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GEAR

Planetary Gears for Bio-Inspired Mobile Robot

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Introduction

- The project focuses on inexpensive legged robots that have passive compliance - can respond to the immediate environment
- This is in contrast to traditional robots which are complex, requiring many sensors, or cannot effectively deal with perturbations

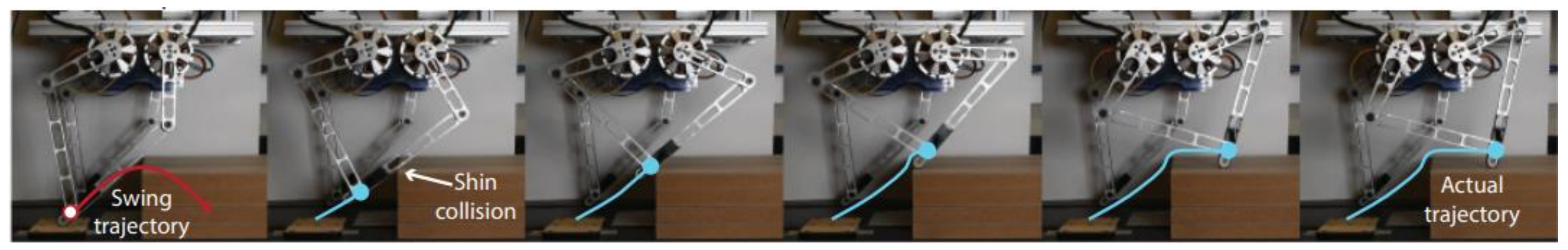

Figure 1
Behavior of a compliant leg mechanism includes a deviation from the projected trajectory, while achieving its goal of overcoming the step.

- Using inexpensive parts results in lower torque, which may hinder the ability to perform high power maneuvers and passive gait control
- It is possible to raise the perceived power while keeping compliance in the motors using a planetary gear set
- The compact gears increase torque while introducing the least error into the system, crucial for the passive control system in the motors

Objective

Show the effectiveness and ease of using commercial 3D printing to rapidly prototype planetary gearsets to complement the control and feasibility of inexpensive and reliable legged robots.

Pictures

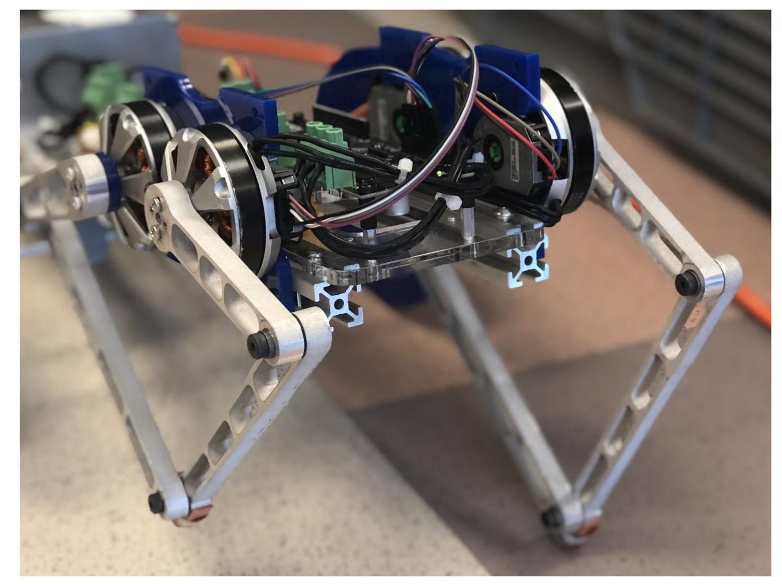

Figure 2: Test robot. This robot is a prototype of the one that the gearbox is designed to improve. Note that many types of robots may use the same leg assembly.

