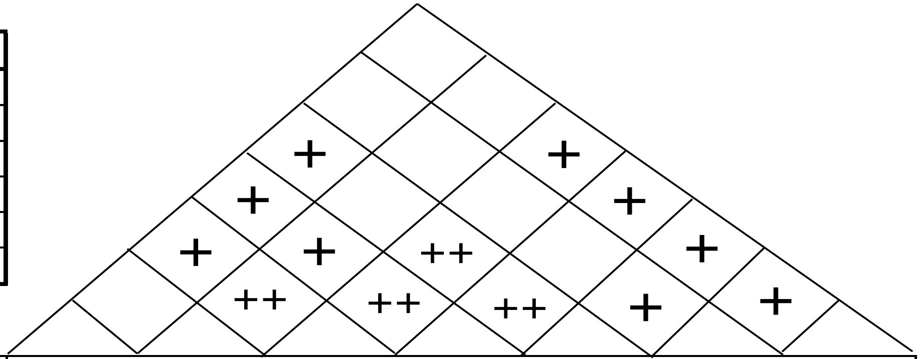
Table 2. Project Constraints with Descriptions

Constraint	Description
Remote Controlled	Snake is controlled by user on ground via a remote
Camera	Camera must give user feedback of the snake'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

HOQ

Figure 1. House of Quality detailing rank of importance of the engineering characteristics

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

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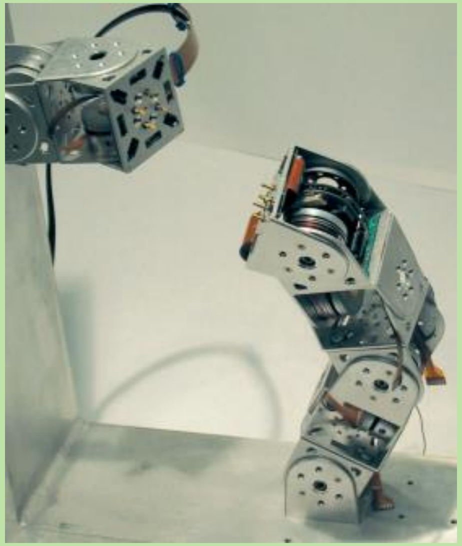
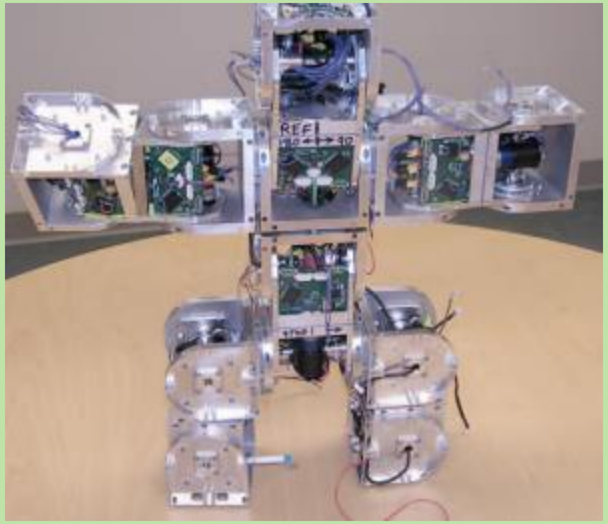
Types of Existing Non-Snake Robots

- Treebot
- Wheel climbers
- Pole like climber
- RISE

Types of Snake Robots

- Lattice
  - Reconfigurable
- String type
  - Modular





Pneumatics

- Pros
  - Uses air pressure to create mechanical energy
  - Reversible directions
  - Lightweight
  - Doesn't overheat with being overworked
  - No reservoir
- Cons
  - Cannot exert as much force as hydraulics
  - Air is compressible

Hydraulics

- Pros
  - Can exert large forces
  - Fluid used is not compressible
  - Controlled motions

- Cons
  - Slow
  - Potential environmental harm
  - Needs a reservoir to store fluid

