Design and Control of a Mesoscale Hip Actuated Powered Walker

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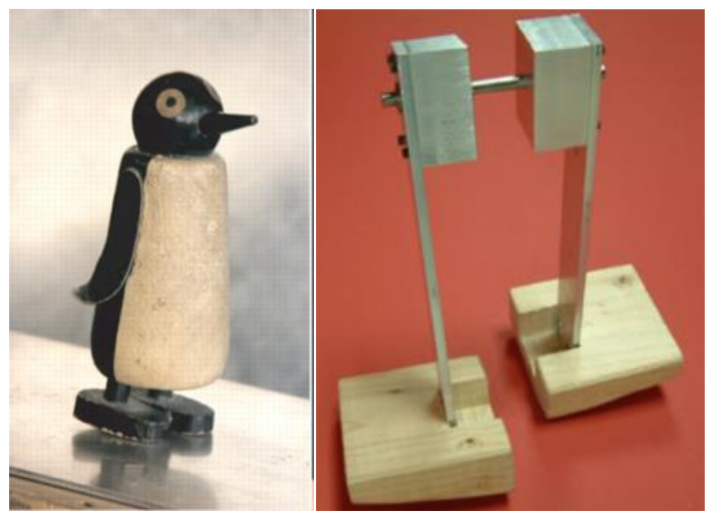
Abstract

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 The current design is in the formfactor 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.

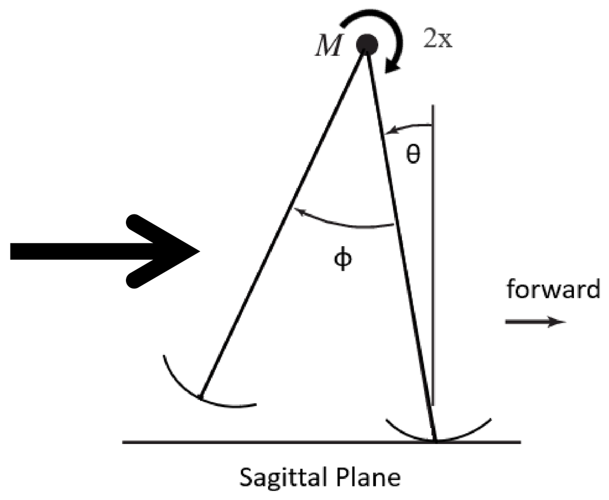
Motivation

4in tall Wilson Walkie Toy[1] can walk down sloped ramp with a small perturbations.

- Walk stably down a small decline without the use of any motors
- Tunable feet design that can be adjusted to change the step frequency and step length of the walker
- Very energy efficient



Left: Wilson Walkie Toy
Right: Tedrake's Simple passive dynamic Walker



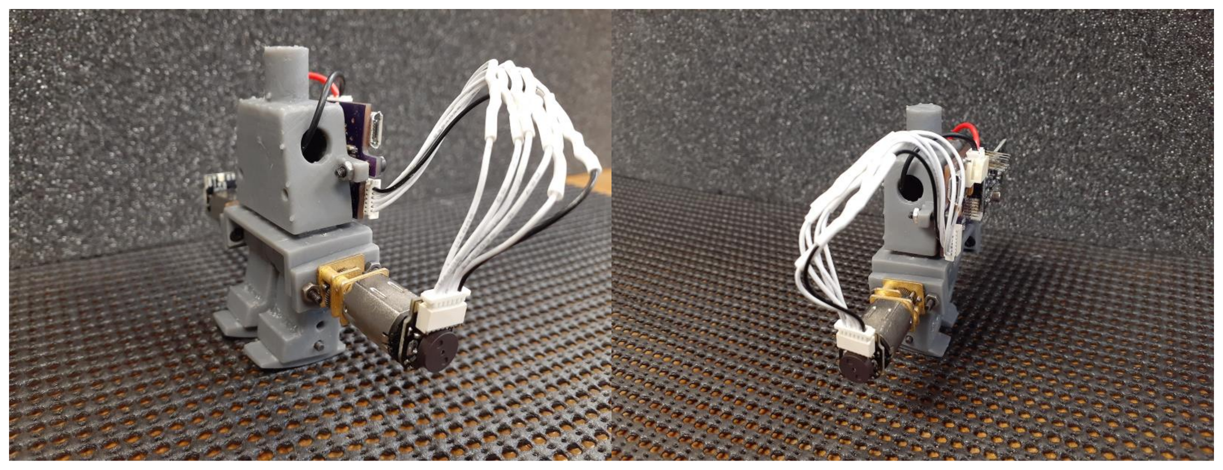
Schematic of walker design with two motors at the hip.

