Development of a Tree Climbing Snake Robot

Update Presentation

Team 10

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Problem Definition

- Unstable trees may fall at any moment
  - Hazard to environment
- Removing tall trees should be done by professionals
  - Requires specific skills and precision
  - 200 tree-related fatal injuries every year

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Tree Removal Services

- Removing Process:
  - De-limbing on the way up
  - Cutting small segments on way down
  - Cut at base once at controllable height
- Price ranges from $150-$2,000
  - Complexity of job
  - Height of tree
- Focus on pine trees
  - Average Diameter: ~2 ft
  - Height: Up to 100 ft
  - Shape: Round and straight

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Project Goal Statement

Original Scope:

- To climb a tree in a helical manner and cut it down via the method of 'topping.'

Revised Scope:

- To climb a branchless tree, in a helical manner, carrying a payload for future iterations.

Goal Statement:

- Build a remotely operated snake-like robot that will safely climb trees.

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Project Goal Statement

Objectives:

- Ascend and descend a tree while satisfying the following:
  - Tree diameter of at least 10 in
  - Climb in a helical (spiral) path
  - Ascend at a speed of at least 1 ft/min
  - Hold up at least 10 lb
  - Attach camera to provide feedback

Stretch Goals:

- Obtain a minimum payload of 20 lb
- Implement deployable stability arm

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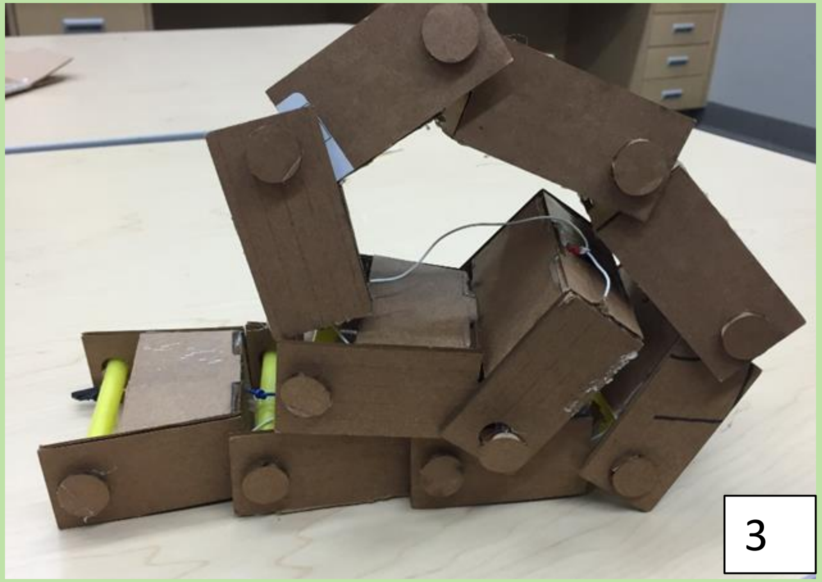
Progress Made


1


2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4


0

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Helical Generation

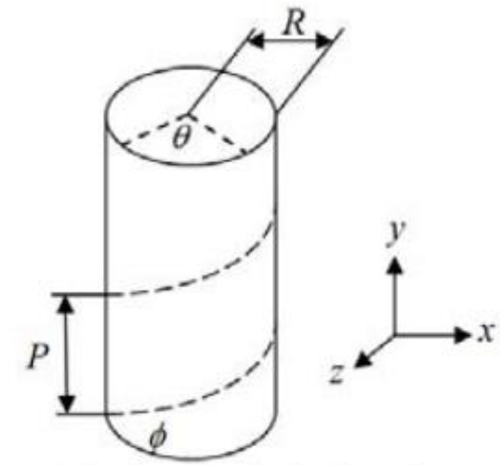

Fig. 1. Circular helix path.

