OPENMUTT - ROBOTIC QUADRUPED RESEARCH TESTBED

Authors: Gabriel Alkire, Jeremy Niemiec, Bryan Gonzalez, Aleiya Deets, Zachary Nadeau
ME DEPARTMENT, EPPL, OUR, RAER
alkireg1@my.erau.edu, gonzab18@my.erau.edu, niemiej1@my.erau.edu, holyoaka@my.erau.edu, nadeauz@my.erau.edu

CUSTOMER IDENTIFICATION AND REQUIREMENTS REVIEW

OpenMutt is an open-source quadruped the ME Department intends to develop to increase multidisciplinary research opportunities for students and faculty. As part of the requirements, the testbed must be modular, easy-to-manufacture, and affordable. To meet these requirements, this quadruped uses James Bruton's openDogV3[3] as a primary basis of design and additively manufactures the majority of components. A quarter model has been assembled and undergone preliminary testing as a proof-of-concept for the full model of the quadruped. Assembly of this model has begun. The requirements for each model are as follows:

Full Model (System) Requirements:

1. The system shall have a maximum empty weight of 118 N.
2. The system shall have a minimum payload capacity 23 N.
3. The system shall have a minimum hip height of 0.4 m, shown in the Full Model Diagram.
4. The system shall have a minimum chassis length of 0.686 m.
5. The system shall cost no more than $6000.
6. The system shall use a battery with an integral, onboard BMS (battery-management syster

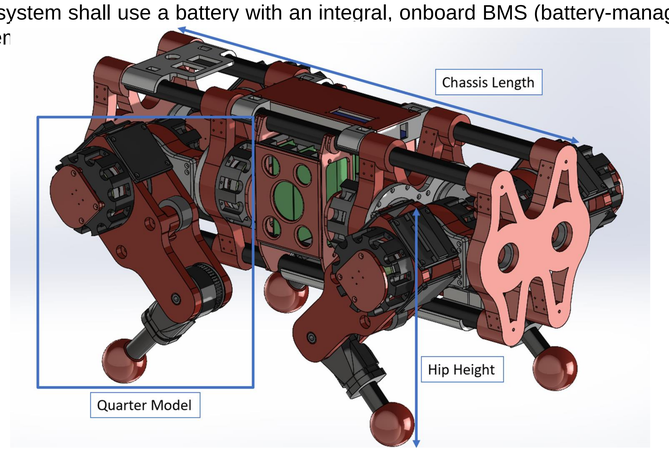

Figure 1: Full Model with example openDogV3 in Idle Position

PROPOSED SOLUTIONS AND DECISION PROCESSES

The OpenMutt quadruped will focus on redesigning existing open-source quadrupeds to allow for easy modification of the drive systems, control systems, and payload integration. The anticipated design includes the use of 12 brushless DC motors, 12 encoders, and 12 motor controllers for actuation. The goal operation time of the quadruped is an hour runtime while standing in idle position and 30 minutes while walking. Mounts on the chassis and above the motors will allow for integration of

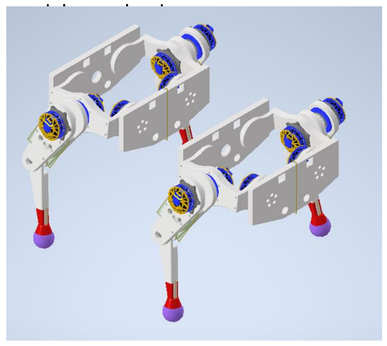

Figure 2: CAD of Anticipated Full Model

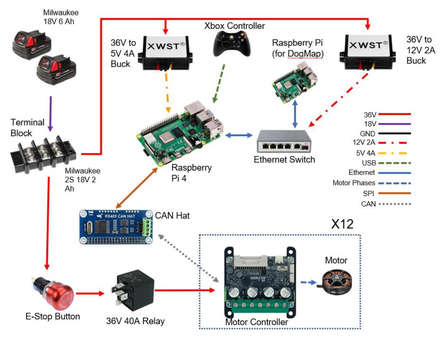

Figure 3: System Diagram of OpenMutt

ABSTRACT

The objective of the OpenMutt project is to build a modular, open-source quadruped as a multidisciplinary research testbed for students and faculty. The design is based on proven models, including the MIT Mini-Cheetah, NYU Open Dynamic Robot, and Bruton's openDogV3, with modifications to decrease manufacturing time and cost.

OpenMutt utilizes 12 brushless motors, each attached to a cycloidal gearbox for actuation. The quarter model has three degrees of freedom, translational and rotational. A remote control will be used for general movement with impedance and PID controllers for torque and joint control.

The majority of parts were additively manufactured with Fused Deposition Modeling (FDM) printers using Polylactic Acid (PLA) and Thermoplastic Polyurethane (TPU).

A power supply will be used for quarter model testing, while the full model will use an onboard battery with the battery-management system (BMS). Due to the 13:1 gear ratio of the cycloidal gearbox, motors like the ones selected are adaptable to the model.

The purpose behind the application of these methods is to ensure a platform that is easy to construct, iterate and learn with.