Prior work addresses larger robots, but not robots smaller than the Wilson Walking Toy.

- Capitalize on the energy efficiency of passive walkers and the robustness of actively controlled system[2].
- Understanding how scaling impacts walking and the use of hip actuation for walking.

Research Question: Can we walk on flat ground at a size smaller than the Wilson Walking Toy?

Design



(Left) Back isometric view of 60-gram bipedal robot. (Right) Front isometric view of the robot

Mechanical Design

- Feet are designed and then 3D-printed as lofted section. The radius sagittal and radius frontal are 1.68 inches
- Motors mounted at the hip to control hips actuation.
- Weighs only 60 grams and is 8.25 cm tall.

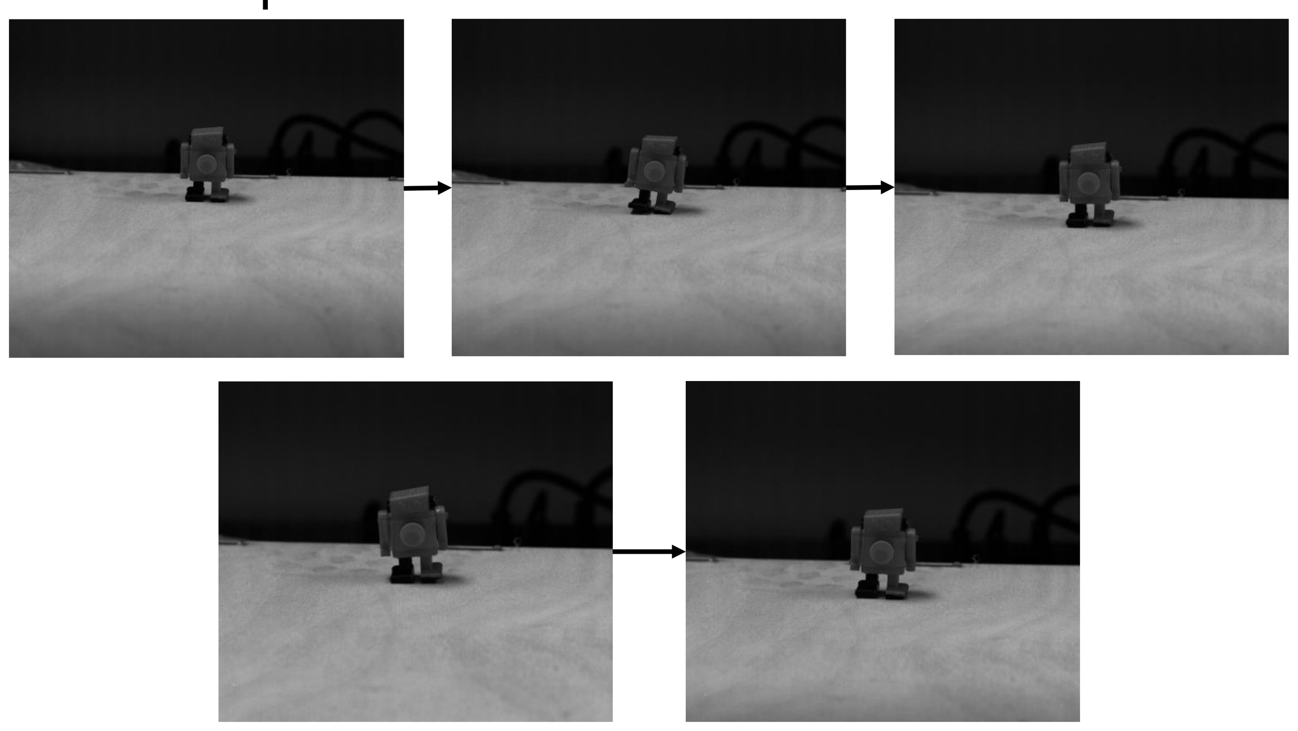
Hardware:

