TURTLE Quadruped Project (QUAD)

TEXAS A&M UNIVERSITY Engineering

Zachary Bucknor-Smartt, Oscar Dominguez, Jonathon Foltyn, Micah Guttman, Shreyas Kannanganat, Jevine Kong, Caleb Parker, Eddy Silva, et al.

Project Lead: Ian Lansdowne

TEXAS A&M UNIVERSITY
ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Problem Definition

Legged robots are more agile and adaptable than robots with other forms of locomotion. The purpose of this project is to design and manufacture a robot capable of balancing and maneuvering on four legs to better understand the capabilities of walking robots.

Approach

Robot dogs are not a new concept by any means. This project has drawn heavy inspiration from other quadrapedic robots such as Boston Dynamics' Spot, MIT's Mini Cheetah, James Bruton's openDog V3, and a prototype by the project lead. To create a working robot, the team started with a robot with dimensions similar to the Mini Cheetah, known as QUAD V1. Upon realizing the difficulty of testing on a large and expensive robot, smaller version was created in order to serve as a software testbed. Most recently, V2 was completed. It took the shortcomings from V1 and framework of mini and improved upon them. Going forward, cycloidal drive was also tested and modeled to use in a future iterations of the dog.

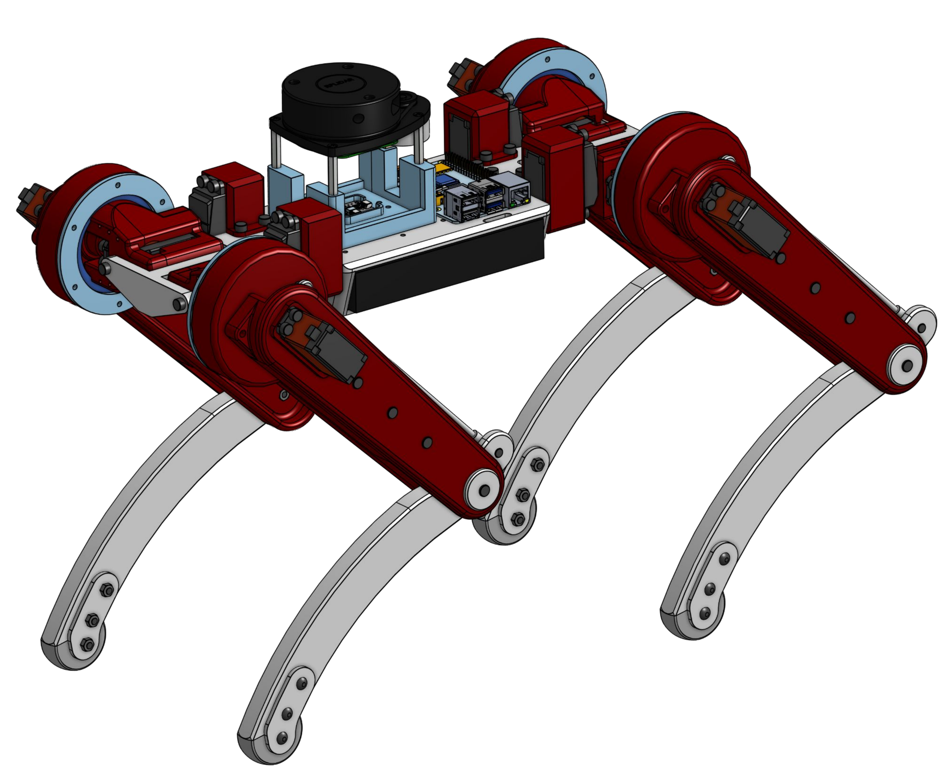

Figure 1. CAD model of QUAD V1.

Hardware

QUAD V1

Version 1 of the quadruped has 3 main joints on each leg: 2 shoulder pivots and a knee pivot. The robot uses a tie rod to actuate the lower leg. The tie rod was chosen to allow the lower leg actuator to reside in the upper leg, lowering the inertia of the leg. Silicone molded feet were chosen to increase grip and prevent slipping on smooth surfaces. QUAD V1 uses a Raspberry Pi 4 as the processor and an offboard PWM driver to control all leg motors. Additionally an IMU and LiDAR sensor were added to experiment with mapping, balancing on uneven terrains, and orientation in different environments.

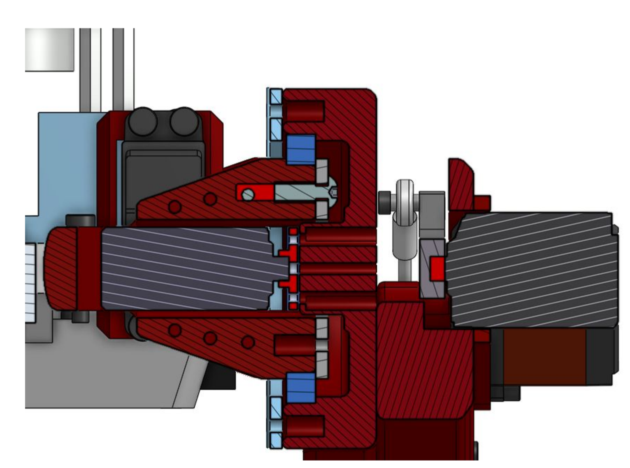

Figure 2. QUAD V1 Shoulder Cross Section.