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Clamping Generation

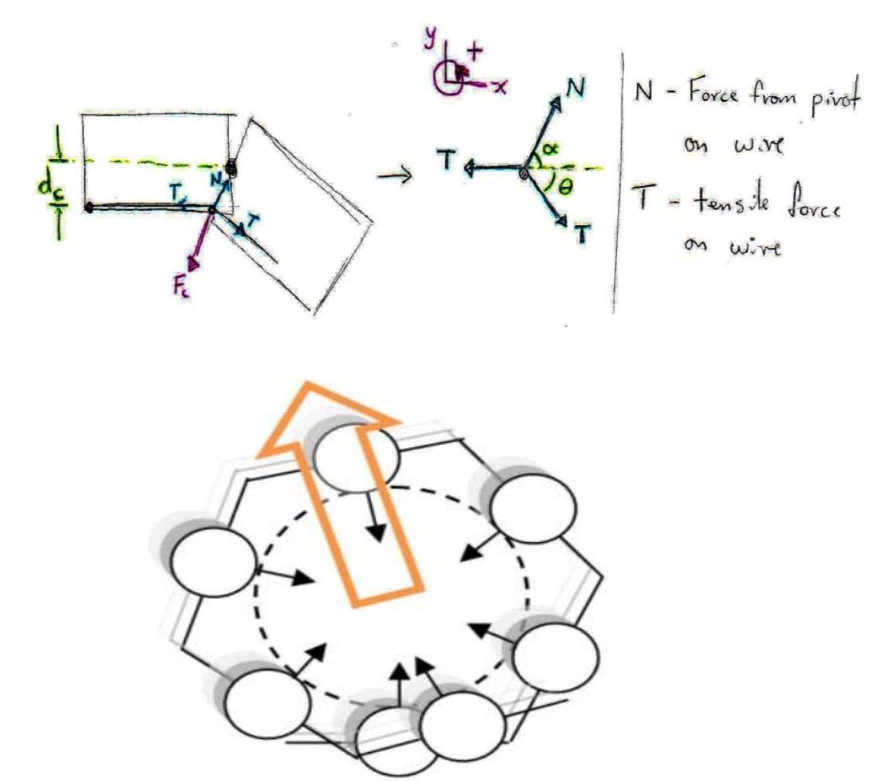
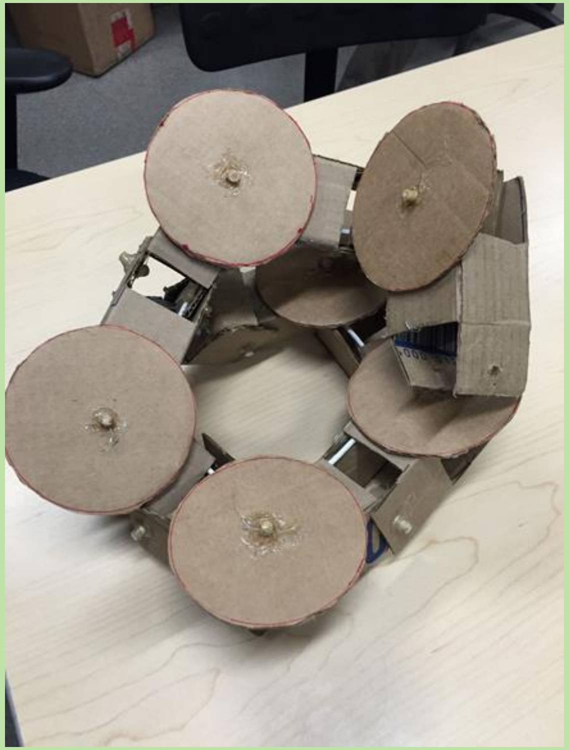
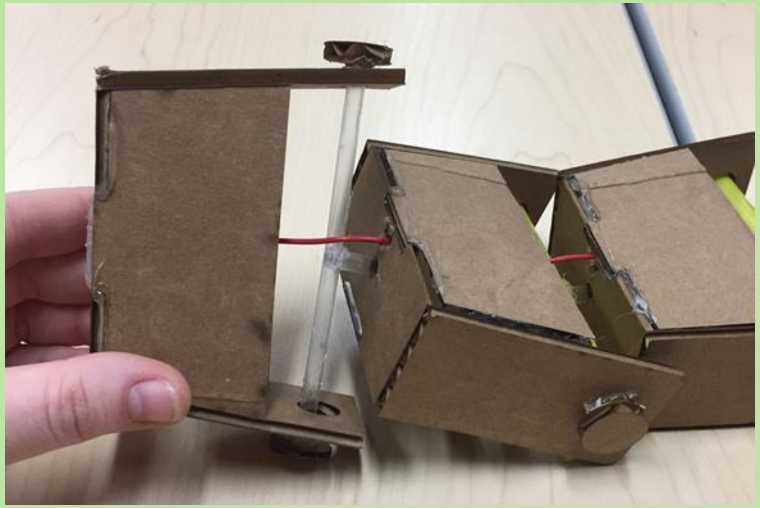
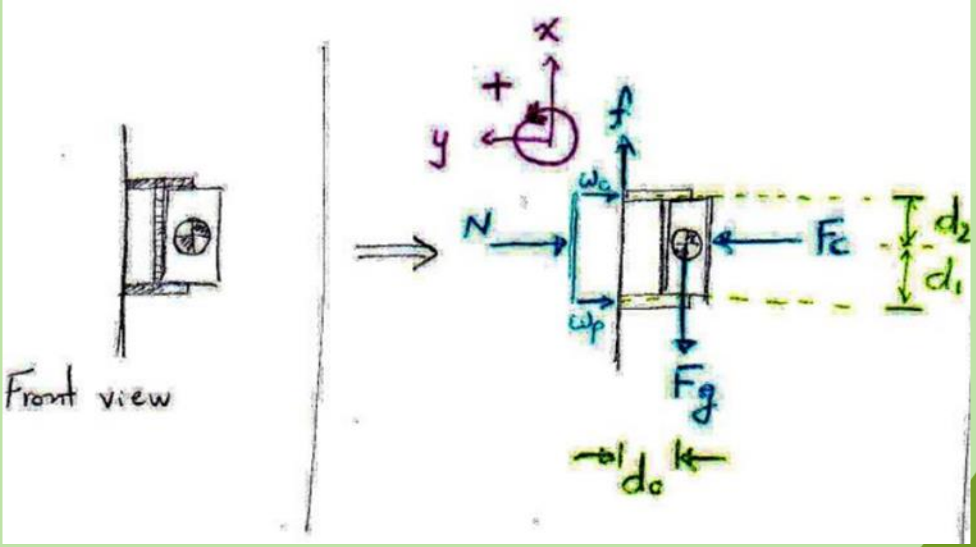


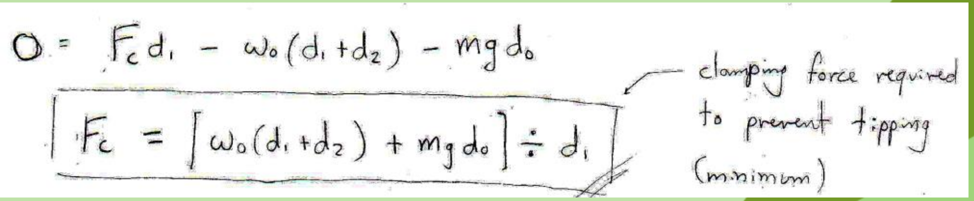
Fig. 12. Represent of resultant force.

Wheel Alignment









$$0 = F_c d_1 - \omega_o(d_1+d_2) - mg\,d_o$$

$$\boxed{F_c = [\omega_o(d_1+d_2) + mg\,d_o] \div d_1}$$

clamping force required to prevent tipping (minimum)

Final Design

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Tests to be performed

Clamping

- Test clamping strength with a sturdier / rigid material (wood)
  - Maximum weight replicating a payload to be added until slippage is experienced
  - Cardboard will simulate the smooth surface
  - Tree bark will simulate the rough surface

Experimental Results

- 11 lb was maximum weight before slippage at a tension of 18 lb

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Tests to be performed

Helical generation

- Constant pitch at varying weight
  - Used to measure force vs pitch angle

- Varied pitch at constant weight
  - Used to determine no-slip condition

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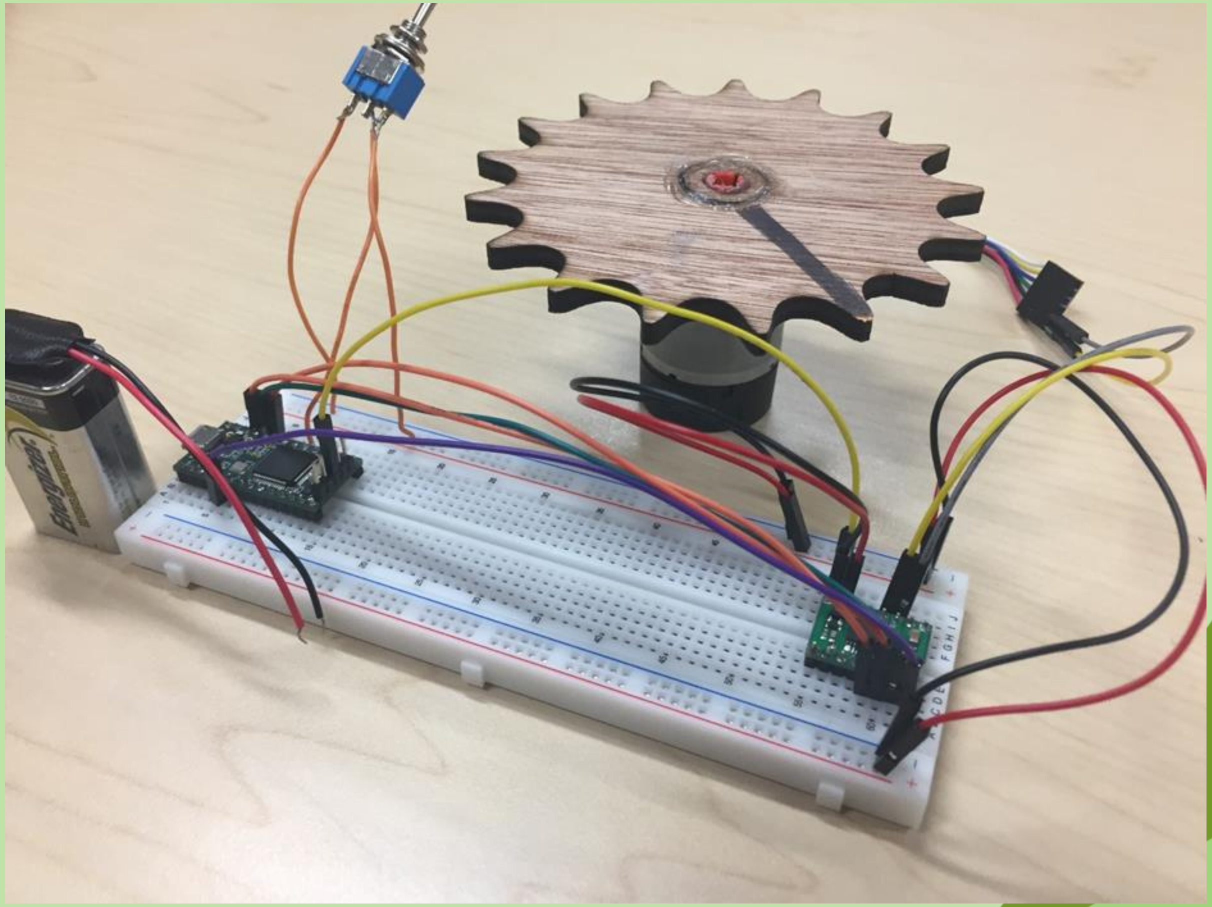
Tests to be performed