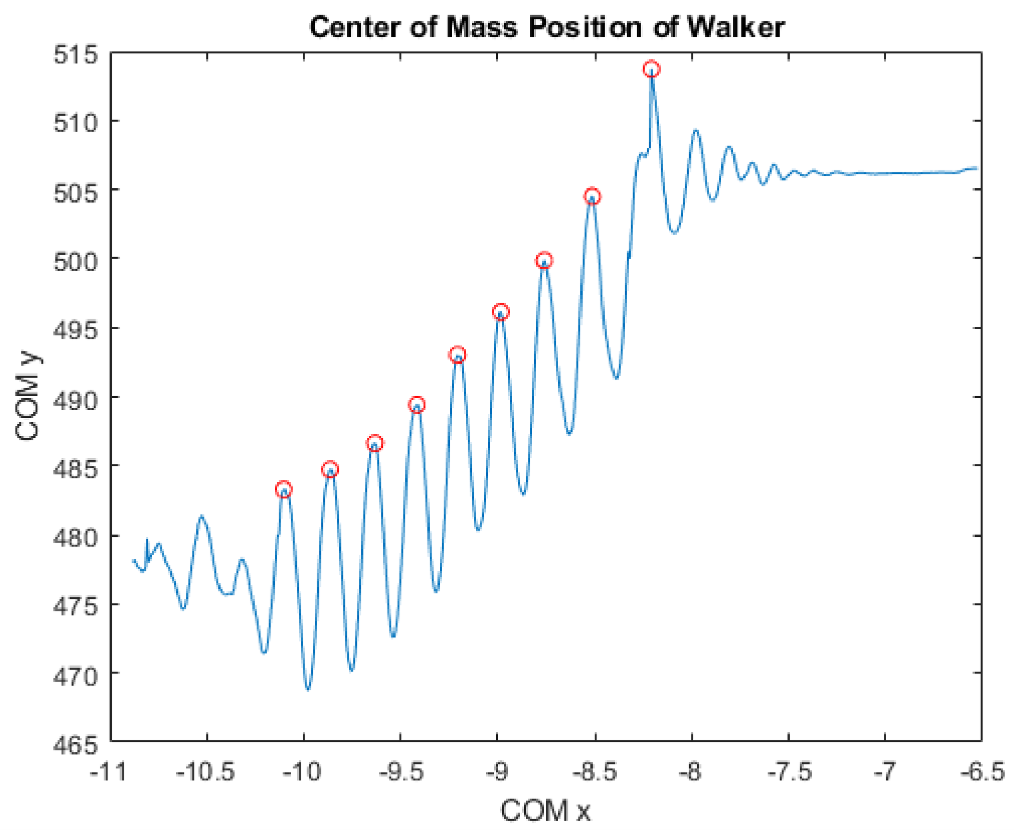
- Quadrature Encoder 12 counts per revolution
- 100:1 Brushed DC Motor
- 3 Axis Accelerometer
- 8-bit Atmega32u4 MCU
- nRF24L01+ 2.4GHz Radio
- 150 mAh LiPo Battery

Controls

Control Scheme

- Frequency matching and resonance characterization of the natural gait of a similar sized passive walker ($f_d = 4.5\ Hz$) from high speed video capture.

