Design and Control of a Mesoscale Hip Actuated Powered Walker

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SUMMARY

The goal of this research is to create a small bipedal robot (the size of a LEGO Minifigure) that can walk on flat ground by drawing inspiration from passive-dynamic walkers. To begin understanding legged locomotion at this size scale, we present a small underactuated bipedal robot that can stably walk forward (Fig. 1). The current design is in the form factor of a 2x LEGO Minifigure (8.25cm tall), weighs 60 grams, and can run untethered. Unlike most actuated robots based on passive-dynamics, the robot we present here uses hip actuation and an asymmetric lofted foot design. At this size space is limited, and hip actuation allows the robot to be very compact. By applying torques at the hip with a sinusoidal trajectory the robot has been able to take small steps forward. The successful completion of this robot will make it one of the smallest bipedal walking robots and give us insight into design requirements for the target size design.

I. MOTIVATION

Passive walking machines like the Wilson walking toy [1] have been around since at least the 1930s. These machines use gravity as their sole power source and can walk down small declines. Researchers have been able to get previously passive walkers to walk on level ground with the addition of motors for ankle push-off [2,3]. We want to utilize the passive dynamic gait at a smaller form factor compared to the Wilson walker and while using hip actuation. At a small scale the inclusion of additional actuators for the pitch and roll of the ankle would be cumbersome.

Another way to actuate a small bipedal robot is to have multiple degree of freedoms in the leg like the 16.5cm tall i-Sobot [4]. The current robot prototype in Fig. 1 is 8.25cm tall and we hope to decrease our size further, so this number of actuators will not be possible. Lastly, Takarama Tomy's Robo-Q [5] toy is only 3.4cm and weighs 12 grams, but walks with a quasi-static shuffle gait rather than a dynamic walk.

II. HARDWARE DESIGN

The robot is designed as a modified 2x scaled LEGO Minifigure [6] with hip actuation as seen in Fig. 1. The structure is made from 3D printed components as this allows for fast iterations. Feet are designed as lofted sections with a sagittal and frontal radius of 42.67mm. This radius creates a center of rotation that is higher than the center of mass of the robot allowing the robot to be statically stable. A rolling contact simulation using the dynamics of passive walkers is planned that will be used to further optimize the robot's physical parameters.

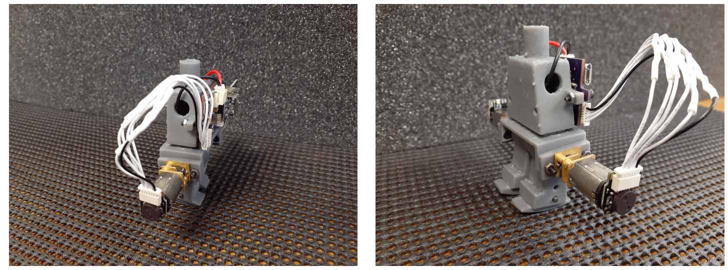

Fig. 1: (Left) Back isometric view of 60 gram bipedal robot. (Right) Front isometric view of the robot

To build a robot this small requires careful design of the electronics. The hips are individually actuated by two brushed geared DC motors. The on-board microprocessor is Atmel's Atmega32u4. An Analog Device's ADXL 335 accelerometer is used to calculate robot body angle and when contact occurs. Quadrature encoders are attached to the motors to control swing and stance foot angle. Wireless communication is done using a 2.4GHz radio chip (nRF24L01+). Lastly, the robot is powered by a 150 mAh Li-Po battery in the robot's torso.

III. RESULTS AND DISCUSSION

With a high speed camera we were able to find the resonant frequency (4Hz) of the robot. The robot is able to achieve a forward shuffling motion by following a sinusoidal trajectory at the resonant frequency. However, the walking gait does not exactly match the passive walking toy examples, and we are continuing to analyze the walking pattern.

In the future, we want to have the electronics fully contained inside the robot, both integrating a smaller hub motor in the robot's hips and moving the electronics board inside the torso. Finally, we hope to incorporate phase control using the on-board accelerometer.

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