Morphological Chart

Table 3.1 Morphological Chart with Concept Development

Requirements	Functional Parameters	Concepts or Solutions		
Climb Trees	Wheels	Spiked Wheels	Rubber Wheels	Continuous Track
	Clamping	Pneumatic	Motor	Hydraulics
	Construction Type	Single Segment	Modular	
Durable	Material	Reinforced Fibers	Aluminum	Steel
Ease of use	Communication	Wireless	Wired	
	Transportation	Self Moving	Carried to tree	
	Power input	Wired	Disposable Battery	Rechargeable Battery

Design 1 - Selection

Table 3.2. Design 1

Requirements	Functional Parameters	Concepts or Solutions		
Climb Trees	Wheels	**Spiked Wheels**	Rubber Wheels	Continuous Track
	Clamping	Pneumatic	**Motor**	Hydraulics
	Construction Type	Single Segment	**Modular**	
Durable	Material	Reinforced Fibers	**Aluminum**	Steel
Ease of use	Communication	**Wireless**	Wired	
	Transportation	Self Moving	**Carried to tree**	
	Power input	Wired	Disposable Battery	**Rechargeable Battery**

Design 2 - Selection

Table 3.3. Design 2

Requirements	Functional Parameters	Concepts or Solutions		
Climb Trees	Wheels	**Spiked Wheels**	Rubber Wheels	Continuous Track
	Clamping	**Pneumatic**	Motor	Hydraulics
	Construction Type	**Single Segment**	Modular	
Durable	Material	**Reinforced Fibers**	Aluminum	Steel
Ease of use	Communication	**Wireless**	Wired	
	Transportation	Self Moving	**Carried to tree**	
	Power input	Wired	Disposable Battery	**Rechargeable Battery**

Concept Selection

Table 3.4. Point system for decision matrix.

Requirements	Functional Parameters	Concepts or Solutions		
Climb Trees	Wheels	△ Spiked Wheels	○ Rubber Wheels	■ Continuous Track
	Clamping	△ Pneumatic	△ Motor	○ Hydraulics
	Construction Type	○ Single Segment	△ Modular	
Durable	Material	○ Reinforced Fibers	○ Aluminum	○ Steel
Ease of use	Communication	△ Wireless	○ Wired	
	Transportation	△ Self Moving	○ Carried to tree	
	Power input	○ Wired	■ Disposable Battery	△ Rechargeable Battery

△ Optimal
○ Desirable
■ Undesirable

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Concept Selection – Pugh Matrix

- **Design 1**

Motorized Modular Aluminum Snake

- **Design 2**

Soft Actuated Fiber Snake

Table 4. Pugh Matrix for selecting a 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 – Motorized Modular Aluminum Snake

- Pros:
  - Motors – Should provide good, adaptable grip. Familiar and easy to set up and purchase.
  - Aluminum – Lightweight. Strength of 40,000psi [9].
  - Modularity – Variable Length.
- Cons:
  - Modularity – Have to apply force to keep in helical shape. Cost increases with each module.
  - Aluminum – Stiff. Forces applied may cause permanent deformation.

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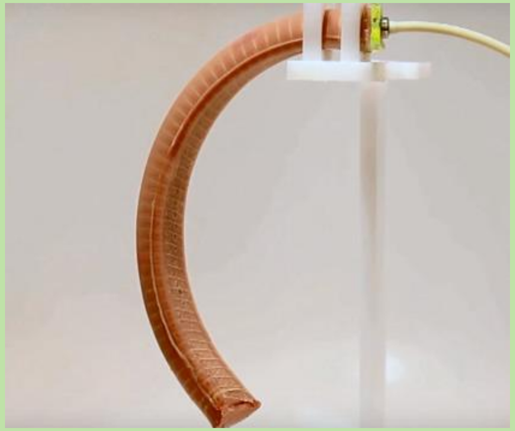
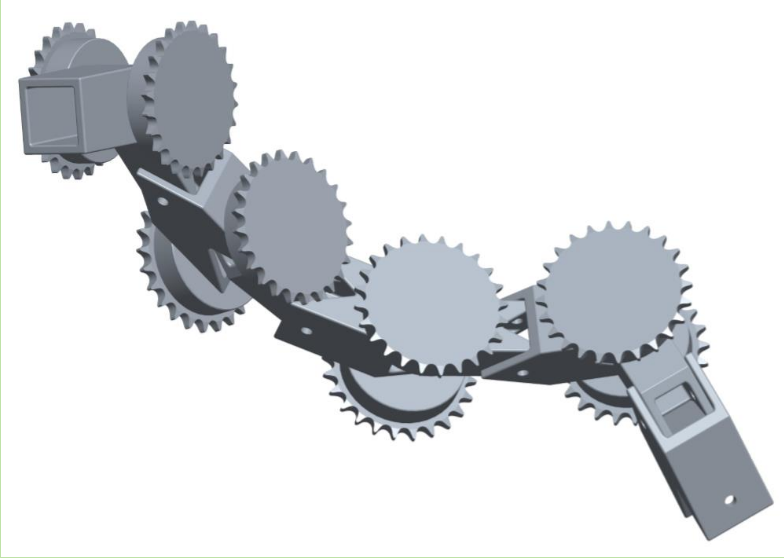
Design 2 – Soft Actuated Fiber Snake

