Walking on an uneven terrain with a SLIP model based compliant biped

Saptarshi Jana* and Abhishek Gupta*

Department of Mechanical, Indian Institute of Technology Bombay, Mumbai, India#

Abstract. A spring-loaded inverted pendulum (SLIP) model-based complaint biped is studied to find a method to walk on known irregular terrain. A 2D model with two degrees of freedom (stance leg only) is investigated over the single support phase, followed by an instantaneous double-support phase. Initial leg compression, a new model parameter, is considered in this study. A series of bumps and dips have been considered for preparing an uneven terrain. The impact conditions are modified to determine the following step. This model can walk past obstacles of different magnitudes each step with the various combination of model parameters. The model can walk on surfaces having a height difference of up to 2% of its leg length in each step.

Introduction

Complaint leg biped based on the SLIP model is considered the fundamental template for walking and running. Numerical optimization for planar walking on the flat-ground has found a self-stable periodic gait. In this study, our motivation is to check the ability of a bipedal walking robot to walk over uneven terrain. A device that can walk on an irregular surface becomes even more critical in hazardous areas. Uneven ground is the same as the discrete height change in each walking step. In 2015, Piovan and Byl found it is essential to adjust the net energy of a SLIP model system to walk on uneven terrain. Y. Liu has proposed a method to vary the system energy by changing the rest length of the leg. We prefer to change the initial leg compression (Δl_{td}) in each step according to the height of the bump (or dip). Δl_{td} is defined as the difference in length between the touchdown length (l_{td}) and the equilibrium length. Impact conditions have been derived using the model's configuration, conservation of angular momentum about the impact point, and energy before and after the impact.

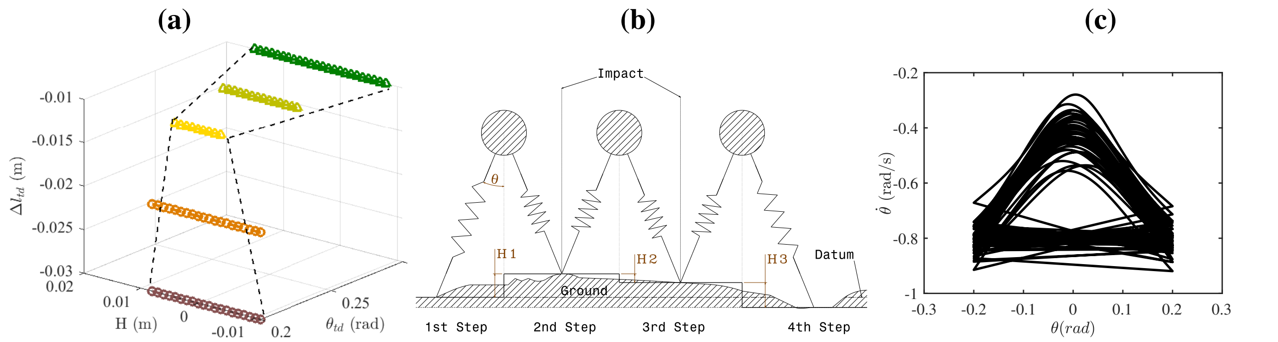

Figure 1: (a) Maximum size of bumps (positive H) and dips (negative H) that the model can overcome for a different combination of initial leg compression (Δl_{td}) and touchdown angle (θ_{td}), Δl_{td} negative indicates more compression from the equilibrium position (b) Kinematic sketch of the model while walking on an irregular surface represented as a series of bumps and dips of heights, H (c) Phase portrait of the configuration variable θ

Result and discussion

For this study, we considered the body mass (m=80 kg), leg stiffness (k=7134 N/m), and rest length of the leg spring (l_0=1.13 m) as constant. Touchdown angle and initial leg compression are varied parameters to obtain the maximum change in surface height (obstacle of the same size present at the impact point) the biped can overcome with that combination (Figure 1 (a)). The model can walk past bigger bumps and dips with greater θ_{td} and Δl_{td}. The impact map determines the initial states of the next step. The impact event gets triggered when the stance leg angle (θ) equals the predefined touchdown angle of the current swing leg (stance leg of next step). The initial leg compression for the next step is adjusted according to the known obstacle height, which eventually decides the l_{td} for the next step. The model can withstand a terrain height variation of 2% of its leg length per step while walking with θ_{td}=0.2 rad and Δl_{td}=-0.03 m. Figure 1 (c) shows the phase portrait of the variable θ while walking on a randomly generated uneven terrain, and the predefined θ_{td}=0.2 rad. Results show the model's ability to walk at least 40 steps on uneven surfaces.

References

[1] Geyer H., Seyfarth A., Blickhan R. (2006) Compliant leg behaviour explains basic dynamics of walking and running. *Proc. R. Soc. B.* **273**:2861-2867.

[2] Piovan G., Byl K. (2015) Reachability-based control for the active SLIP model. *The International Journal of Robotics Research* **34(3)**:270-287.

[3] Liu Y. (2015) A Dual-SLIP Model For Dynamic Walking In A Humanoid Over Uneven Terrain. PhD thesis, The Ohio State University.