Scuffer: A Quadrupedal Robot Study

Long Nguyen, Susana Salazar, Su Cheol Son, Huukie Tran, Samid Ceballos, Daniel Ponce
California State University, Long Beach
Mechanical and Aerospace Engineering Department

Abstract

This work covers the the team's development and design optimization of a quadruped robot, which the team named Scuffer. Mechanical legs are an imperative component of quadrupedal robots because they give them excellent maneuverability and versatility that determine the robot's performance in various applications, including job adaptability, walking speed, and load capacity. For decades the field of engineering has been taking inspiration from nature and developing mechanisms and robots based on nature. Most notable example of this is the success of Boston Dynamics and their development of Spot and other similar quadrupedal robots. Following suite the team began development through an extensive literature study in which would include the analysis of the 8 DOF of the 5 bar linkage system that has a fixed link equal to zero. In designing the leg-linkage system, the gait analysis of the animals played a significant role when it came to the inverse kinematics and leg-linkage system. The overall design architecture was inspired from Stanford's Pupper.

Motivation

The motivation of this review is to summarize and analyze previous research efforts and provide useful guidance for future robotic designers to develop more efficient mechanical legs of quadruped robots and to gain a better understanding of the mechanics and control systems needed to create a functioning four-legged robot .

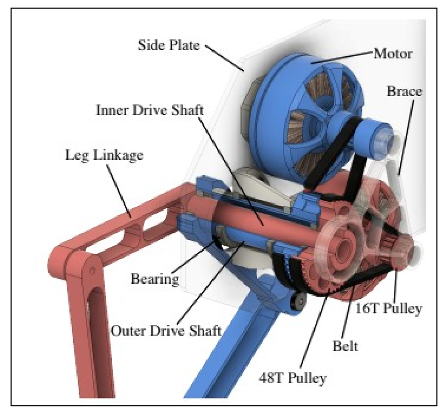
Objective

Learn about the design process of how to create and build a four-legged robot based on the literature reviews conducted to make it walk and stay level on both even and uneven surface.The intention of the project is to develop a better understanding of the mechanics and control systems needed to create a functioning four-legged robot. The goals of the robot were to be able to display a simple walking cycle with its motorized legs and be capable of supporting, moving, and operating under its own weight.

Background

Quadruped Study

- Use direct drive (DD) or quasi-direct drive (QDD) actuators to maximize torque, bandwidth, and power while minimizing friction, inertia, and mass
- QDD actuators combine a pancake style brushless DC motor with a gear reduction less than 10:1
- QDD's are backdrivable, allow for torque control and force estimation, however, they are expensive to build or buy
- Low cost quadrupeds, such as Pupper, use servo motors to drive the leg and open-loop control strategies to enable trotting



Stanford Doggo QDD actuator

Stanford Pupper

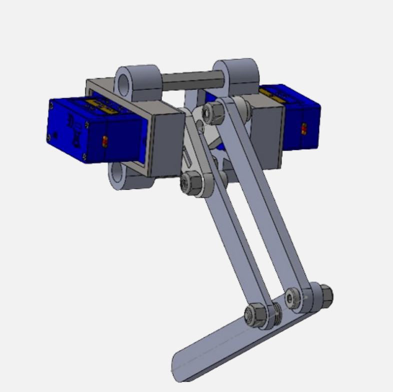
Gait Study Of Animals

- Gait analysis for the cat: Right Foreleg: RF, Left Foreleg: LF, Right hind leg:RH, Left hind leg:LH. When walking first the RF and LH tilt down, then level, and they til up with LF and RH.
- animals at stance: hip angle 120 degree. swing: reduces to 95 degree average and stifle stays around 110 degrees.

