Integrating Passive Dynamic Wobbling with Leg Extension to Produce Stable Gaits in a Two-Actuator Bipedal Robot

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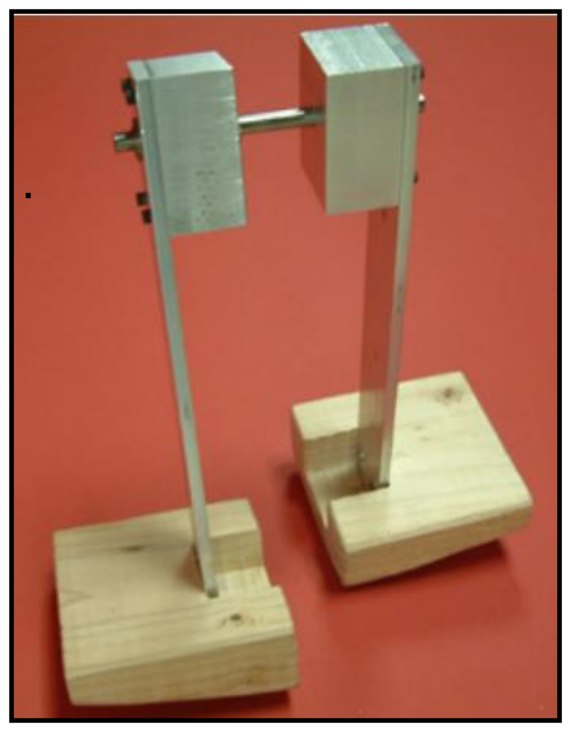
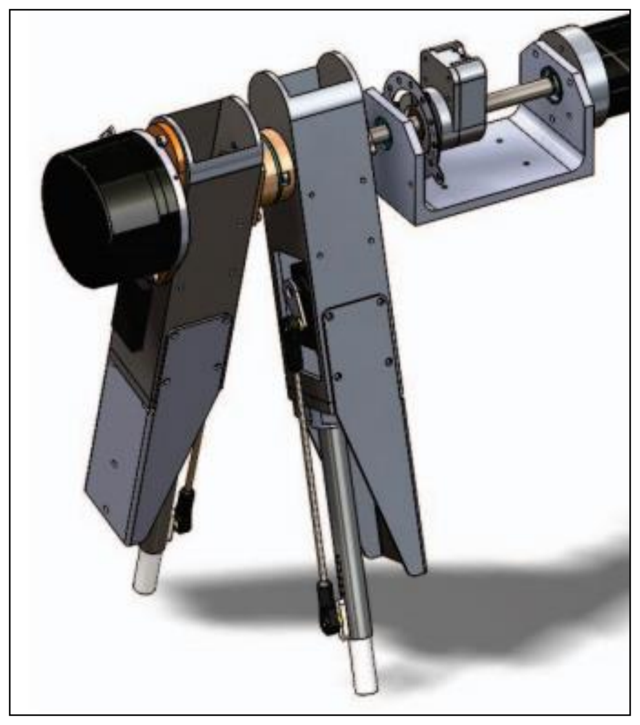
Summary

- The long-term goal of this project is to achieve bipedal walking at the small scales – the size of a Lego minifigure (4cm)
- The robot featured is ~9 times larger than the final scale with 13cm legs at full extension. It incorporates single leg extension per leg and leverages passive dynamic wobbling.
- Open loop controllers with offset sinusoidal trajectories have successfully been able to walk but did not fully integrate the leg extension with the wobble. Closed loop PID controllers were able to adjust the frequency to take advantage of both the leg extension and passive dynamic wobbling.