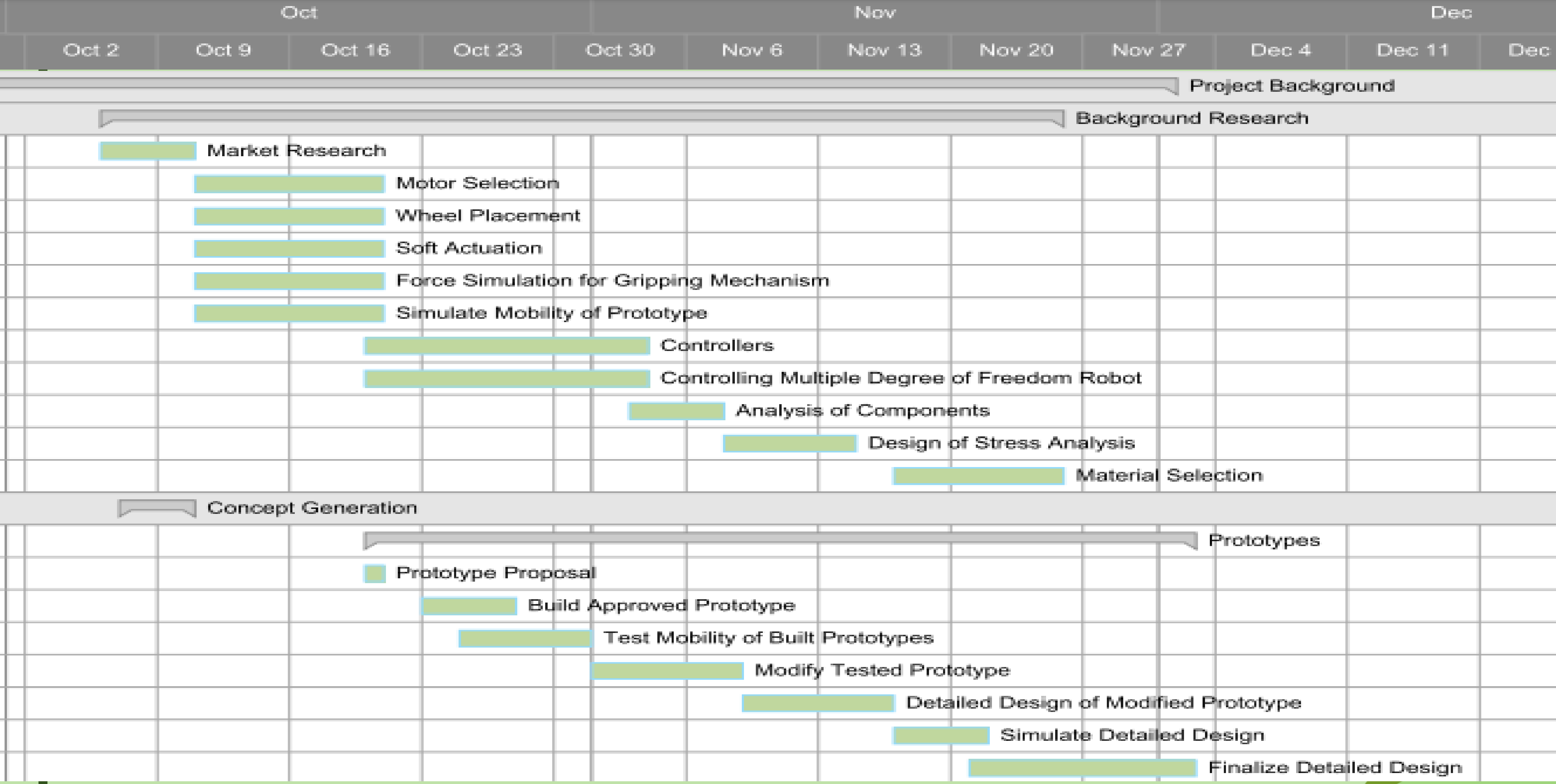
- Pros:
  - Soft Actuated – Naturally wraps around in a helical shape.
  - Soft Fiber – Ultra Lightweight. Flexible.
  - Single Segment – Easy to build.
- Cons:
  - Soft Actuated – Have to make ourselves (can't be purchased off the shelf).
  - Single Segment – Fixed Length. Invariable and may need several models to adapt to trees.