Motor Control

- Test with DC and Stepper motors
- Set up apparatus with 1 wheel
- Add potentiometer to change wheel speed



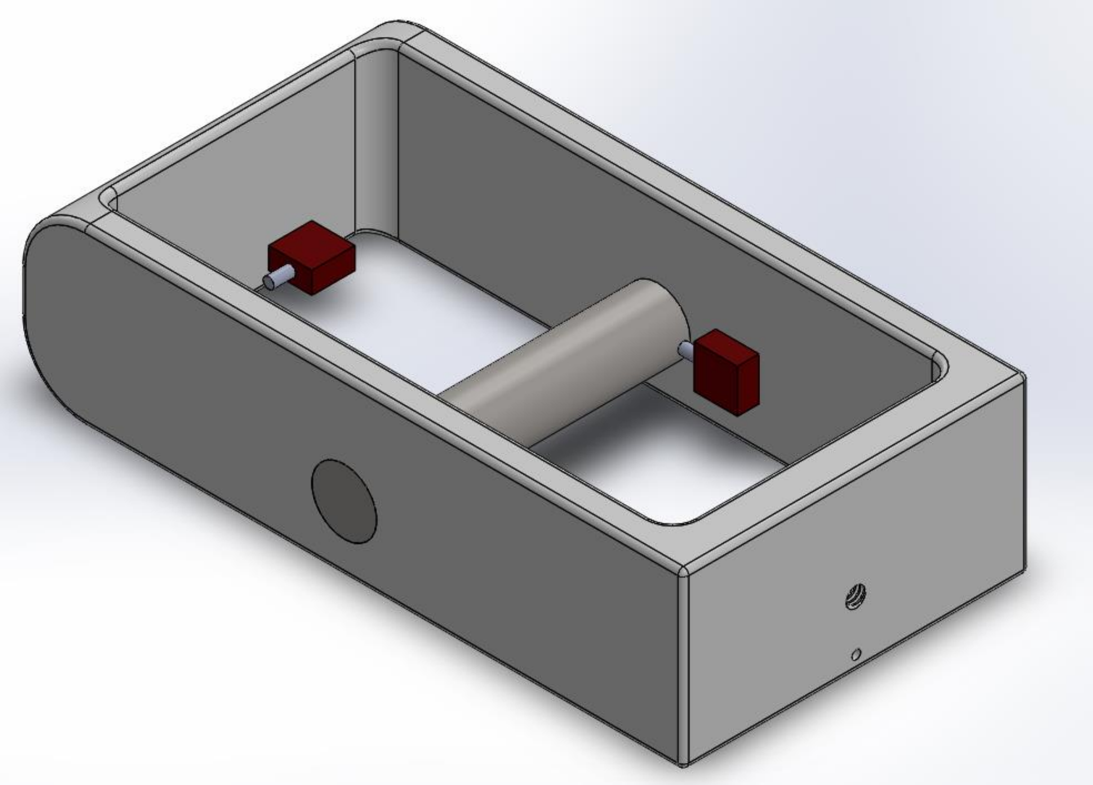
Tests to be performed

Wheel motion

- Assemble 2 driving wheels
    - 1 motor attached to each wheel

- Drive robot on the ground

- Test driving ability around cylinder
    - Pre-loaded spring will apply tension to system
    - Test varying weights



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Challenges

- Literature is scarce
  - Helical climbing snake robots are a novel topic in literature
- Budget limits sophistication
  - Can’t include a motor at every joint
- Building and assembly of design
  - Some aspects novel to group leading to more time consumed in the assembly stage
  - Optimization of assembly and manufacturing
- Implementation of electronics is a foreign topic to design team
  - Testing of functionality of circuitry consumes time

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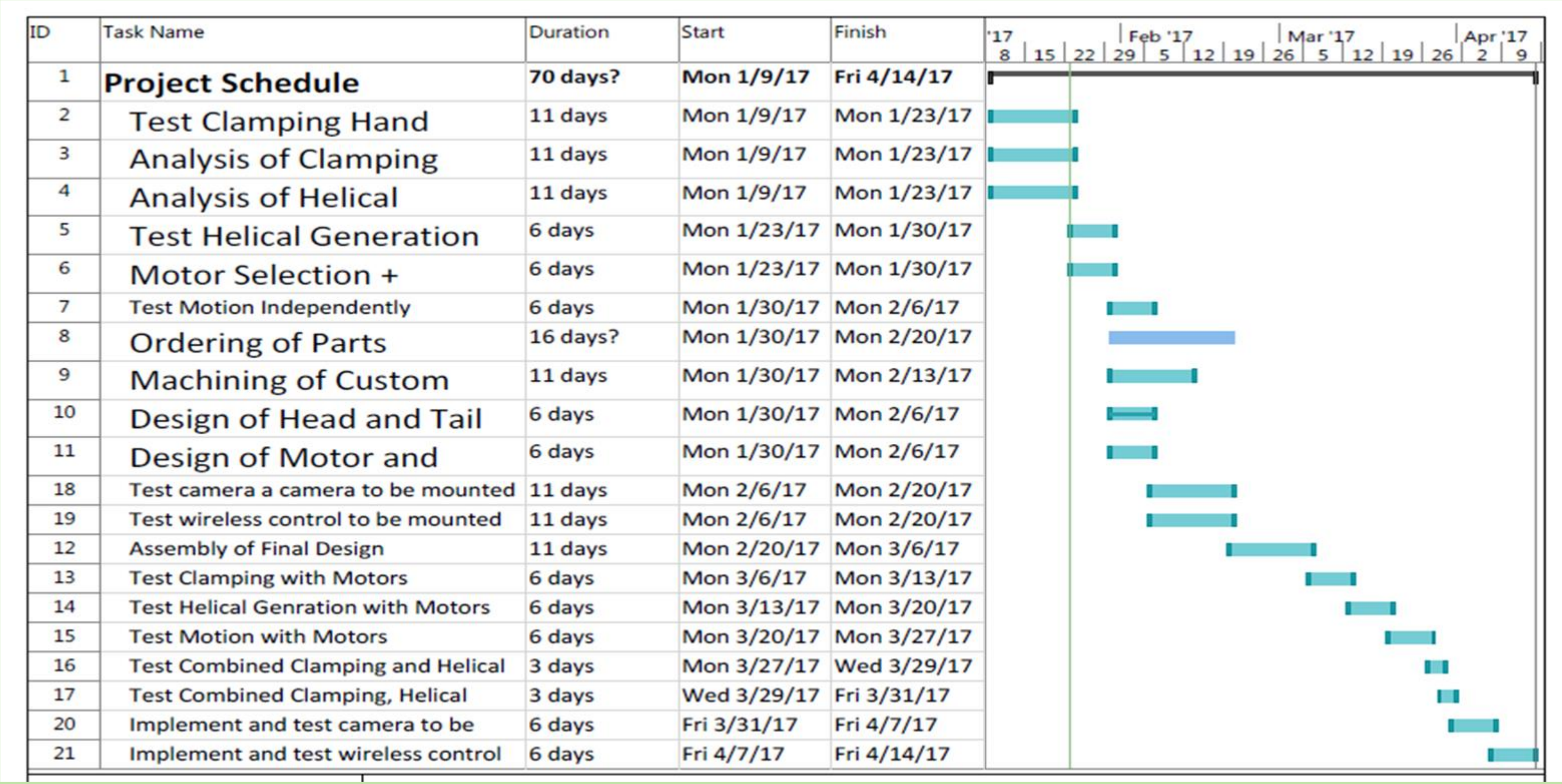
Deliverables and Schedule



