OPENMUTT - QUARTER MODEL OF ROBOTIC QUADRUPED

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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 developed and undergone preliminary testing as a proof-of-concept before assembly of the full model commenced. The requirements for the quarter model are as follows:

Quarter Model (Test Article) Requirements:

- The test article shall have a maximum empty weight of 23 N.
- The test article shall have a minimum payload capacity of 6.0 N.
- The test article shall have a minimum hip height of 0.4 m, shown in the Quarter Model Diagram.
- The test article shall have a minimum of 3 degrees of rotational freedom.
- The test article shall cost no more than $2000.

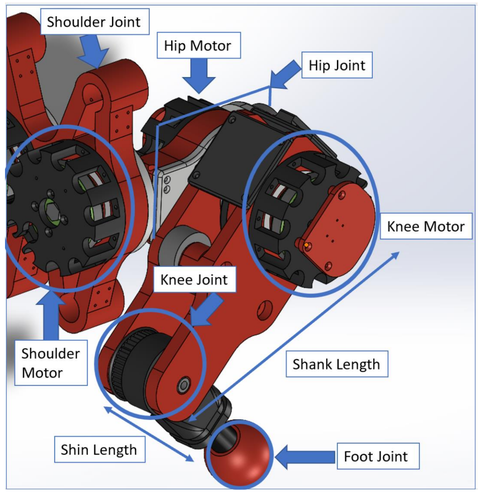

Figure 1: Quarter Model with example openDogV3 in Idle Position

PROPOSED SOLUTIONS AND DECISION PROCESSES

The OpenMutt quarter model will act as a testing platform of the drive systems, control systems, and payload integration before assembly of the full model. The anticipated design includes 3 brushless DC motors, encoders, and motor controllers for actuation from the hip to the knee. A system diagram of the quarter model integrated with the electrical system of the full quadruped is shown in Figure 4. 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 allow for integration of modular payloads.

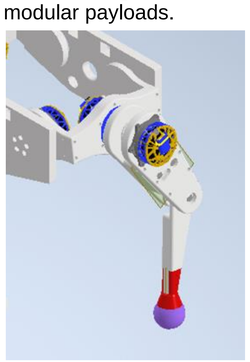

Figure 2: CAD of Anticipated Quarter Model

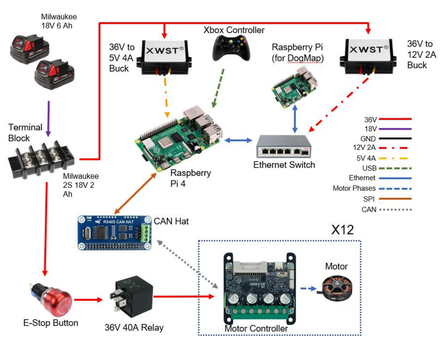

Figure 3: System Diagram of OpenMutt Quarter Model

ABSTRACT

Embry-Riddle Aeronautical University is seeking a robotic dog as a research avenue for different biomechanical designs, control systems, and robotic designs for experimentation and study. The quadruped is based on several open-source platforms including James Bruton's openDogV3, the MIT Mini-Cheetah, and the NYU Open Dynamic Robot Initiative.

Implementation of this research will begin with a quarter model, consisting of a singular leg from the hip to the foot. The leg will be mounted on a benchtop test stand that allows for controlled movement and accessible experimentation. The leg will be separate from the full-model quadruped strictly for experimentation and any full-model revisions.

The OpenMutt's quarter model uses 3 Brushless DC Electric Motors attached to 3 cycloidal gearboxes as its main form of actuation. The majority of parts were manufactured using Polylactic Acid (PLA). Some leg testing has already been completed, but a synchronized movement is yet to be completed.

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.

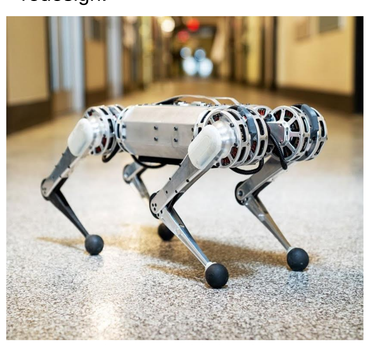

Figure 4: MIT Mini-Cheetah

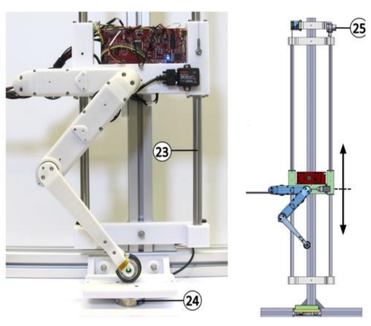

Figure 5: NYU Open Dynamic Robot

CURRENT SOLUTIONS AND SUPPORTING ANALYSIS

Calculations for the static system and general power consumption were determined as a baseline for future testing of the quarter model. The Modified DH Parameters were used to determine torques at each joint. The general movement case of the quarter model the power draws approximately 4.0 W from the power supply.

Funding from the Spark grant and ME department was used for part ordering and manufacturing of the quarter 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. A completed quarter model costs about $1,600.

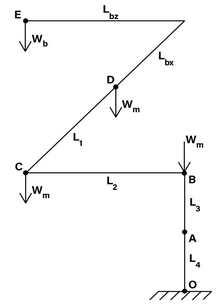

Figure 6: Static Calculations Diagram

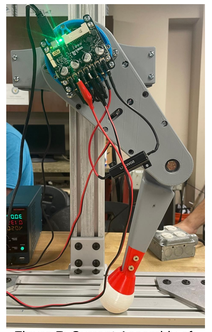

Figure 7: Current Assembly of Quarter Model

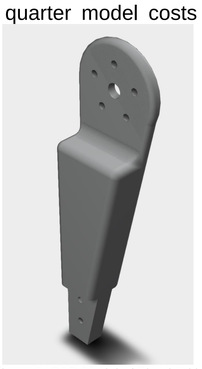

Figure 8: CAD Model of Shank with Adjustable Knee Section

By additively manufacturing the majority of the components for the quarter model, a redesign based on Bruton's openDogV3[3] with a focus on modularity was completed. FDM printers with PLA filament were used to print the majority of the components for the gearbox, hip, and leg. The cycloidal gearbox uses a 13:1 gear ratio, reducing backlash and improving impact resistance. It also allows for similar brushless DC motors to be used with the model. Another feature of modularity on the quadruped is located at the knee section. The area allows for different actuation attachments, like belts, couplers, etc. A 3D-printed, thermoplastic polyurethane (TPU) belt was used during testing for knee actuation.

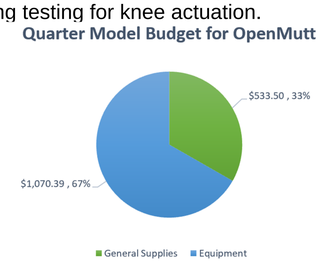

Figure 9: Budget for Quarter Model of OpenMutt

Figure 10: Printed Cycloidal Gearbox

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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