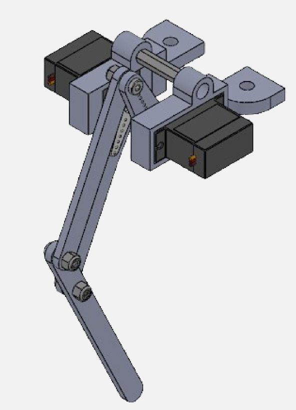
Design

Leg Design Iteration

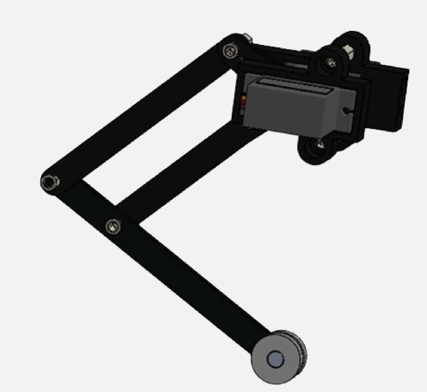
- 5 bar linkage design with motors placed higher up to reduce inertia (based on Pupper)
- Initially used plastic-geared sg90 servo motors
- Redesigned servo housing to allow for a greater range of motion and attachment the testing rig
- Leg was redesigned to add rubber washers for balance and stability for the feet



Leg design with sg90 servos



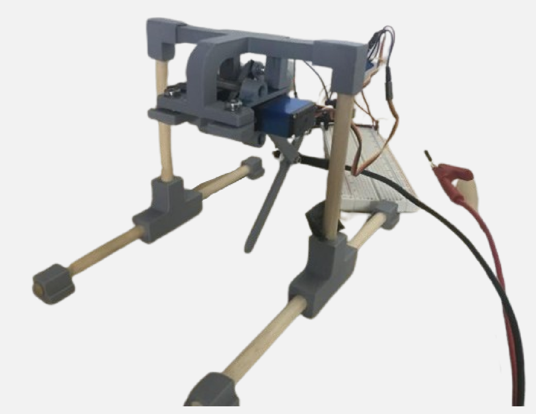
Leg design with MG92B servos



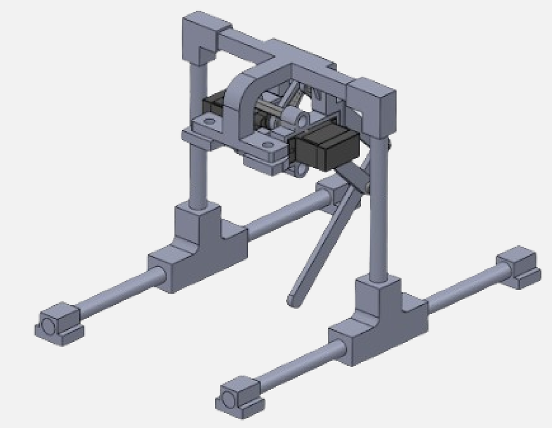
Final leg design with footing

Testing Rig

- Designed to verify the inverse kinematics model and test a basic swing and stance gait cycle



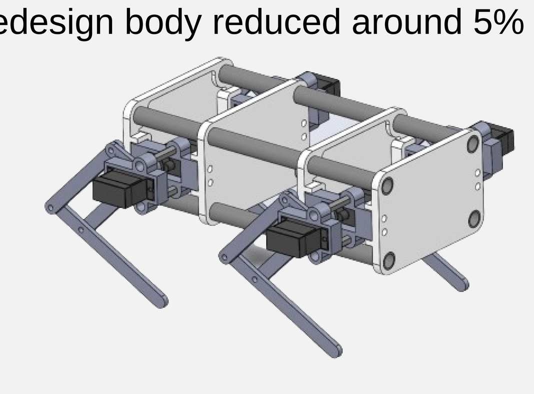
Physical Testing rig with leg attached



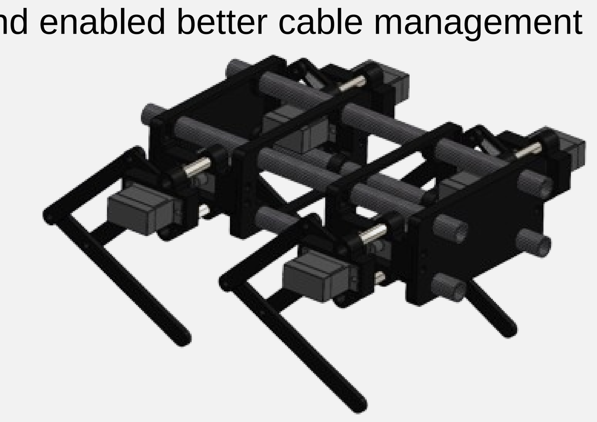
3D Solidworks testing rig model

Body Design Optimization

- Four plate and four tube design to attach the four leg assemblies
- Redesign body reduced around 5% total weight and enabled better cable management



