Continuum Robotic Quadruped

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Abstract

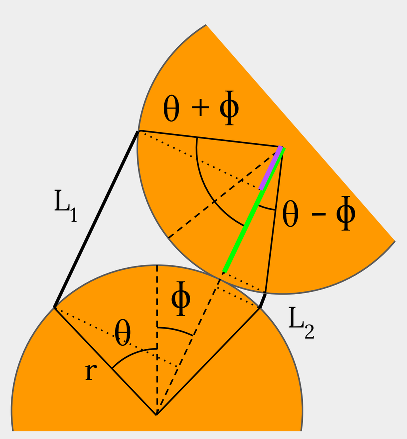
Soft robots show promise in exploring dangerous and complex environments due to their adaptability. Common soft and continuum robotic manipulators use flexible or corrugated materials to form actuators. These flexible structures can create an obstacle to their practical implementation, because they are often unable to carry the weight of their power and control systems. The Continuum Robotic Quadruped (CRoQ) uses a novel, 2DoF, cable-driven actuator with discrete rigid segments that allow for strength and compliance, while also exhibiting a slight Fin Ray Effect. This design allows for an untethered platform with adaptable movement over complex terrain with a simple control system.

Objectives

- Develop and iterate upon a novel cable-driven, continuum actuator from the ground-up
- Implement the continuum actuator into a quadruped
- Traverse rough terrain without the need for complex control systems
- Maintain a budget of < $100

Cam Implementation

To keep tension on the cables, the control cams need specific geometry, calculated as a function of the distance between points on two circle's surfaces as they roll across each other



— $r*\cos(\theta + \phi)$

— $r*\cos(\theta - \phi)$

$$L_1 = 2r - 2r*\cos(\theta + \phi)$$
$$L_2 = 2r - 2r*\cos(\theta - \phi)$$

$$L_1 = 2r*(1 - \cos(\theta + \phi))$$
$$L_2 = 2r*(1 - \cos(\theta - \phi))$$

Where:

- θ is the angle between the holes of the ball and the center axis
- ϕ is the angle between the axes
- L_1 and L_2 are the string lengths between the balls

For G balls, the equations become (where γ is total bending angle) :

$$L_1 = 2Gr*(1 - \cos(\theta + (\gamma/2G)))$$
$$L_2 = 2Gr*(1 - \cos(\theta - (\gamma/2G)))$$

With maximum servo actuation of λ_{max} and arm actuation of γ_{max} :

$$L_1 = 2Gr*(1 - \cos(\theta + (\gamma_{max}/2G\lambda_{max})\lambda))$$
$$L_2 = 2Gr*(1 - \cos(\theta - (\gamma_{max}/2G\lambda_{max})\lambda))$$

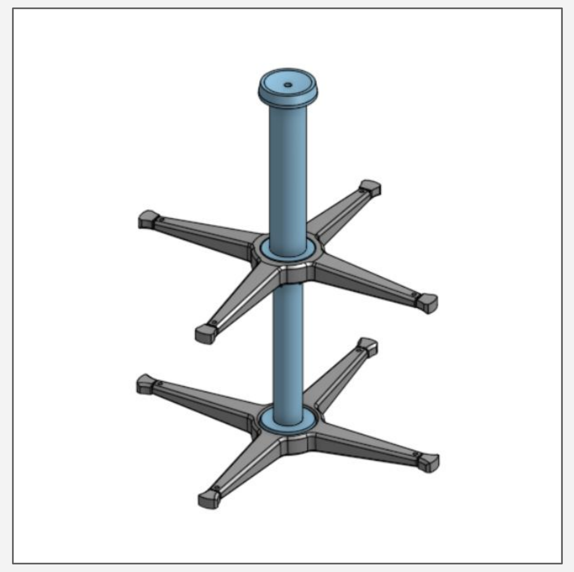
To find radius at a given servo actuation λ, we imagine a cylinder. The spooled string is equal to the integral of the radius with respect to theta (the angle it is spooled to). The radius is then equal to the derivative of this integral. Using this analogy, we find:

