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

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I. Summary

The long term goal of this project is to achieve bipedal walking at the small scales – the size of a Lego mini-figure (4cm). At this small scale, the number and power of the actuators will be extremely limited. This necessitates a walking gait that takes advantage of passive dynamics with only limited excitation from the actuators. In order to design these walking patterns and test the placement and power requirements on the actuators, in this abstract we present the design and control of a prototype that is 12 times larger, with 17cm legs. The robot, shown in Fig. 1, incorporates a single leg extension actuator per leg and leverages passive dynamic wobbling. With the current design, several different sinusoidal control trajectories were tested. The most successful being a 120° and 180° offset between the legs. Although walking is possible with this design and different trajectories, we found that the phasing of the wobble in the frontal plane and the leg extension were not what is predicted from a compas gait model.

II. Design

Leg extension is a common actuation scheme for walking models [1,2] and in bipedal robot designs [3] (though in this case supported by a boom). For this project, with a target robot size of 4cm, our robot will not be supported by a boom arm and cannot fit multiple actuators. Therefore, we will use leg extension in combination with passive dynamics, as described by McGeer in [4], to compensate for the lack of hip actuation and achieve a stable gait without a fixed support. Refining the design and control using the prototype presented in this abstract will give us insight as to the viability of this approach at smaller scales.

The current prototype, pictured in Fig. 1, is a 3D printed assembly with 7 components. For each leg, there is a motor housing, foot, and linkage. Additionally there is a torso about which the legs rotate. On the torso, the OpenCM9 controller and 7.5V Lithium Ion battery are mounted. Finally, there are two tabs on the torso that limit the swing angle to 20° in either direction of the center line. The linkages are attached to the ankle of the foot and driven by Dynamixel XL-320 servos. The feet are designed to be curved according to McGeer's passive dynamics and are sloped downward to offset the center of mass and center of pressure. This offset gives the robot forward momentum once the legs clear the ground.

III. Results and Discussion

With the current design, the robot is successfully able to walk with several different sinusoidal trajectories. With a 120° offset, the gait is stable but the swing leg never goes past the stance leg. This gait was also surprising in that the push off was at the start of stance. Most walking models describe a push off at the end of stance after the swing leg is planted. With a 180° offset, the gait is stable and is more similar to other traditional walking patterns. This trajectory results in a push off at the end of stance after the swing leg touches down. However, this trajectory creates an inconsistent gait where the pitch and yaw from the wobble is sometimes perturbed by the leg extension.

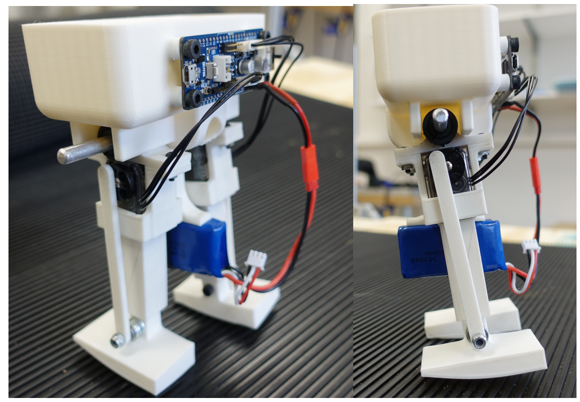

Fig. 1: (Left) Isometric View of the Robot from Back, (Right) Sagittal View of Robot showing Forward Lean

Although both of these trajectories result in a walking robot, they both need tuning in the design and control to successfully integrate leg extension and passive walking dynamics. In future work, a simulation model will be created to experiment with different aspects of the design such as: limit angle of the swing, offset difference between center of mass and center of pressure, and mass distribution. Additionally, different control methods will be tested such as integrating an IMU to control the extension based on the pitch of the robot.

References

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