Motivation



Bipedal Passive dynamic walker



3D Model of 2D bipedal leg extension robot with actuation at the hip and legs

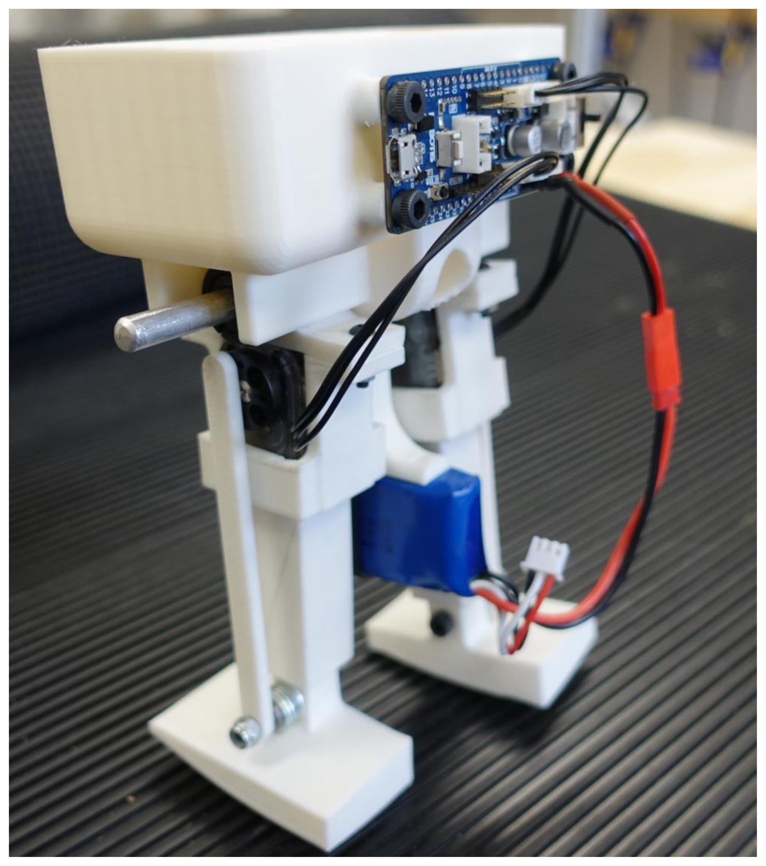
Passive Dynamics: An energy efficient model for bipedal walking that can walk unactuated. Depends on a sloped incline to recover impact losses and gain forward momentum

Leg Extension: A common walking model used for robotics and humans. Leg extension robots are usually attached to a boom arm for a stability and are actuated at the hip and the legs.

Integrated Passive Dynamics and Leg Extension:

- At the final size of 4cm, multiple actuators are not feasible. We must leverage the efficiency of passive dynamics
- Leg extension is intended to excite the passive dynamic wobble.
- Combining these two walking models will allow for an untethered, minimal actuated bipedal walker

