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Stable bipedal walking with a swing-leg protraction strategy Short Communication

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2 **Stable bipedal walking with a swing-leg protraction strategy**

3 **Short Communication**

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5 **Abstract**

6 In bipedal locomotion, swing-leg protraction and retraction refer to the forward and backward motion,
7 respectively, of the swing-leg before touchdown. Past studies have shown that swing-leg retraction
8 strategy can lead to stable walking. We show that swing-leg protraction can also lead to stable walking.
9 We use a simple 2D model of passive dynamic walking but with the addition of an actuator between the
10 legs. We use the actuator to do full correction of the disturbance in a single step (a one-step dead-beat
11 control). Specifically, for a given limit cycle we perturb the velocity at mid-stance. Then, we determine
12 the foot placement strategy that allows the walker to return to the limit cycle in a single step. For a
13 given limit cycle, we find that there is swing-leg protraction at shallow slopes and swing-leg retraction
14 at steep slopes. As the limit cycle speed increases, the swing-leg protraction region increases. On close
15 examination, we observe that the choice of swing-leg strategy is based on two opposing effects that
16 determine the *time from mid-stance to touchdown*; the walker speed at mid-stance and the adjustment
17 in the step length for one-step dead-beat control. When the walker speed dominates, the swing-leg
18 retracts but when the step length dominates, the swing-leg protracts. This result suggests that swing-leg
19 strategy for stable walking depends on the model parameters, the terrain, and the stability measure
20 used for control. This novel finding has a clear implication in the development of controllers for robots,
21 exoskeletons, and prosthetics and to understand stability in human gaits.

22 **Keywords:** Swing-leg Retraction, Walking Stability, Poincaré Map, Dead-beat Control, Locomotion

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