THE UNIVERSITY OF UTAH
Department of Mechanical Engineering

Quadruped Robot for Smart Agriculture

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Introduction

The Quadruped Robot for Smart Agriculture is a wireless, eight degree of freedom, four-legged robot. Its purpose is to serve as an open source alternative to other industrial quadrupeds which do not allow access or modification to low level control. This design uses the open-source Open Dynamic Robot Initiative (ODRI) as a starting point. The ODRI actuator module design was integrated with a fully accessible motor control system, power system, and body to create an accessible research platform without manufacturer restrictions.

Leg Actuator Module

The ODRI leg modules use T-Motor MN4004 KV300 brushless motors with a peak power output of 216 W. The modules include a 9:1 ratio belt system to achieve 2.1 Nm of torque, for a body weight limit of 12.6 pounds. 5000 count-per-rotation indexed optical encoder wheels are used to track joint angles. The legs were 3D-printed in Carbon Fiber PLA (CF-PLA) for added strength.

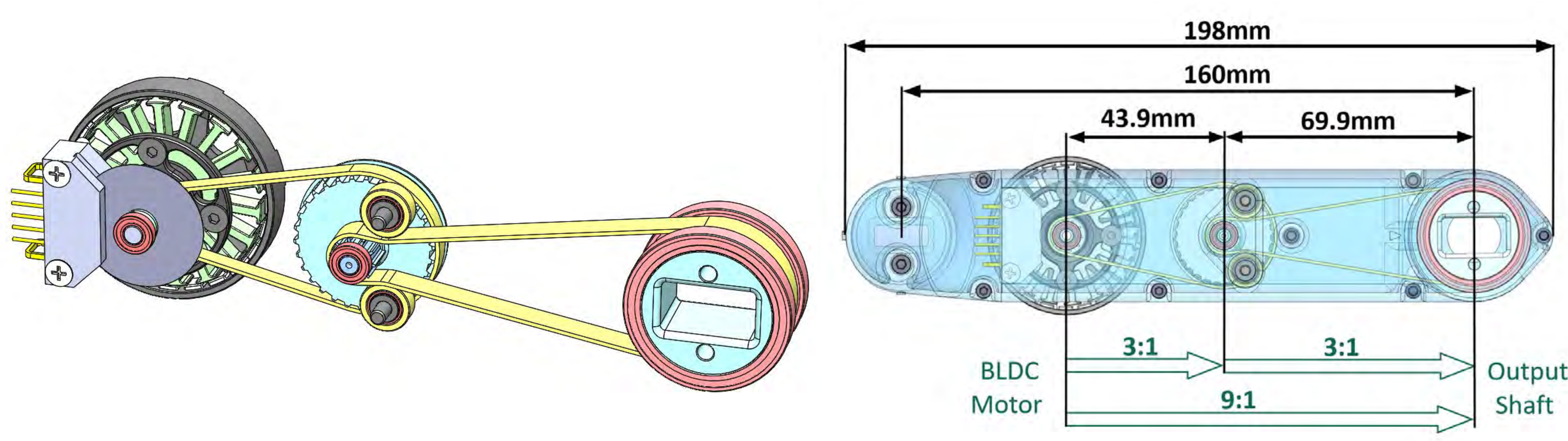

Figure 1: ODRI 9:1 belt system assembly (left) and actuator module shell (right)

Motor Control

The Orange Pi 5 was selected as the central controller. It runs Robot Operating System 2 (ROS2) Humble Hawksbill, an open source robot control system, on Ubuntu 22.04. It supports a CAN bus via transceiver. ODrive S1 motor controllers combine three phase brushless motors with an encoder to achieve closed loop servo control. The ODrive S1 was chosen for it's high current rating, open architecture, and CAN bus daisy chain support allowing integration with both the motors and the Orange Pi.

