MiniRHex: A Small, Open-source, Fully Programmable Walking Hexapod

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***Abstract*—Here we introduce MiniRHex, a miniature hexapod robot based on the design of RHex. The main motivation for designing MiniRHex was to create a low cost, easy to build, fully programmable robot suitable for teaching and outreach programs. The cost, just over $200 each, is critical to be able to support educational programming with a higher robot-to-student ratio than more expensive platforms. The design of the robot features a laser-cut frame, 3D printed legs, off-the-shelf actuators and control board, and an intuitive software package with fully programmable leg control. Despite its low cost, the platform is quite capable and can carry up to six times its body weight in payload.**

I. Introduction

MiniRHex was designed to be an educational and outreach tool to allow students to experiment with a fully functional walking robot at a much lower cost. Unlike many low cost small robots, which only offer differential drive control, the independent control of each leg allows for a richer range of instructional topics and greater freedom for students to explore its capabilities. The low price tag allows us to build a fleet of machines for a reasonable cost, giving each student more hands-on interaction with the hardware. Educational units planned with the platform include: 1) gait design and optimization; 2) leg materials and shape exploration; 3) mobile robot sensor feedback control; and 4) multi-robot behaviors.

The robot design, seen in Fig. 1, is available freely online[1] as open source hardware and software. In the future we plan to also post curricular materials based on this platform.

II. Design and Control

Overall the design objectives were to build a low cost robot that was easy to build, but still capable of interesting behavior. Certainly a small robot of this type could be built with higher performance or at a lower cost however this design finds a nice middle ground while placing a premium on off-the-shelf parts (instead of custom designs) and easy manufacturing. There were three main challenges in the design of this robot that we will discuss here: 1) compliant leg design; 2) actuator selection; and 3) continuous rotation control.

The robot design is based on RHex [5, 2], with six one degree-of-freedom legs. Each leg is a compliant "C" shape to better navigate rough terrain and obstacles like staircases [4]. One challenge with the design of a small and low cost RHex is the leg construction. Rather than the custom fiberglass composite legs that RHex uses, we would like to use rapid prototyping techniques so that the robot is easy to build. The initial 3D printed leg design was too stiff – animals run with a dimensionless leg stiffness of about 10 (ranging between 5 and 15) [1], and the initial legs had a stiffness of 60. Making the legs 1/6th the width would work but would be too brittle. Instead, since the stiffness of the legs roughly correlates with the square of the material thickness we were able to use legs with half the material for a final stiffness of 15. This is now within the observed range in nature, though it could be further reduced to get to the average of 10.

The continuous rotation of the legs at reasonably fast rates (at least 1 but ideally 2 or 3 rotations per second), while still requiring position feedback and control, limits the options available for actuator selection. While these properties are achievable in fully customized designs combining discrete motors, gearboxes, encoders, and motor controllers, very few off-the-shelf options exist that achieve this. The Robotis Dynamixel XL-320 was the only actuator to meet the speed,

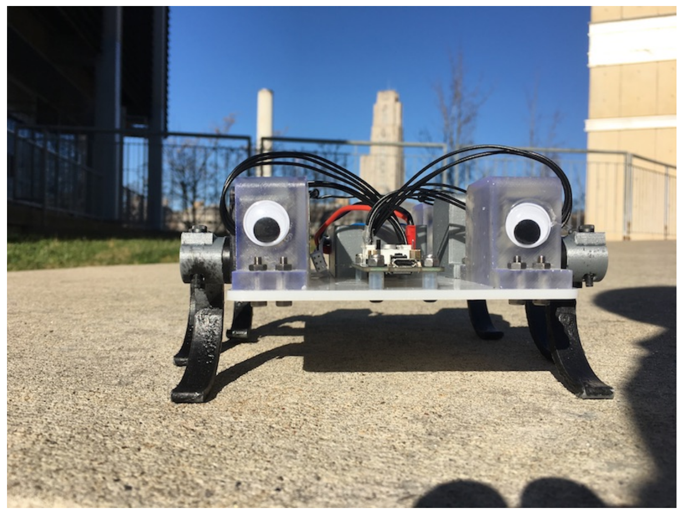

Fig. 1. The MiniRHex platform, an low cost and easy to build hexapod robot.

[1] https://robomechanics.github.io/MiniRHex/