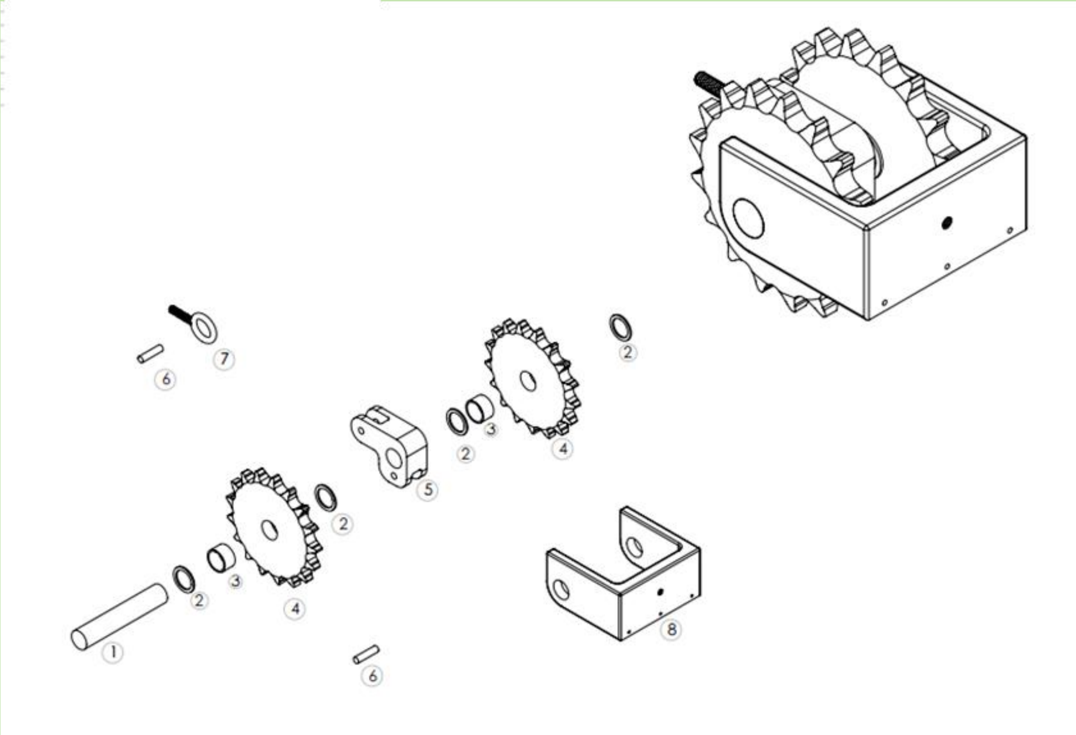
ID	Task Name	Duration	Start	Finish
1	**Project Schedule**	**70 days?**	**Mon 1/9/17**	**Fri 4/14/17**
2	Test Clamping Hand	11 days	Mon 1/9/17	Mon 1/23/17
3	Analysis of Clamping	11 days	Mon 1/9/17	Mon 1/23/17
4	Analysis of Helical	11 days	Mon 1/9/17	Mon 1/23/17
5	Test Helical Generation	6 days	Mon 1/23/17	Mon 1/30/17
6	Motor Selection +	6 days	Mon 1/23/17	Mon 1/30/17
7	Test Motion Independently	6 days	Mon 1/30/17	Mon 2/6/17
8	Ordering of Parts	16 days?	Mon 1/30/17	Mon 2/20/17
9	Machining of Custom	11 days	Mon 1/30/17	Mon 2/13/17
10	Design of Head and Tail	6 days	Mon 1/30/17	Mon 2/6/17
11	Design of Motor and	6 days	Mon 1/30/17	Mon 2/6/17
18	Test camera a camera to be mounted	11 days	Mon 2/6/17	Mon 2/20/17
19	Test wireless control to be mounted	11 days	Mon 2/6/17	Mon 2/20/17
12	Assembly of Final Design	11 days	Mon 2/20/17	Mon 3/6/17
13	Test Clamping with Motors	6 days	Mon 3/6/17	Mon 3/13/17
14	Test Helical Genration with Motors	6 days	Mon 3/13/17	Mon 3/20/17
15	Test Motion with Motors	6 days	Mon 3/20/17	Mon 3/27/17
16	Test Combined Clamping and Helical	3 days	Mon 3/27/17	Wed 3/29/17
17	Test Combined Clamping, Helical	3 days	Wed 3/29/17	Fri 3/31/17
20	Implement and test camera to be	6 days	Fri 3/31/17	Fri 4/7/17
21	Implement and test wireless control	6 days	Fri 4/7/17	Fri 4/14/17

Summary

Reduce the cost and hazards of removing trees

Create a 3 DOF modular aluminum snake robot
- Hold a concentrated weight of 10 lb
- Ascend tree at a speed of at least 1 ft/min

Test
- Helical Generation
- Electrical Components



References

- P. Polchankajorn and T. Maneewarn, “Development of a helical climbing modular snake robot,” in 2011 IEEE International Conference on Robotics and Automation, May 2011, pp. 197–202.
- Snake Robot: http://farm4.staticflickr.com/3779/9313104039_867fafb326.jpg
- Pine tree: https://img1.cgtrader.com/items/152956/f9362d2d16/pine-tree-collection-3d-model-obj-3ds-fbx-3dm-dwg.jpg
- http://www.dot.state.mn.us/bridge/pdf/insp/USFS-TimberBridgeManual/em7700_8_chapter03.pdf

Questions?