Design 1 and Design 2 – Comparison

- Circumference =πd
- Average Diameter: 2.5 ft
  - Circumference = (2.5 ft)* π
- Length = 1.5 * Circumference ~ 12ft

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Nov 6
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Nov 20
Nov 27
Dec 4
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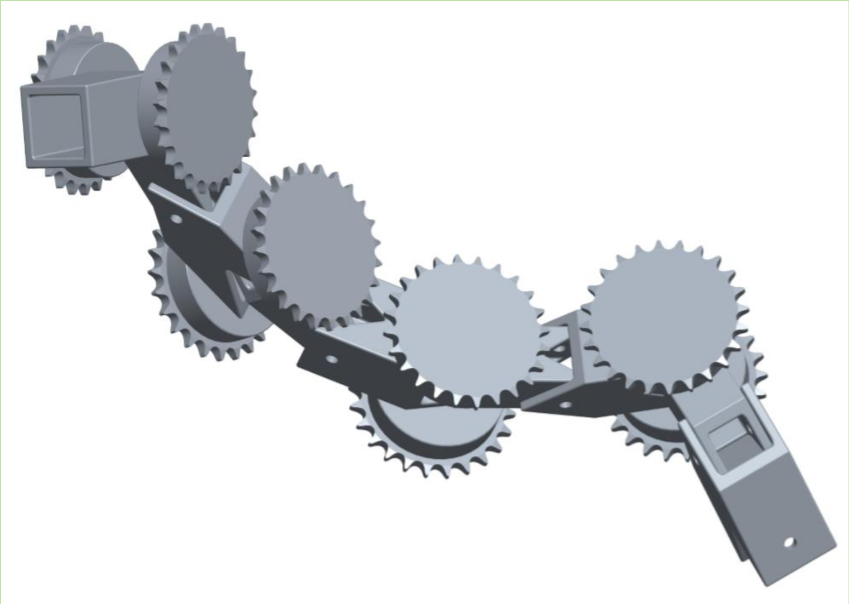
Project Background
Background Research
Market Research
Motor Selection
Wheel Placement
Soft Actuation
Force Simulation for Gripping Mechanism
Simulate Mobility of Prototype
Controllers
Controlling Multiple Degree of Freedom Robot
Analysis of Components
Design of Stress Analysis
Material Selection
Concept Generation
Prototypes
Prototype Proposal
Build Approved Prototype
Test Mobility of Built Prototypes
Modify Tested Prototype
Detailed Design of Modified Prototype
Simulate Detailed Design
Finalize Detailed Design

Summary

- Goal Statement:
  - Build a remotely operated snake-like robot that will safely climb trees.
- Design Idea
  - Motorized Modular Aluminum Snake
  - Add pneumatics
- Future Plans
  - More research
  - Prototype



Questions?

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