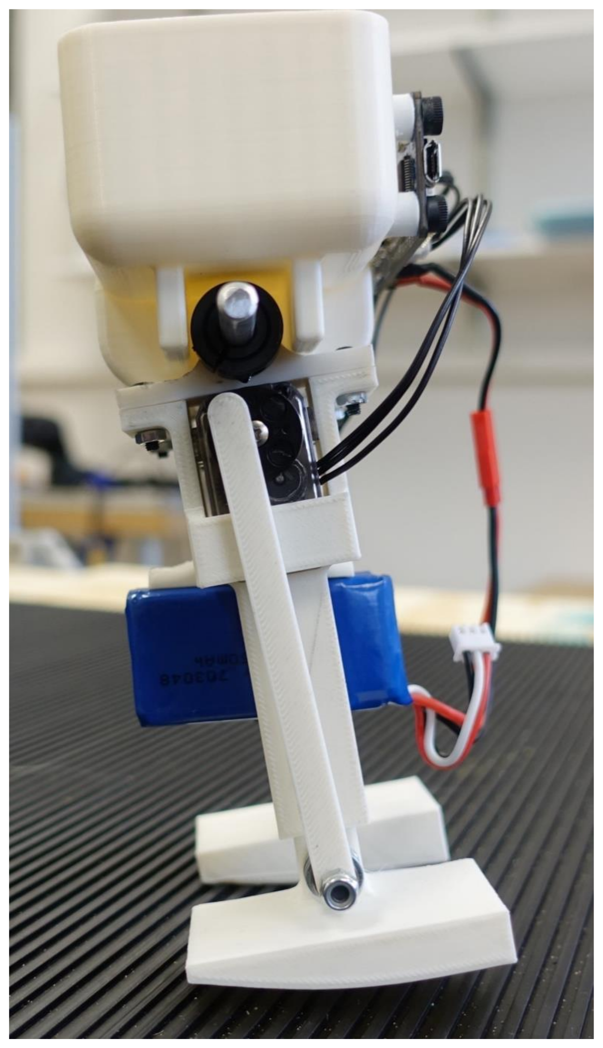
Design



Isometric view of prototype

- The current design is a total of 20cm tall with 17cm legs and a 3cm torso
- The legs are actuated by Dynamixel XL-320 servos
- An inertial sensor is attached inside the torso

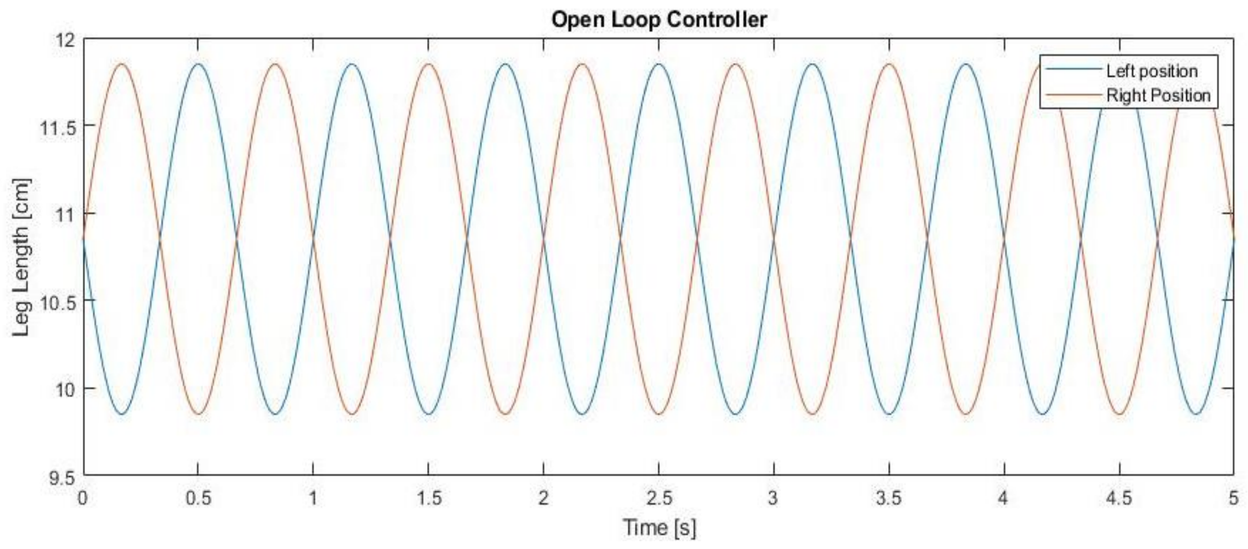
- In both frontal and sagittal planes, the feet are curved such that the center point of their curves is above the point of rotation
- In the sagittal plane, the curve is asymmetric to create an offset in center pressure and mass.