Motor Selection – Details

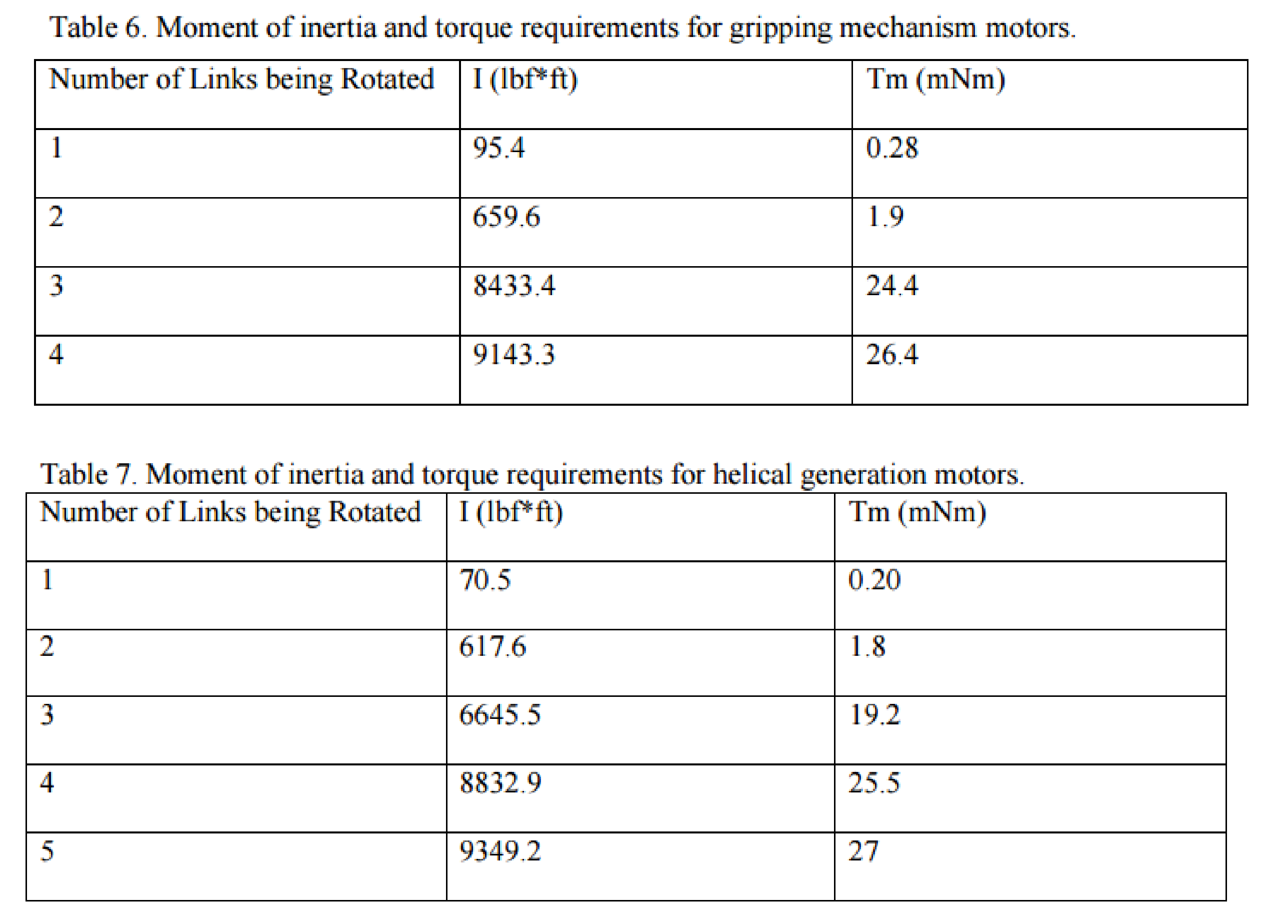


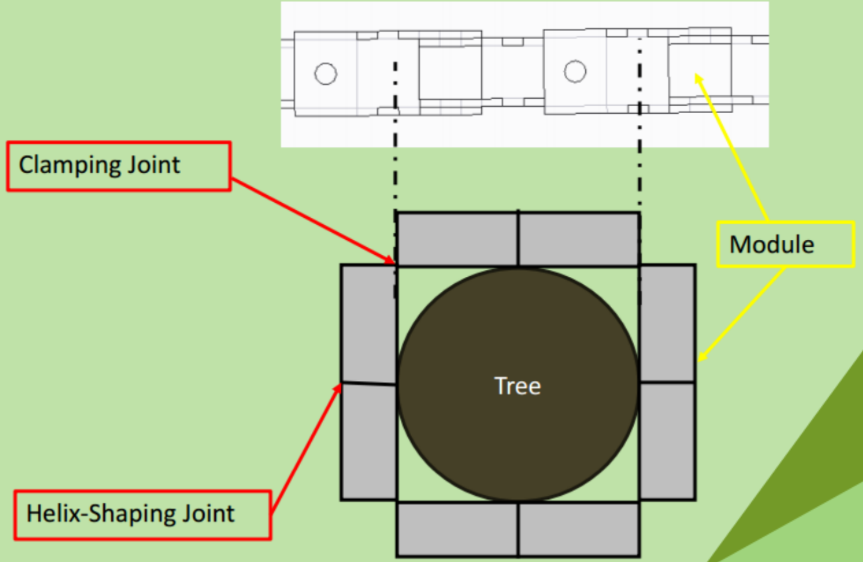
Table 6. Moment of inertia and torque requirements for gripping mechanism motors.

Number of Links being Rotated	I (lbf*ft)	Tm (mNm)
1	95.4	0.28
2	659.6	1.9
3	8433.4	24.4
4	9143.3	26.4