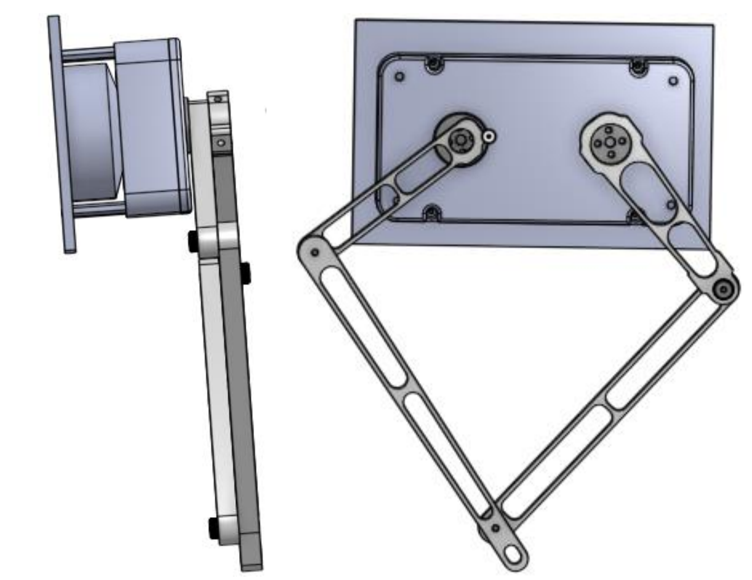

Figure 3: Front and side views of robot leg assembly with gearbox iteration 6. The baseplate represents part of the robot superstructure.

Results

- Prototypes were 3D printed for iteration 2, 4 and 6, the print for iteration 6 survived basic testing
- Using the Prusa Slicer program, time used and material cost of prints was determined - Iteration 6 print required 48 print-hours and cost $8.50 in filament, and small bearings brought cost to around $16
- Compare this to buying a motor three times as powerful, which would cost $105 (three times more than current motor at $33)

Experimental Design Process

- Design constraints:
  - Sizing: A thin frame to minimize the distance of the motors from the robot legs, reducing bending moments in the gearbox and axles
  - Complexity: Easy to assemble and integrate with the robot, and easily replaceable, all parts can be made using injection molding
  - Structure: Rigid when receiving expected impulsive and static loads, and gears mesh tightly and rotate with little resistance
- To make a suitable design:
  - Made multiple iterations of prototyping using 3D printers
  - Improved design each iteration until the design requirements were met, using CAD and commercial printer technology
  - Modelled the system in SimMechanics (MATLAB) for simulations and comparison to real-world tests

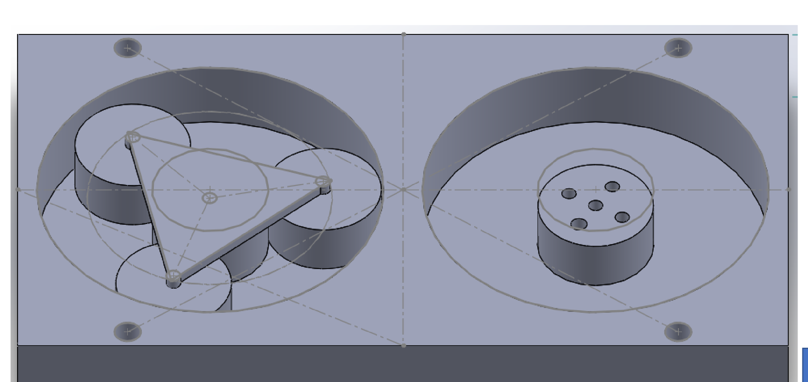

Figure 6: Iteration 1
Made to simulate dimensions and gear ratio. Mainly used for brainstorming. Iteration 2 added teeth to gears, and tested the tolerance of error of 3D printer.

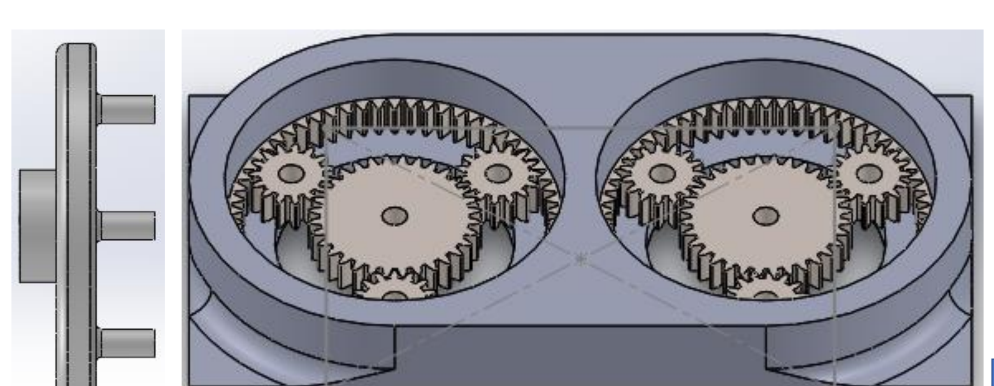

Figure 7: Iteration 3
Updated design to reduce size and weight, introduced first carrier design. Reduced thickness of case. Iteration 4 tested printing the ring gear as part of the case. Gears dynamics had too much friction.