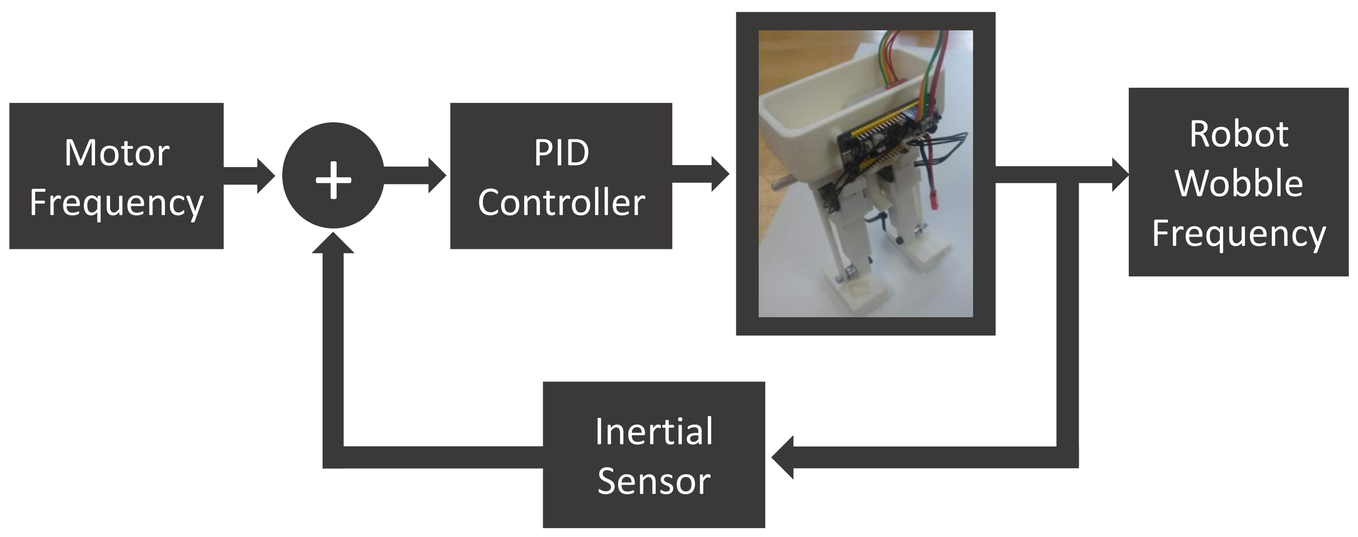
Sagittal Plane view of walker depicting asymmetric curve in feet

Control

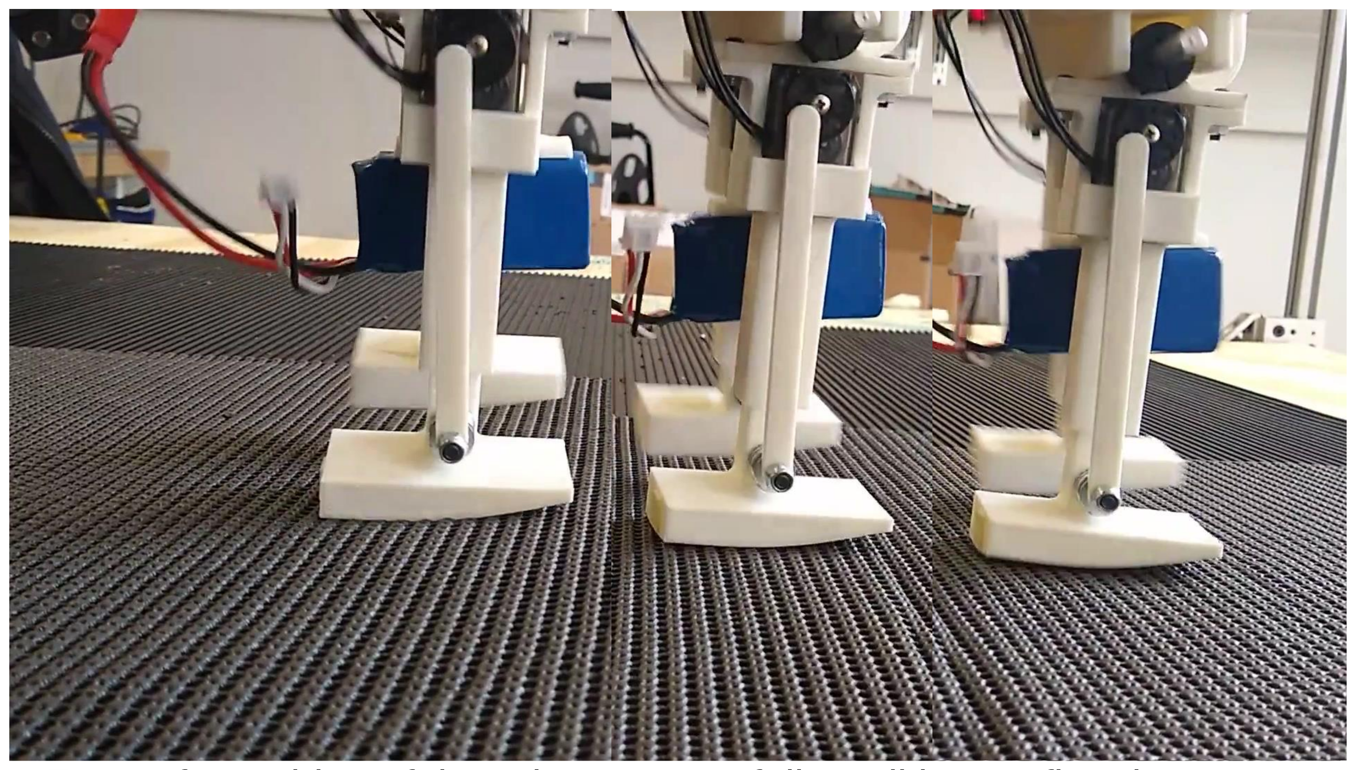
Open Loop Controller: Actuate motors with sinusoidal trajectories with a 180-degree offset