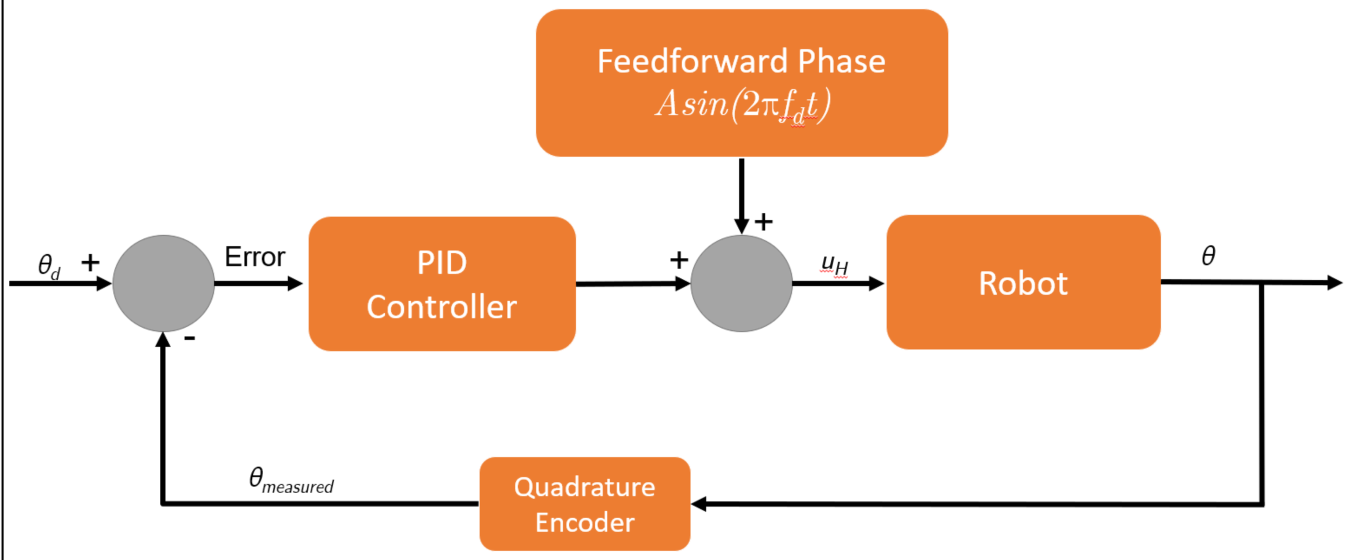




Controls

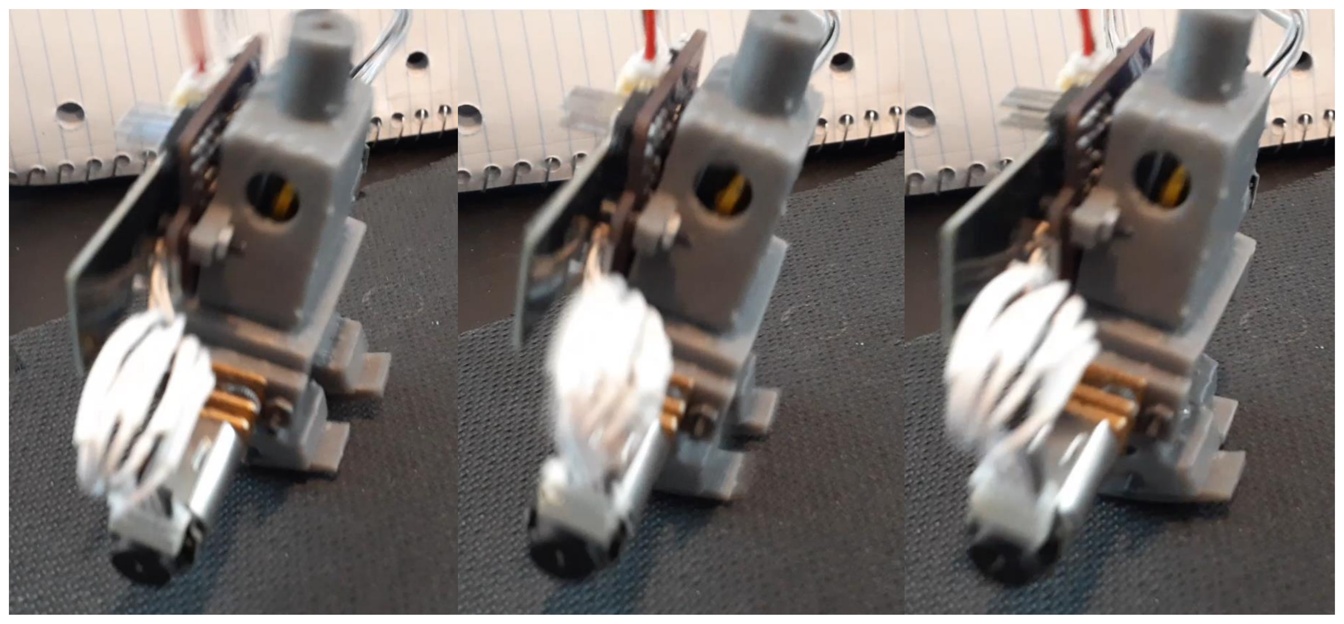
- Minimalistic control strategy[3]
- Sinusoidal trajectories executed with feedforward and PID feedback,