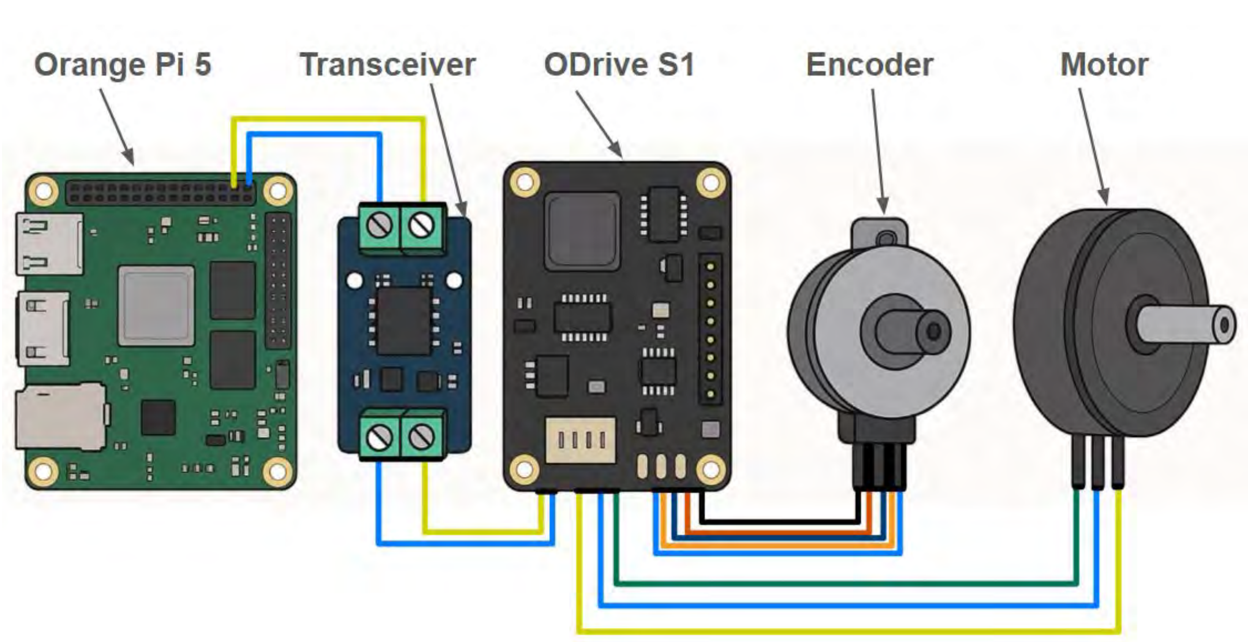

Figure 2: Single Motor Control Setup Using ODrive

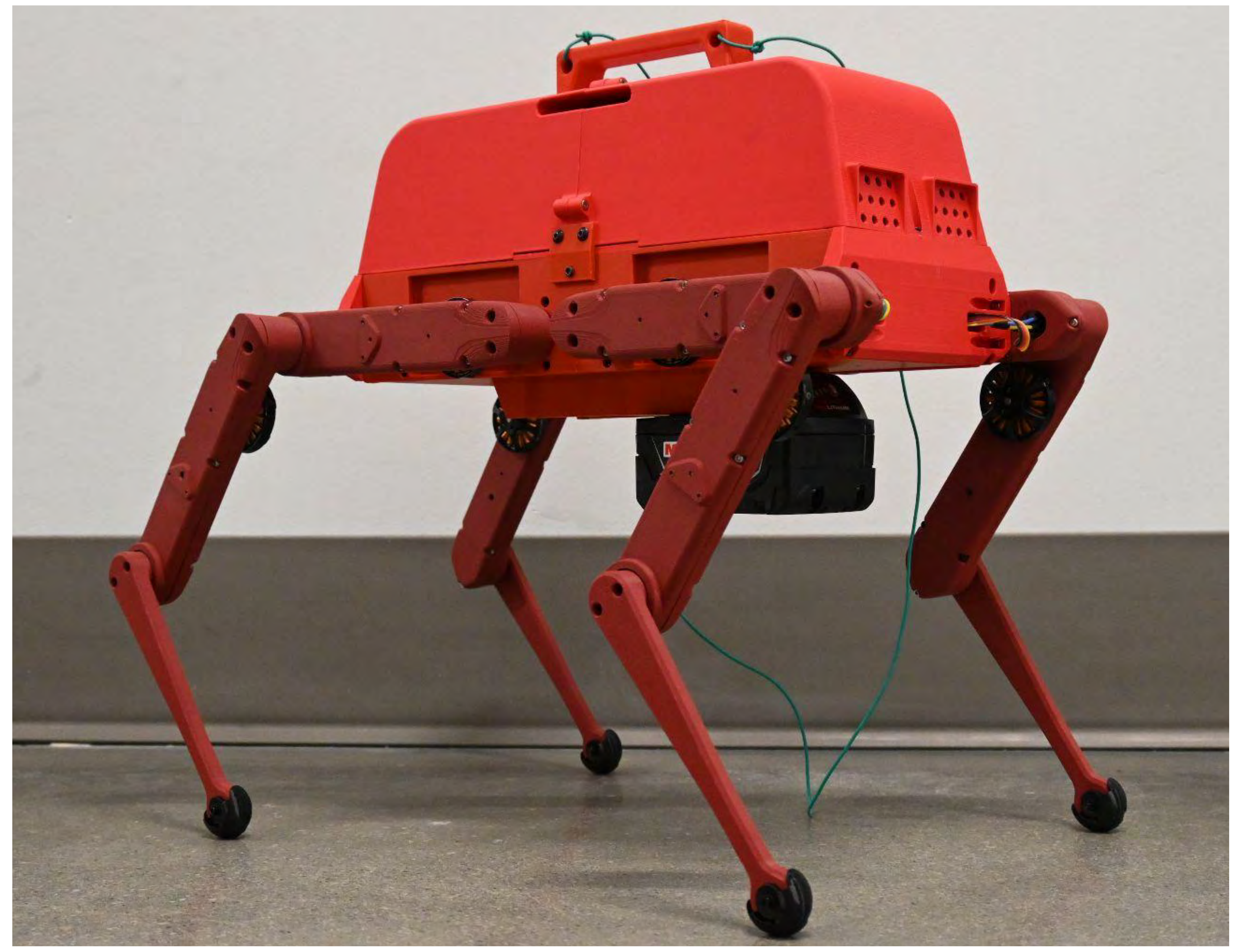

Figure 2: Robot standing using battery power.

Body

The body is fully 3D printable. The ODrive boards are mounted vertically allowing four boards to fit on each end of the body. For untethered power delivery, two battery mounts–to reduce weight only one is used–were added on the bottom of the robot. A lid was added to protect internal systems, with an 80mm cooling fan attached in the center.

Figure 3: CAD Rendering of 3D Printed Parts

Power System

The system runs off of a Milwaukee 18V XC5.0 battery to reach a 42* minute run time. The choice to use Milwaukee batteries was made for easy access and to use the built-in safety features included with the battery.

Results

The final performance values of the robot are shown in Table 1. The leg torque desired value is the given value from the ODRI project, while the final value is what we measured. We were able to achieve most of these specifications as well as basic walking motion. However, due to limitations with the 8 degree of freedom platform, we were unable to achieve a full range of motion. Further, while we were unable to meet the target current draw, which was derived from the peak draw of all motors simultaneously, during testing no motor exceeded 7 amps. The most all the motors attempt to draw simultaneously was 18 amps total. Runtime was tested under a static load.

Table 1: A collection of measured capabilities compared to desired metrics

Metric	Final Value	Desired Value
Single Leg Torque	2.142 Nm	>2.1 Nm
Robot Weight	9.75 lbs	<12.64 lbs
Battery Power Output	18.7 V, 20 A	18 V, >80 A
Robot Runtime	42 minutes	>30 minutes
Basic Walking	Tethered	Untethered
Rough Terrain Walking	Unsuccessful	Untethered