$$L_{spooled} = \int_0^{\lambda} R(\theta)\, d\theta = L_{\lambda} - L_0$$

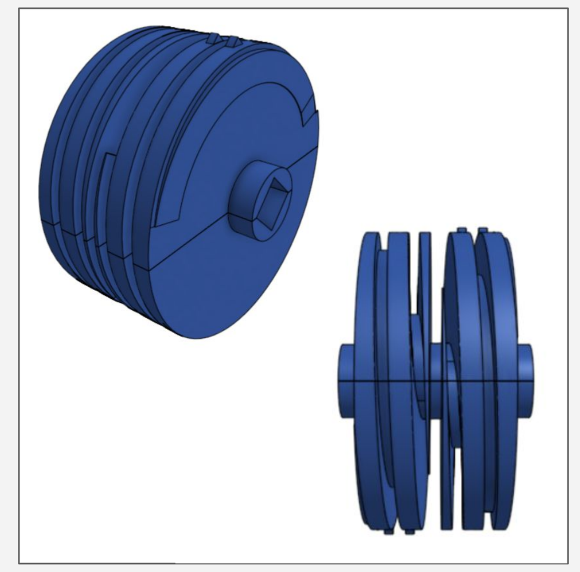
$$R(\lambda) = (\gamma_{max}/\lambda_{max})*r\cos(\theta + (\gamma_{max}/2G\lambda_{max})\lambda)$$

$$R(\lambda) = d/d\lambda(L_{\lambda} - L_0) = d/d\lambda\,(2Gr - 2Gr*\cos(\theta + (\gamma_{max}/2G\lambda_{max})\lambda) - (2Gr - 2Gr*\cos(\theta)))$$