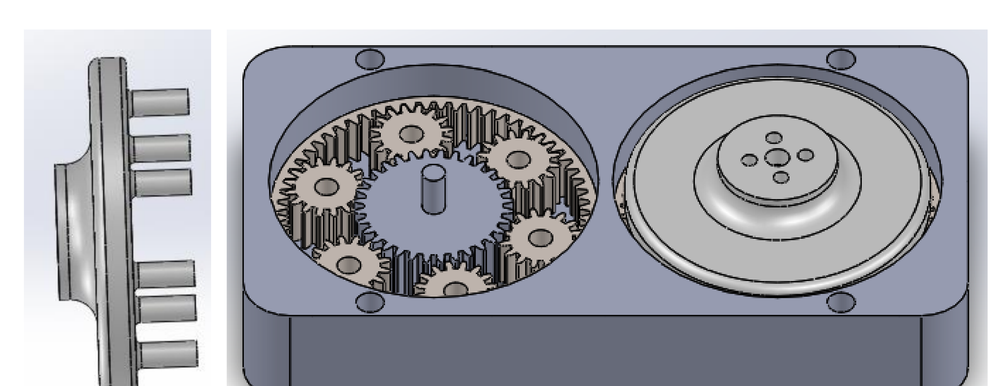

Figure 8: Iteration 5
Designed for stability and rigidity by adding more and thicker gears. Decreased pressure angle of gears for smoother spin. Iteration 6 tested integration with motor as a full assembly.

Conclusion

- Using modeling results and printed prototypes, it is demonstrated that implementing a gearbox to support a legged robot with compliance and additional torque required for maneuvering and gait control is cost effective and relatively simple
- Adding the gearbox improves upon the overarching goal of building a compliant, effective and cheap legged robot

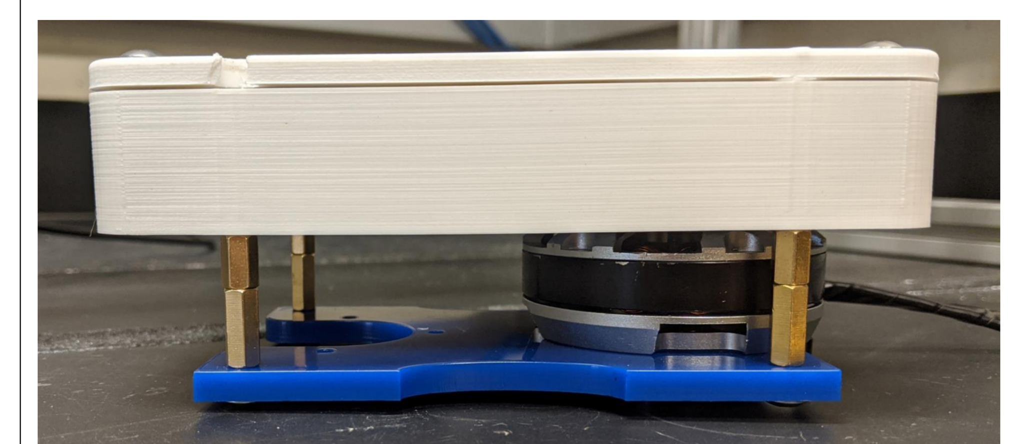

Figure 4
Iteration 6 gearbox attached to motor. There is only 1.5 mm clearance between motor and case.

Figure 5
Iteration 6 gearbox, minus cover and gear carrier.

Future Work

- Due to the deterioration of society during the timeline of the project, actual structural and dynamic testing with the prototype was not conducted. The best way to continue would be to:
  - Complete testing with gearbox prototype attached to the frame, using expected static and dynamic loading for analysis, and
  - Analyze the results to show:
    - internal losses and change in transient response time attributed to the planetary gears
    - change in compliance and performance with basic maneuvers

References

[1] Chen, Tian, et al. “Harnessing Bistability for Directional Propulsion of Soft, Untethered Robots.” *Proceedings of the National Academy of Sciences*, vol. 115, no. 22, 2018, pp. 5698–5702
[2] Kau, Nathan, et al. “Stanford Doggo: An Open-Source, Quasi-Direct-Drive Quadruped.” 2019 International Conference on Robotics and Automation (ICRA), 2019.

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