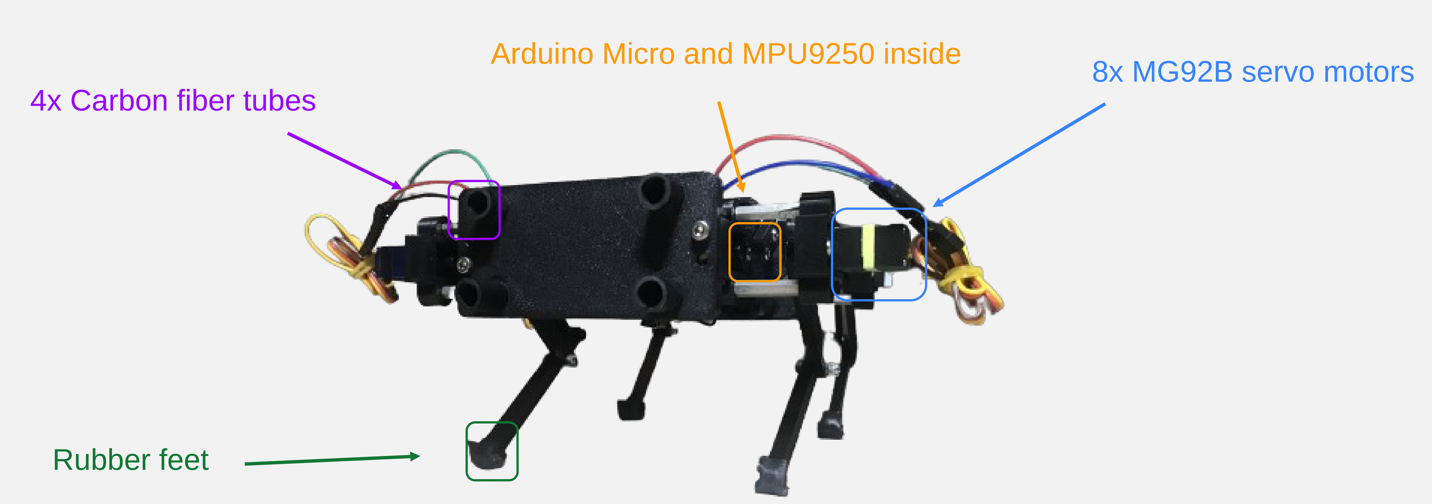
Initial Design printed in PLA plastic



Optimized Design printed in ABS plastic

Final Assembled Design

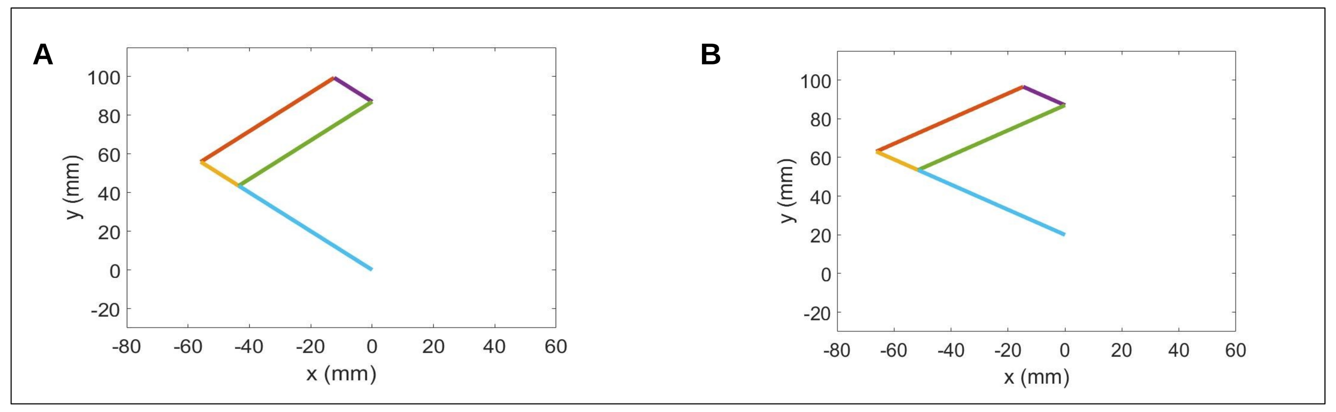
- 3D printed with Polymaker ABS Filament