BACKGROUND

As part of the preliminary design process, research into current, proven models was conducted. Robotic dogs are rising in popularity within industry and academia, with the current standard being Boston Dynamics' "Spot," costing approximately $74,500 per unit[4]. Research with this platform would also be extremely limited due to Spot being a closed-source system, making modifications extraordinarily difficult. James Bruton's openDogV3 offers a robust cycloidal drive design located in the upper leg, as well as the concept of using a highly 3D-printed body[3]. The MIT Mini-Cheetah[1] and NYU Open Dynamic Robot[2] offer efficient gait mechanic and overall leg design.

While others have made these open-source robot dogs before, none have used or designed them to be easily modifiable for research avenues such as biomimicry, gait, and path-planning controls at the university level. The use of additive manufacturing has allowed for rapid prototyping and redesign.

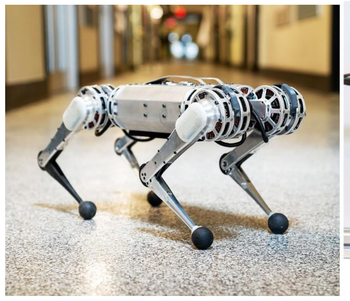

Figure 4: MIT Mini-Cheetah

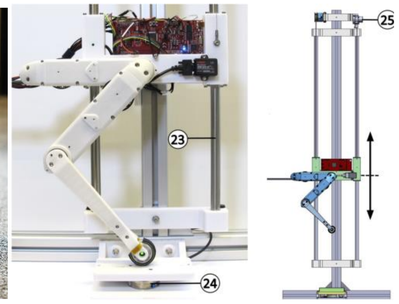

Figure 5: NYU Open Dynamic Robot

CURRENT SOLUTIONS AND SUPPORTING ANALYSIS

By additively manufacturing the majority of the components for OpenMutt, a redesign based on Bruton's openDogV3[3] with a focus on modularity was completed. PLA was used to print structural parts of the quadruped, like the majority of the gearbox, hip, and leg. The cycloidal gearbox uses a 13:1 gear ratio, reducing backlash, improving impact resistance, and allowing compatibility with similar DC brushless motors. Each gearbox consists of 46 additively manufactured components, making it the most intricate sub-assembly on the quadruped.

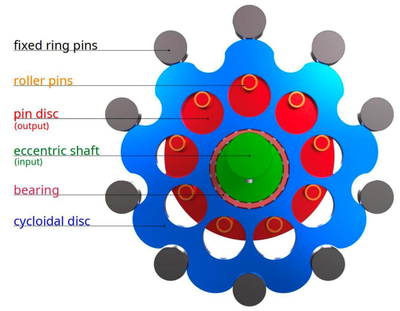

Figure 6: Diagram of Cycloidal Gearbox

Figure 7: Printed Cycloidal Gearbox

Funding from the IGNITE grant and the ME department was used for part ordering and manufacturing of the full model. The main cost of this project is the equipment needed to drive the quadruped, like the motors and motor controllers. General supplies include PLA spools, bearings, screws, etc. The full model costs approximately $5,800, excluding the test payload equipment. Currently, a quarter model of the quadruped has been assembled and is undergoing testing to finalize design of the actuation systems for the full OpenMutt system.

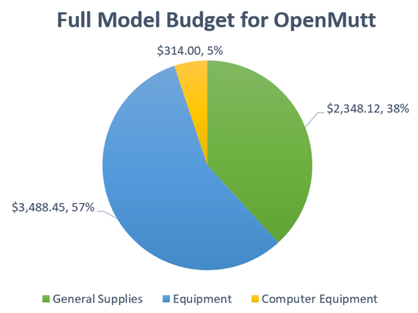

Figure 8: Budget for Full Model of OpenMutt

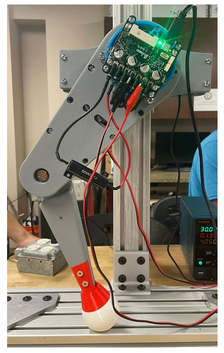

Figure 9: Current Quarter Model Assembly

REFERENCES

[1] MIT Biomimetic Robotics Lab (2019) Cheetah-Software [Source Code]. https://github.com/mit-biomimetics/Cheetah-Software

[2] Grimminger, Felix & Flayols, Thomas & Fiene, Jonathan & Badri-Spröwitz, Alexander & Righetti, Ludovic & Meduri, Avadesh & Khadiv, Majid & Viereck, Julian & Wuthrich, Manuel & Naveau, Maximilien & Berenz, Vincent & Heim, Steve & Widmaier, Felix. (2020). An Open Torque-Controlled Modular Robot Architecture for Legged Locomotion Research. IEEE Robotics and Automation Letters. PP. 1-1. 10.1109/LRA.2020.2976639.

[3] Bruton (2022) openDogV3 [Source Code].https://github.com/XRobots/openDogV3

[4] E. Ackerman, "Boston Dynamics' Spot Robot Dog now available for $74,500," *IEEE Spectrum*, 09-Feb-2023. [Online]. Available: https://spectrum.ieee.org/boston-dynamics-spot-robot-dog-now-available. [Accessed: 14-Feb-2023].

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