Analysis of capturability for biped locomotion subject to limited swing torques

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1 Motivation

Recovering from disturbances is an important ability for biped robots. The robot will never fall, if the swing leg is put fast enough in the direction of push disturbance to insure the geometric biped configuration. In reality, every robot is subject to limited swing torques, which has a significant effect on the performance of push recovery. This study is motivated by the following three questions: 1) How to select the step length/time when the swing torque is limited? 2) When does the robot have to take more than one step? 3) How to select step length/time for multi steps?

2 State of the Art

Capture point is a useful concept for biped robots to determine the appropriate location to step [1]. In recent work, the closed-form analysis of capturability has been carried out based on the assumption that the step length is independent of step time [2]. This assumption allows the robot to realize the maximum step length simultaneously with the minimum step time. However, the step length is not independent of step time in most cases, and the relationship between step length and step time is subject to the swing torque.

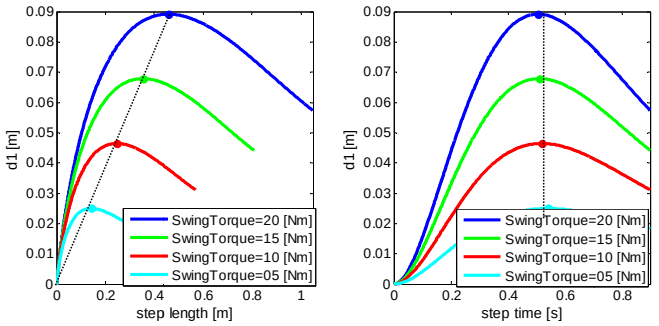
3 Methods and Results

We use a constant torque to swing the leg, and the simulation results indicate that the step length is a power function of step time approximately. For a given initial instantaneous capture point, there exists a minimum swing torque that can ensure the robot one-step capturable. For a given limited swing torque, there exists a maximum value of d_1 that allows the state is one-step capturable (see Fig. 1).

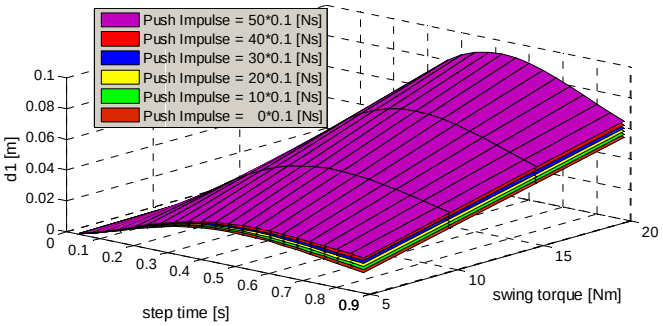
If the initial capture point is larger than this value, the robot has to take two or more steps to stop. The result of two-step capturability is shown in Fig.2, from which one can see that it would be better to choose a relative short step length for the first step.

4 Discussion

Previous model suggests the robot take the maximum step length for multi-step capturability. However, our relative realistic model shows that there exists an optimal sequence of step lengths subject to the limited swing torque. We are currently extending this method to a walking model with a non-instantaneous double support phase.



(a) d_1 versus step length (b) d_1 versus step time



(c) d_1 versus step length and swing torque

Figure 1: One-step capturability. d_1 is defined as the initial position of instantaneous capture point when the state is one-step capturable.

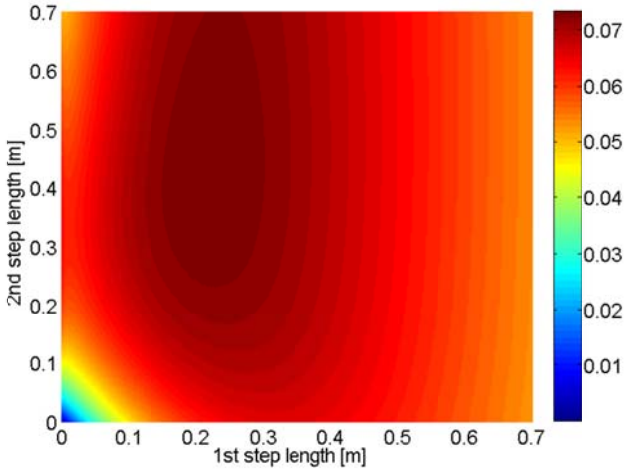


Figure 2: Two-step capturability.The contour is d_2, defined as the initial position of instantaneous capture point when the state is two-step capturable.

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References

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[3] J. Pratt, T. Koolen, T. De Boer, J. Rebula, S. Cotton, J. Carff, M. Johnson, and P. Neuhaus, “Capturability-Based Analysis and Control of Legged Locomotion, Part 2: Application to M2V2, a Lower Body Humanoid,” to appear in *International Journal of Robotics Research*, 2012.