Control

Inverse Kinematics (IK)

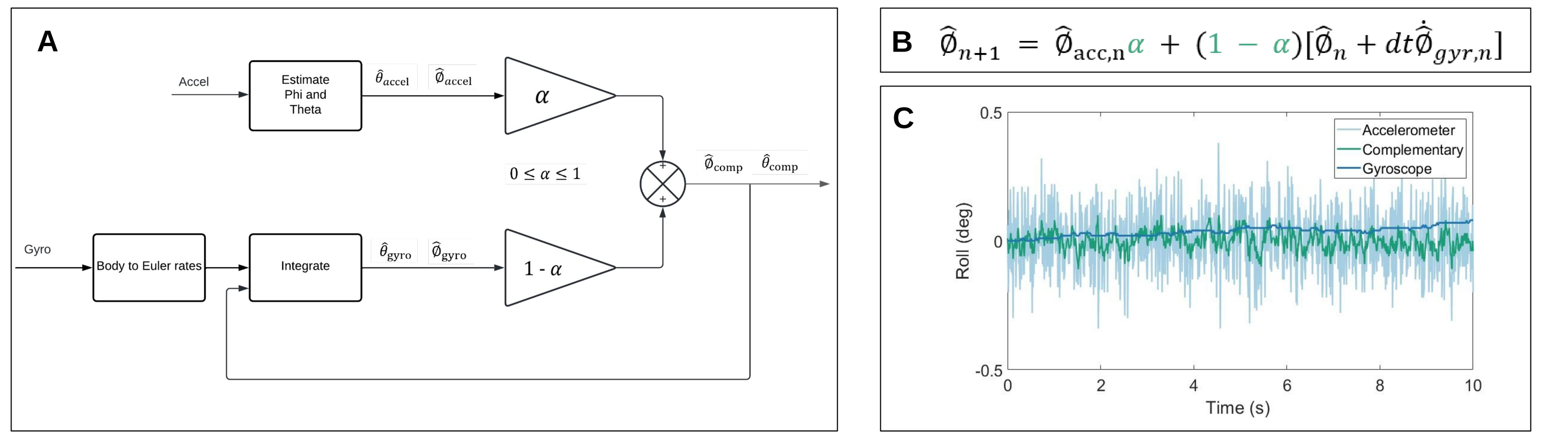
- Developed an IK model in MATLAB
- Returns the servo angles needed to move the end effector to the desired position



(A) End effector position at (0,0) mm **(B)** End effector position at (0,20) mm

Inertial Measurement Unit (IMU) Integration

- Enables the estimation of Scuffer's orientation (roll and pitch angles)
- Implemented a complementary filter to fuse accelerometer and gyroscope estimates
- Allows for a PID controller to be added for static balance



(A) Complementary filter block diagram **(B)** Equation used to estimate roll and pitch angles **(C)** Comparison between accelerometer, gyroscope, and complementary filter roll estimates

Gait

- A simple trot gait is generated in Arduino using the IK model
- Speed of the gait can be adjusted

Conclusion

Initial criteria for the group involved examining and investigating the design of a quadruped robot. The state-of-the-art direct drive (DD) quadrupeds DD or QDD actuators were the beginning of the research, but later the team decided to do a more efficient project due to the limited time and cost. Therefore, the decision was made to base the design on examples of the Stanford Pupper and PAWDQ. Using the information collected and developed throughout the semester, the design perspective of the legs and the overall system was modified to include the analysis of the 8 DOF of the 5 bar linkage system that has a fixed link equal to zero. In designing the leg-linkage system, the gait analysis of the animals played a significant role when it came to the inverse kinematics and leg-linkage system. A robot based on Pupper was built in order to complete two primary objectives of the team; develop the system of the robot using the higher-end servos and then analyze the motion to enhance our knowledge of the kinematics and dynamics of limb-linkage systems.

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