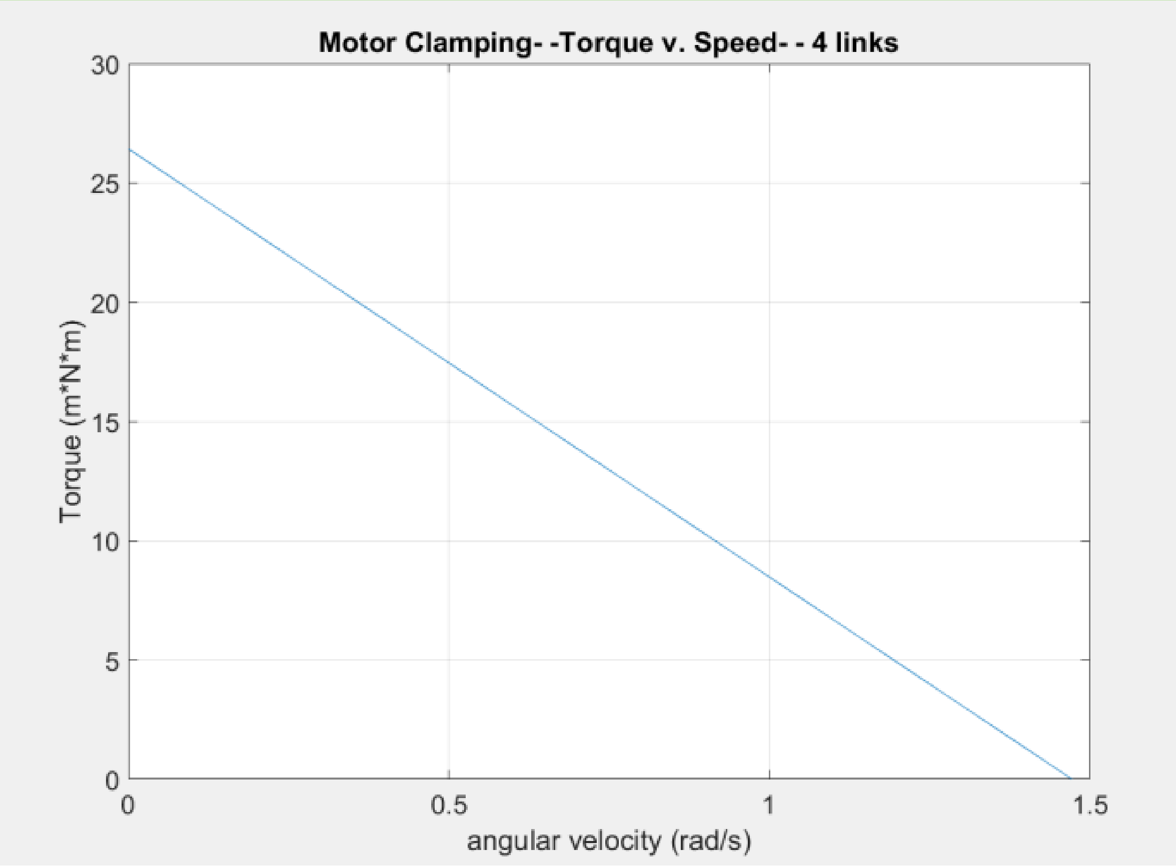
Table 7. Moment of inertia and torque requirements for helical generation motors.

Number of Links being Rotated	I (lbf*ft)	Tm (mNm)
1	70.5	0.20
2	617.6	1.8
3	6645.5	19.2
4	8832.9	25.5
5	9349.2	27

- Quintic polynomial was used for angular velocity requirements (ensures acceleration, velocity start and stop at zero) start at zero degrees and end at 45 degrees



Motor Selection—Plots and Motor



MKS 4234-290	
Specification	
Phase	2
Rated Voltage	DC 3.1 V
Phase Resistance(20°C)	3.1×(1±15%)Ω
Holding Torque	⩾290 mN.m
Direction of Rotation	A-AB-B clockwise
MAX Running Pulse Rate	⩾3500 PPS
Electric Strength	AC600V/1mA/1S
Rotor Inertia	44 g.cm2
Step Angle Accuracy	1.8°±0.09°
Rated Current	DC 1.0A
Phase Inductance(1KHz)	5.2×(1±20%)mH
Orientational Torque	15 mN.m REF
Max KPPS	⩾2400 PPS
Insulation Resistance	⩾100MΩ (DC 500V)
Insulation Level	B
N.Weight	0.24KG REF.

Properties of Wood

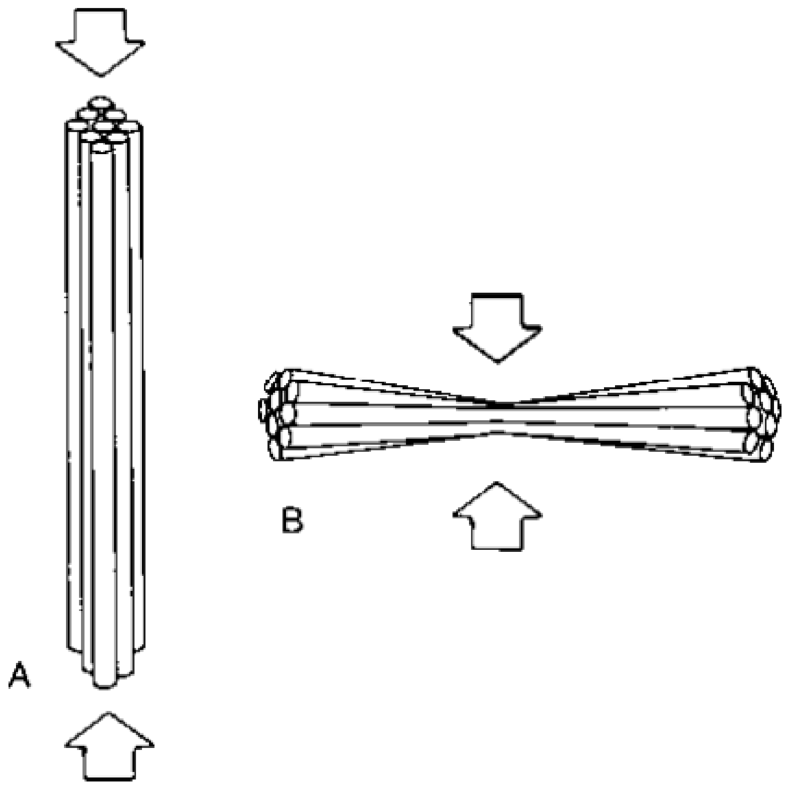


Figure 3-1.- Simplified depiction of the structure of wood, comparing it to a bundle of thin-walled drinking straws. (A) Parallel to their longitudinal axis, the straws (wood cells) can support loads substantially greater than their weight. (B) When loaded perpendicular to their longitudinal axis, the straws yield under much lower loads.

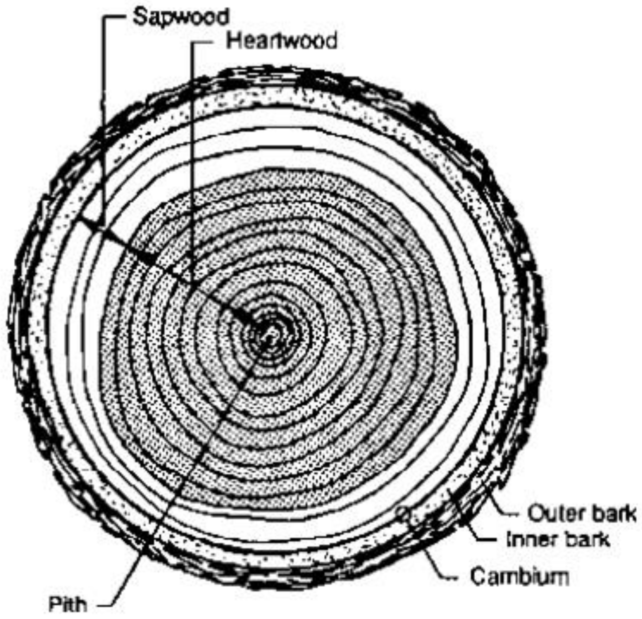


Figure 3-3.- Tree cross section showing elements of the macrostructure that are normally visible without magnification.