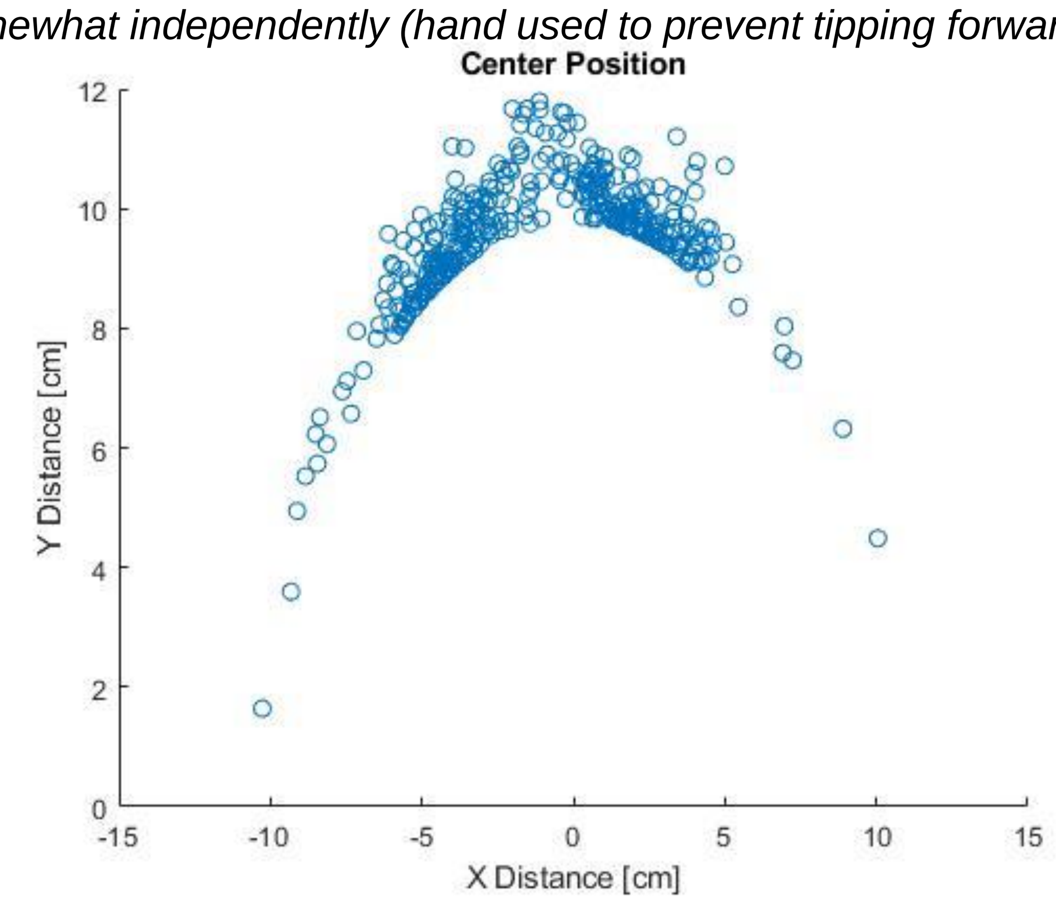
PID Controller: Set desired frequency for wobble and adjust frequency for frequency of sinusoidal motor trajectory with 180-degree offset.