$$u_H(t) = Asin(2\pi f_d t) + PID(position)$$

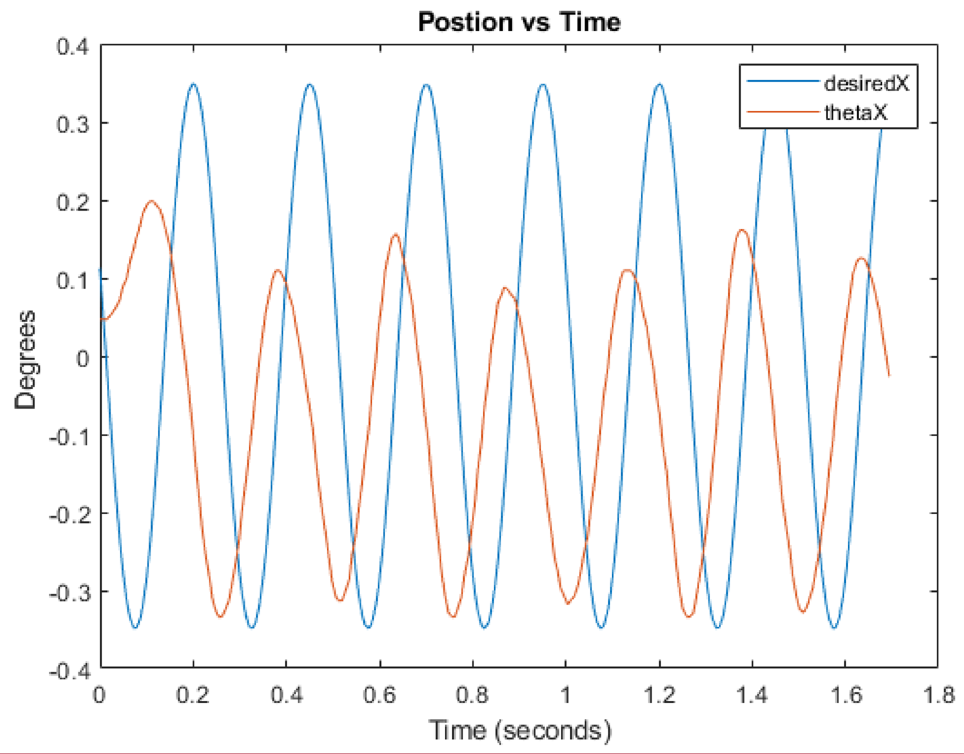


Results

Stumbles back and forth but does rock.



Compensate for disturbance with ground contact



Future Work and References

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.

[1] Wilson, John E. "Walking toy." U.S. Patent No. 2,140,275. 13 Dec. 1938
[2] Collins, Steve, et al. "Efficient bipedal robots based on passive-dynamic walkers." *Science* 307.5712 (2005): 1082-1085.
[3] Iida, Fumiya, and Russ Tedrake. "Minimalistic control of a compass gait robot in rough terrain." *2009 IEEE International Conference on Robotics and Automation*. IEEE, 2009.