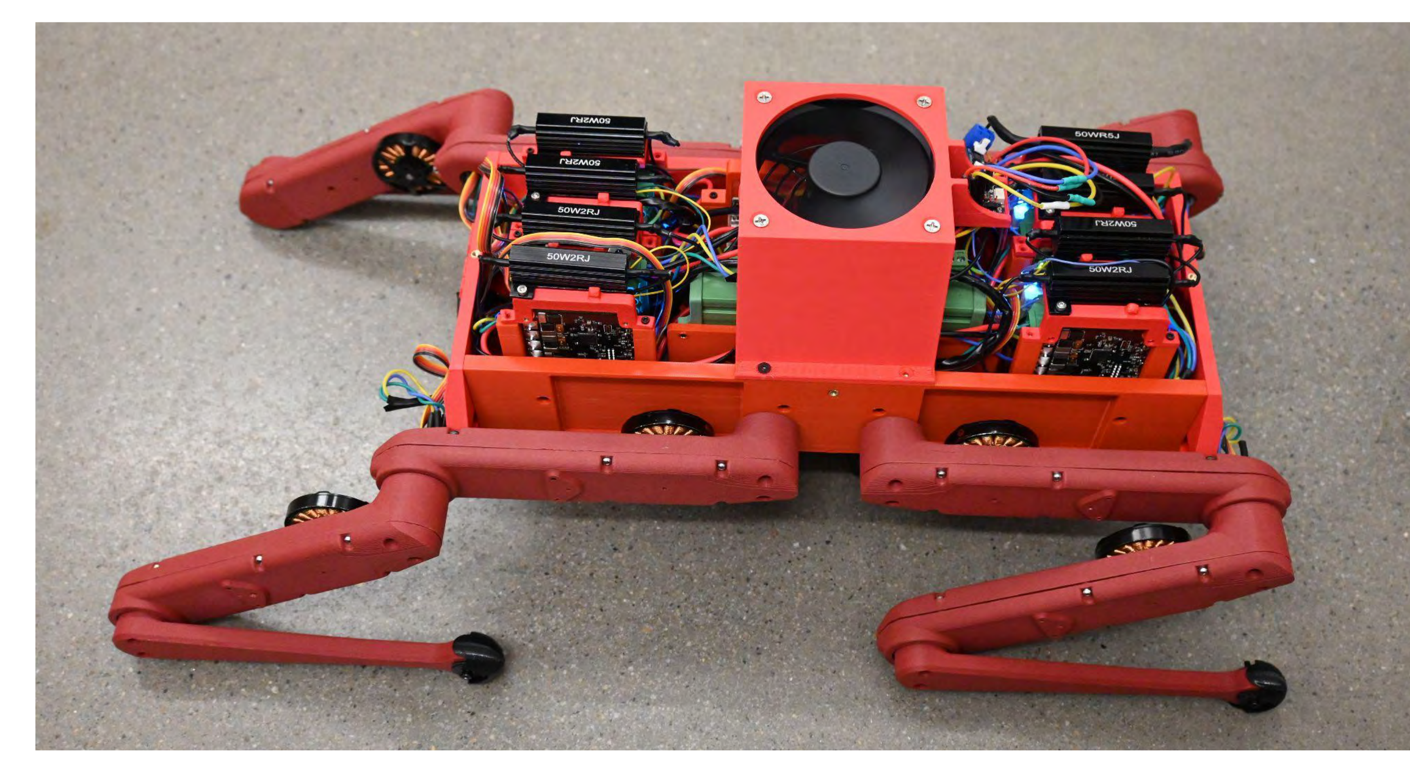

Figure 4: Internal wiring of robot

Conclusion

The Quadruped Robot for Smart Agriculture successfully demonstrates the ability to make basic movements (stand and sit). It is a fully open architecture which allows future research into robot control. To achieve field readiness (rough terrain walking capability) 12 degrees of freedom should be used as opposed to 8. This would allow the robot to perform a twisting action which would allow it to stabilize more effectively while stepping in addition to enabling turning. Custom batteries would also need to be assembled to reduce weight. Alternatively, the actuator modules could be redesigned to increase torque output capabilities and consistency.