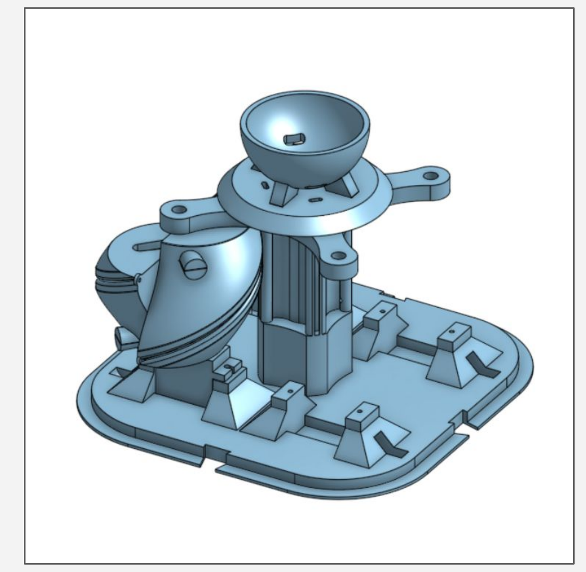
Design Iterations



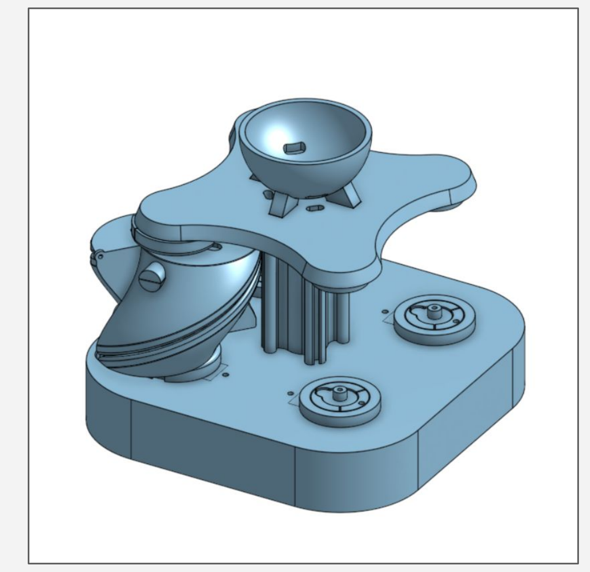
Proof of Concept
Two Stage



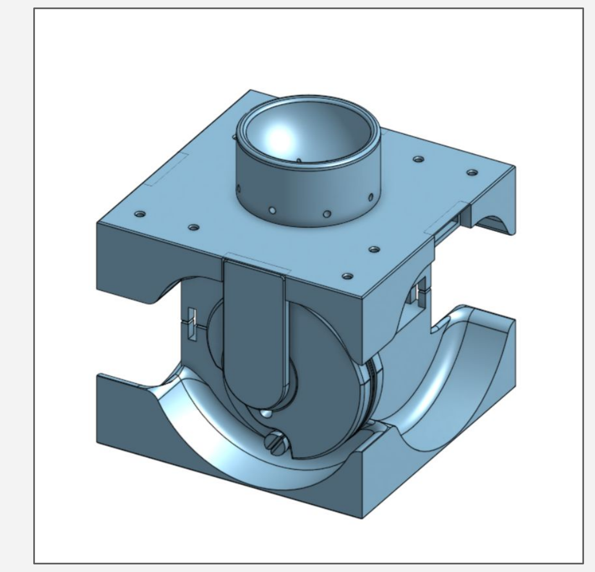
Initial Spool Testing



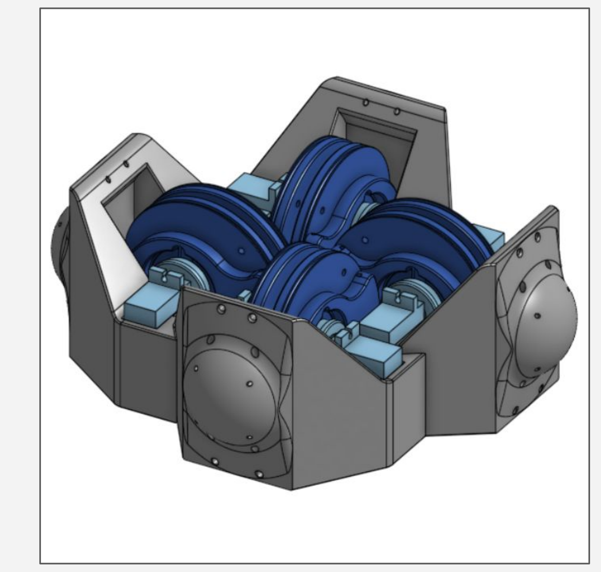
Applied Spool Testing V1
Two Stage, 133 x 133 x 81mm