Mini QUAD V1

Mini quad tackles the challenge of starting a miniature line of dogs in parallel to the standard QUAD series. Motivated by a need to have a dog that is lower maintenance than a standard QUAD as well as serve as a software testbed.

Figure 3. Mini QUAD V1 Leg.

QUAD V2

Based on the results of the V1 and Mini QUAD iterations, several improvements are being considered for the second version. Ensuring the robot can support more than its own weight will be the main priority, so the maximum torque output will be improved by using a 19:1 cycloidal gear reduction and replacing servo motors with powerful brushless DC motors.

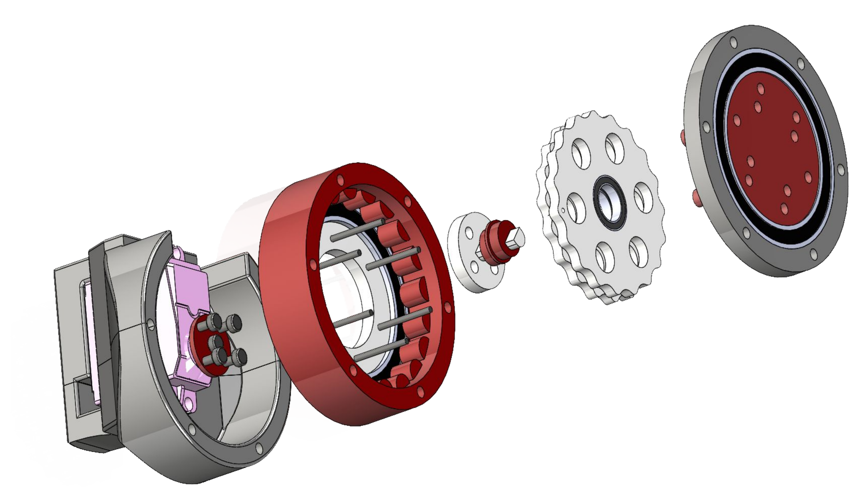

Figure 4. Section View of Cycloidal Actuator CAD model.

Software/Modelling

Software for all of the quadrupedal robots was standardized as a single package, so the same software can be run on any robot with different parameters. Since both existing robots use position-controlled servos to actuate the legs, the angle of each joint must be calculated to move the leg to a desired position, $\mathbf{p}$. The formulae for the joint angles α, β, and γ as shoulder, upper leg, and lower leg angles is shown in figure 5. The constants l_s, l_u, l_l, r_f are the lengths of the shoulder, upper leg, and lower leg and foot radius. Each angle is mapped to a pwm duty cycle through a calibration routine unique for each robot. All settings are saved in a JSON configuration file that is read on start.

The trajectory of the foot used for walking is created by interpolating between a resting, lifted, and forward stepping state to emulate walking. Each leg is shifted a quarter-period out of phase for multiple legs to touch the ground at once.

To command the robots remotely, driver station software was built. The software was made in python, and reads joystick angles and sends them over UDP to the robot. The custom driver station software allows for added functionality beyond driving the robot.

Future Iterations

Mini QUAD V1 Revisions

Several improvements can be observed for change in the next iteration of Mini QUAD. This includes to having a fixed, established mean of connecting the shoulder joint to the servo horn rather than super gluing the faces. Additionally, there is a need to improve the interfacing in the shoulder joint; the ball and socket do not possess the physical properties/dimensions of a smooth hinge. Lastly, the joint connecting the lower and upper leg can be improved with the addition of a heat insert providing a secure and stable connection.

QUAD V1 Revisions

Several issues have been identified with the first quadruped revision, including lack of torque from the 20 kg·cm servos, inability to read angles of the joints, and the limitation of position control. Version 2 will be designed to overcome these limitations. To increase torque, a cycloidal gearbox will be added to drive the lower leg joint. Higher-torque brushless motors with encoders will be used on each joint to alleviate issues with leg strength and allow the joint angles to be directly read.

Figure 5. Joint Angle Equations.

$$\mathbf{p} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + (z + r_f)\hat{\mathbf{k}}$$

$$\alpha = \operatorname{arctan2}(z, y) - \arccos\left(\frac{l_s}{\sqrt{y^2+z^2}}\right)$$

$$\beta = \operatorname{arctan2}(\sqrt{y^2 + z^2 - l_s^2}, x) - \arccos\left(\frac{l_u^2+x^2+z^2-l_l^2}{2l_u\sqrt{x^2+y^2+z^2-l_s^2}}\right)$$

$$\gamma = \arccos\left(\frac{l_s^2+l_u^2+l_l^2-x^2-y^2-z^2}{2l_u l_l}\right)$$