Controlled symmetries for the compass biped

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Introduction

In general, it is very difficult to analyze the stability of bipedal walking, since bipeds are hybrid, under-actuated systems with impulsive effects and they commonly have a large number of degrees of freedom. Most commonly used stability methods are too conservative to guarantee stable walking overall [2]. Valuable insights into stability and dynamical behavior of bipedal walking can be gained by studying a compass biped, as shown in Figure 1. A compass biped is the simplest planar biped without knees, feet or a torso. It is well-known that this biped can walk naturally and without actuation down a shallow slope [3]. The resulting gait is energy efficient, since gravity is the only source of energy. This makes it an interesting system to analyze, because realization of efficient gaits is the main goal in bipedal walking.

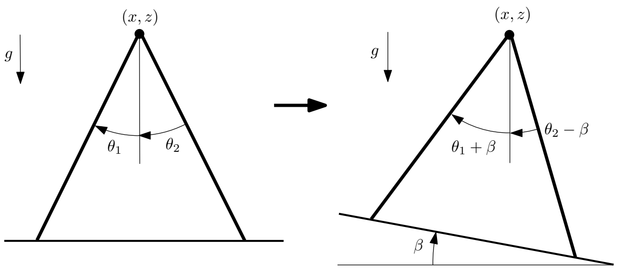

Figure 1: Visualization of controlled symmetries

Simulation and control

Since the compass biped can walk passively and energy efficient down a shallow slope, we try to induce a similar gait for an actuated biped on a horizontal surface. We use the controlled symmetries approach [1] to achieve this. This controller mimics the behavior of the biped as if it would be on a slope with angle β, which is schematically drawn in Figure 1. Basically, the controller adds the same amount of energy to the system as gravity would do on a shallow slope.

To verify the control law in simulations, we derive a model of the compass biped using the framework of systems with unilateral constraints. In this way we can incorporate contacts, friction and impulsive forces in a single model and numerically integrate it using a time-stepping instead of an event-detection algorithm [2].
We perform two simulations, one with a compass biped on a shallow slope with angle 0.015 rad, and the other with the same biped on a horizontal surface. In the second simulation, the controlled symmetries approach is applied with $\beta = 0.015$. The results are shown in Figure 2.

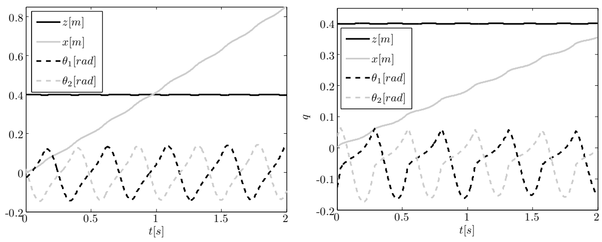

Figure 2: Simulation results: passive (left) and controlled (right)

Future work

We are in the process of building an experimental version of a compass biped, shown in Figure 3. The biped is able to walk passively down a slope and it has a DC motor to walk on a horizontal surface. On this biped we want to validate the control approach. This biped can already walk stably down a shallow slope. The next step is to apply our control law and realize the similar walking gait on a horizontal surface.

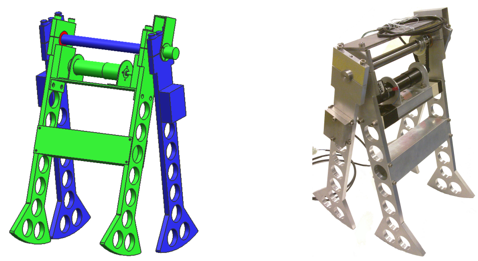

Figure 3: Compass biped CAD and experimental set-up

References

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[3] M. Wisse, A.L. Schwab, R.Q. van der Linde, and F.C.T. van der Helm. How to keep from falling forward: elementary swing leg action for passive dynamic walkers. *IEEE Transactions on Robotics*, 21(3):393 – 401, 2005.