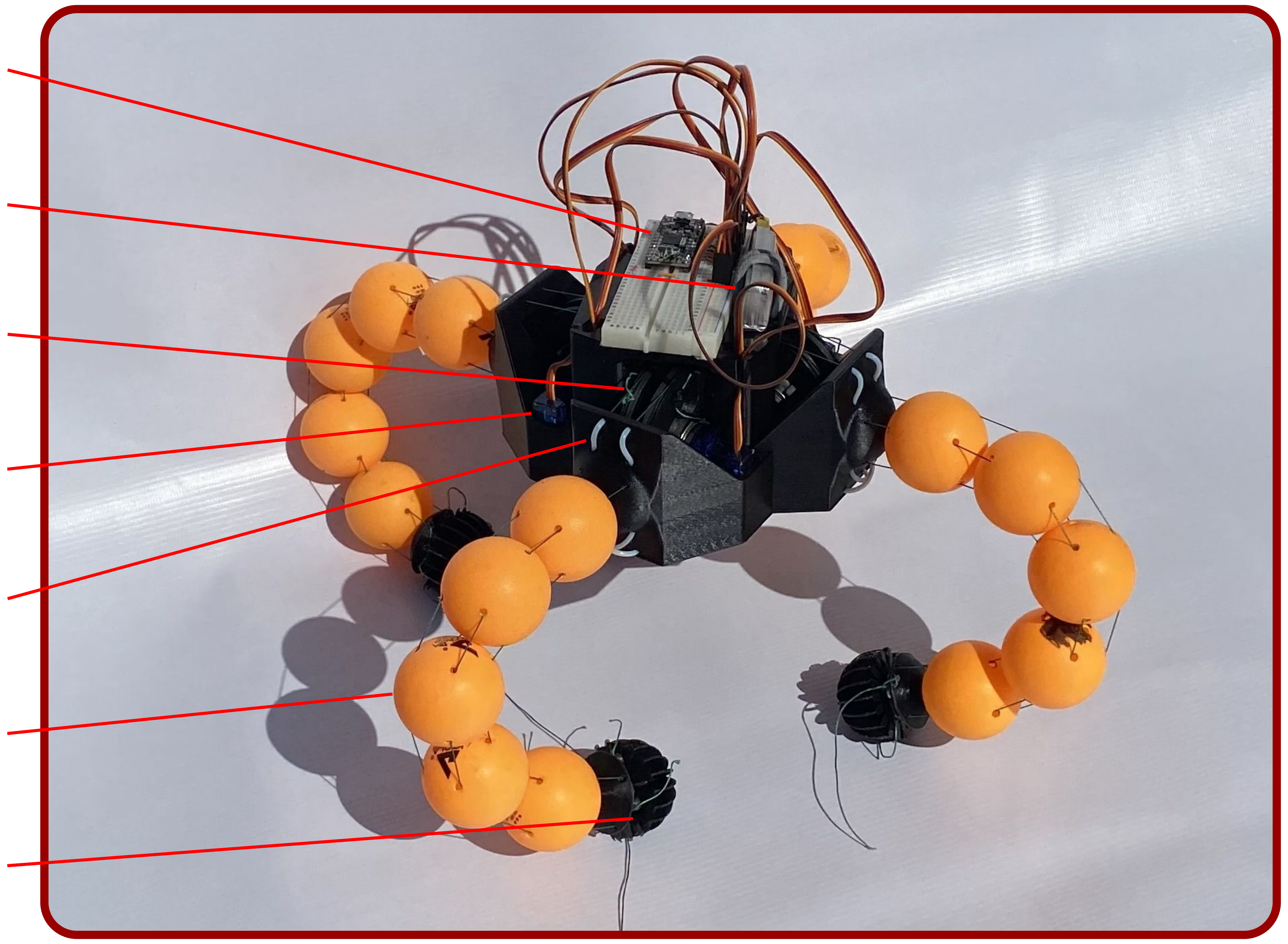
Applied Spool Testing V2
Two Stage, 123 x 123 x 82mm



Cam Testing V1
Two Stage, 98 x 98 x 82mm



Cam Testing V2
Full Robot, 144 x 144 x 73.5mm



Bill of Materials

Item	Total Cost
PLA FIlament	$5.43
Bearings	$28.88
9g Servos	$15.90
Ping Pong Balls	$3.72
Fishing Line	$0.27
Screws	$1.00
TPU Filament	$0.57
Teflon Tube	$0.74
3.7V 1100mAh LiPo Battery	$6.50
Final Cost:	**$63.01**

Outcomes

Unfortunately, with only 9g servos, the robot is unable to lift itself over obstacles. Despite this, the robot does show obstacle conforming behaviors. Overall, this platform shows promise in the future for a simple, powerful, untethered robot.

Future Work

In the future, this platform can be modified slightly to use stronger servos. This was not explored in this project due to budget constraints. Other avenues to increase the power would be to use motors and an external potentiometer, allowing for external gearing and position control