Properties of Wood

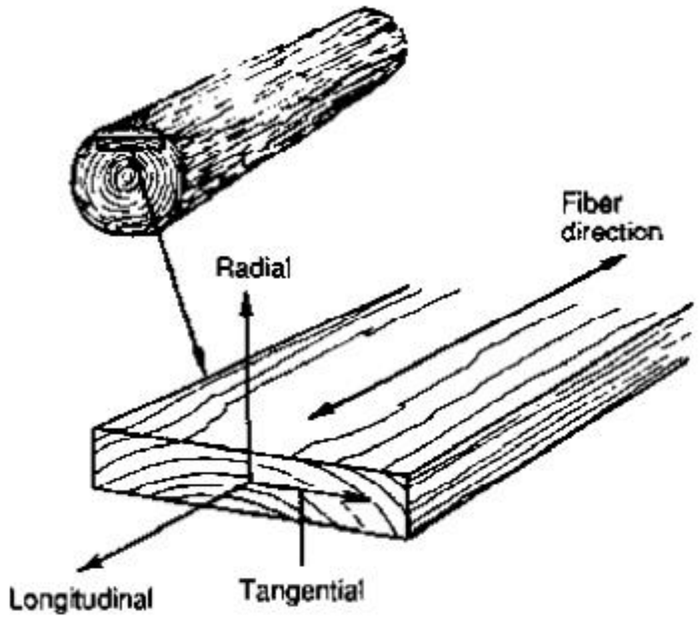
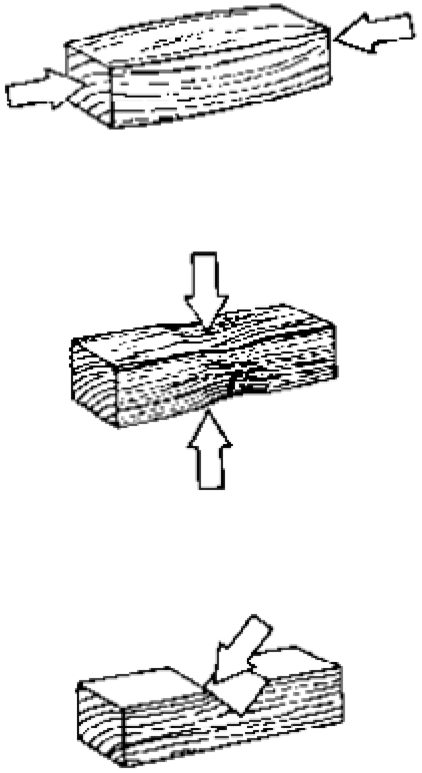


Figure 3-5- The three principal axes of wood with respect to grain direction and growth rings.



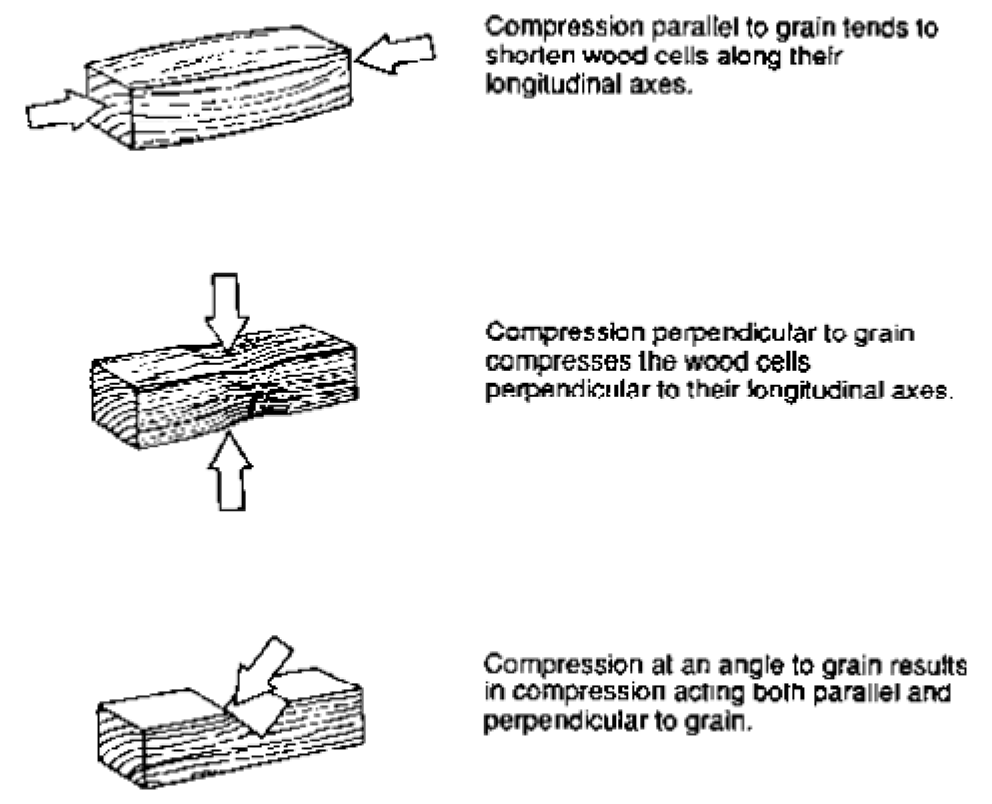
Compression parallel to grain tends to shorten wood cells along their longitudinal axes.

Compression perpendicular to grain compresses the wood cells perpendicular to their longitudinal axes.

Compression at an angle to grain results in compression acting both parallel and perpendicular to grain.

Figure 3-12.- Compression in wood members.

Properties of Wood



Compression parallel to grain tends to shorten wood cells along their longitudinal axes.

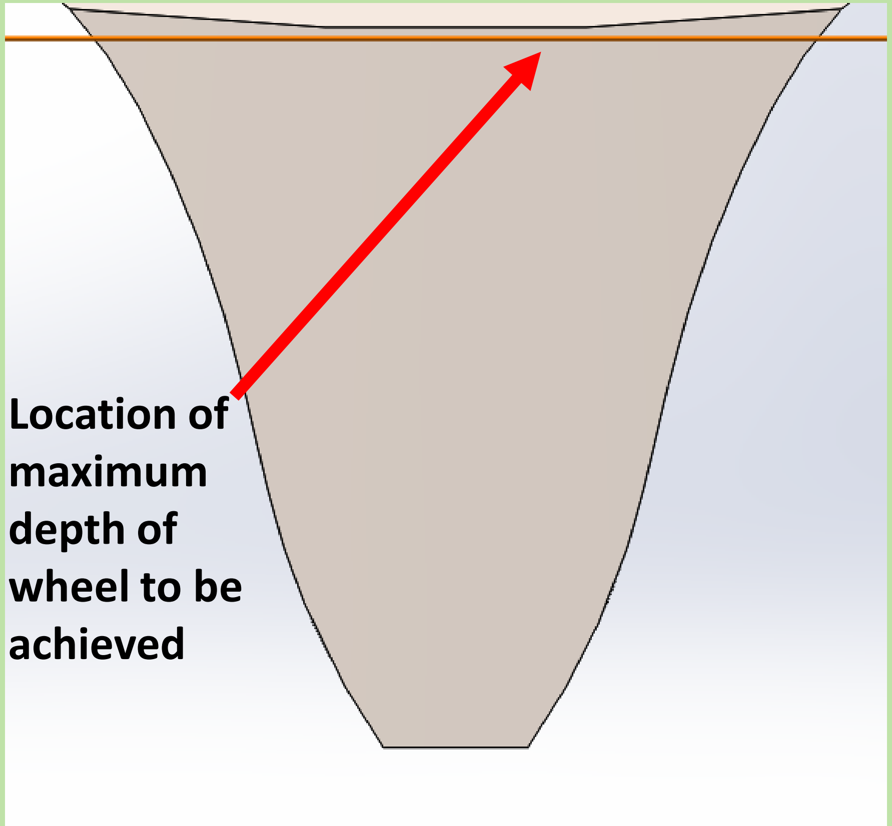
Compression perpendicular to grain compresses the wood cells perpendicular to their longitudinal axes.