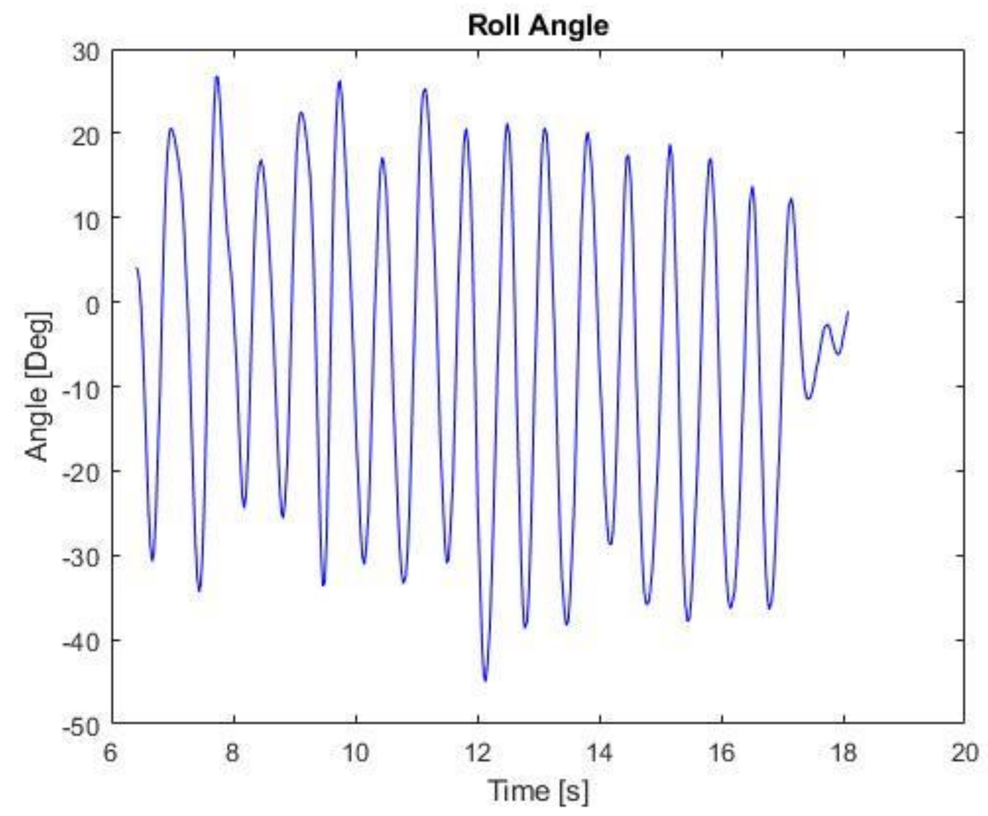
Results



Frame from video of the robot successfully walking on flat plane somewhat independently (hand used to prevent tipping forward)



Tracking the position of the center of the torso over time. Plot showing the trajectory of the wobble based on variable leg length and roll angle.



Roll angle over time. Data captured from robot wobbling in place.

Conclusions:

- We were able to build a bipedal walker with minimal actuation leveraging passive dynamics at relatively small scales. It was able to walk somewhat independently
- The PID controller will yield better integration of the passive dynamics and leg extension

Future Work

- Adjust foot design to increase stability in the sagittal plane
- Adjust PID code to control position based on phase offset between left and right leg
- Scale down prototype closer to final scale