Sensitivity of foot intrusion kinematics during walking on granular media

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(Dated: May 20, 2013)

I. MOTIVATION

Many legged organisms and robots must contend with walking across granular media (GM), substrates whose properties depend on compaction and disturbance history. Movement over GM can be particularly challenging because the ground may yield to an intruder, displaying both solid and fluid-like behavior [1]. This yielding behavior can lead to the locomotor performance of an animal or device being highly sensitive to its foot kinematics.

II. STATE OF THE ART

Previous studies of a short-legged, hexapedal robot walking over GM revealed that mobility was sensitive to limb kinematics [2]. However, this robot had short limbs, biologically unrealistic feet (compliant c-shapes), and fixed spatial kinematics.

III. OWN APPROACH

To understand foot kinematics' role on long-legged locomotion, we studied a bipedal robot (39 cm tall, 1.6 kg) walking over a GM of poppy seeds. Each leg was composed of 4 motors connected by segments which mimic avian limb morphology and its feet are flat disks (diameter 9.2 cm). The robot used an alternating striding gait in which toe tips trace rectangular trajectories in the body frame. The robot was constrained by bearings to horizontal and vertical motion, but not rotation. An air fluidized bed created loosely and closely packed GM with volume fraction (ratio of solid to occupied volume) $\phi = 0.58$ and $\phi = 0.62$, respectively.

IV. CURRENT RESULTS

The average velocity of the robot was found to be insensitive to changes in the angle of foot intrusion. However, outside of a range of foot intrusion angles, the robot sunk further and further into the GM with each step. This continued until it reached the bottom of its vertical bearing, invalidating further motion as the robot was no longer supporting its own weight.

V. BEST POSSIBLE OUTCOME

With understanding of dependence on foot intrusion kinematics it is possible to gain further insight not only in improving robotic devices but also in the motion of biologic organisms over complex media. The automated method developed allows for biped walking to be studied beyond foot intrusion and into exploring different gaits and foot properties.

VI. ACKNOLWEDGEMENT

[1] Heil et al. (2004) Phys Rev E

[2] Li et al. (2009) PNAS