Compression at an angle to grain results in compression acting both parallel and perpendicular to grain.

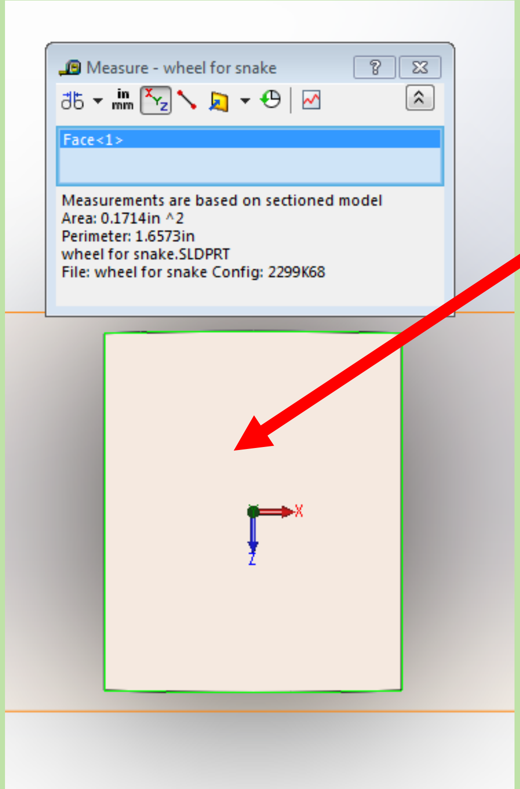
Figure 3-12.- Compression in wood members.

- **Loblolly pine trees have yield stress of 3,511 lb/in^2 under compression along axis parallel to grain**
- **Loblolly pine trees have yield stress of 661 lb/in^2**
- **When applied along an angle will have parallel and perpendicular components and therefore will have intermediate yield stress**

Area of Contact Analysis



Location of maximum depth of wheel to be achieved

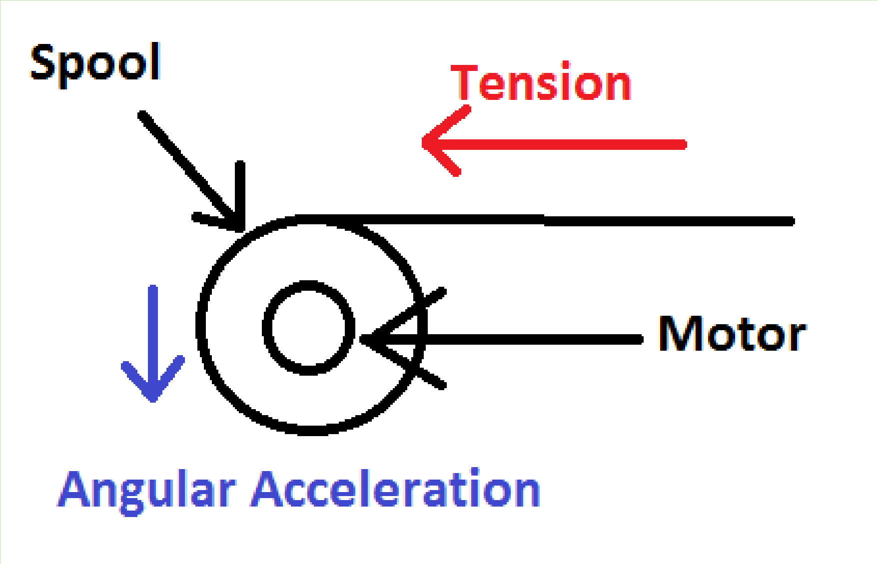


Measurements are based on sectioned model
Area: 0.1714in ^2
Perimeter: 1.6573in
wheel for snake.SLDPRT
File: wheel for snake Config: 2299K68

- **Area of cross section in which maximum depth is predicted to be achieved**
- **Area = 0.1714 in^2**

Stress-Force Analysis

- Stress along axis perpendicular to grains of loblolly pine trees = 661 lb/in^2
- Maximum area of contact to be achieved = 0.1714 in^2
- Stress = Force/Area
- Force = Stress*Area = 661 lb/in^2 * 0.1714 in^2 = 113. 3 lb = 0.504 kN
- Force = Force Clamping = T*(2-2cos(theta))^(1/2)
- T = Force Clamping/(2-2cos(theta))^(1/2)
- From free-body diagram:
  - I*alpha = T*r = Moment due to motor



Assume Clamping is normal to diameter of tree

Work breakdown Structure

Ordered List of Tasks	Chronological Order of Operations	Estimated Duration
Test Clamping Hand Actuated	A	1 week
Analysis of Clamping	A	2 weeks
Analysis of Helical Generation	A	2 weeks
Analysis of Motion	A	2 weeks
Test Helical Generation Hand Actuated	B	1 week
Motor Selection + Electrical Componenet Selection	B	1 week
Test Motion Independently	C	1 week
Ordering of Parts	C	3 weeks
Machining of Custom Parts	C	2 weeks
Design of Head and Tail Modules	C	1 week
Design of Motor and Battery Housing	C	1 week
Assembly of Final Design	D	2 weeks
Test Clamping with Motors	E	1 week
Test Helical Generation with Motors	F	1 week
Test Motion with Motors	G	1 week
Test Combined Clamping and Helical Generation	H	1/2 week
Test Combinged Clamping, Helical Generation, Motion	I	1/2 week
Test camera to be mounted for feedback	J	2 weeks
Test wireless control to be mounted for feedback	J	2 weeks
Test wireless Control	J	1 week
Implement and test camera to be mounted for feedback	K	1 week
Implement and test wireless control	L	1 week
Optimization Phase	M	
Construct Database + user manual for future users and engineers	L	

Tests to be performed

Consolidated Test

- 9 modules needed
- Integrate motors to module
  - Add motor for tensioning cables and driving wheels
- Test clamping motor
  - May be a direct switch (preliminary test)
- Test helix generation motor
  - May be a direct switch (preliminary test)
- Test motion
  - Test on smooth surface (potentially cardboard), use motors to tension robot
  - Test on rough surface (tree)
  - Drive front wheels
    - Wireless connection preferred, but direct switch can be used
  - Add weight to body till slippage