Gait Design Using Self–Manipulation

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***Abstract*—Design insight into steady–state locomotion requires careful analysis of the dynamics within and transitions among the combinatorially many possible contact conditions that a legged robot will experience. To that end the self–manipulation formalism, originally intended to aid in the analysis of dynamical transitions, leans on the well established manipulation literature to systematically populate these continuous and discrete dynamics and apply a consistent structure that has proven to be useful in the analysis of grasping tasks. These ideas are instantiated on RHex with a pronking gait in which all legs are used together. Here a new behavior is presented that is both significantly faster than prior pronking gaits and also inherently stable allowing for open-loop operation. This new, stably robust pronk will enable dynamic transitions such leaping from running in any stride without requiring a decision two strides ahead of the leap.**

Keywords–Legged locomotion; robotics; motion analysis

I. Introduction

This talk applies legged self–manipulation analysis [4] (which leverages the tools of manipulation [7] for the similar, but not identical, problem of locomotion) to the design of a new pronking gait for the hexapedal robot, RHex [8]. Pronking, or stotting, has been hypothesized in animals to have many different functions from predator detection to play [3]. For legged robots it can be an efficient running gait [6] as well as a convenient way to prepare [2] leaping or other behaviors that use all of the limbs in concert [5]. On RHex there have been several studies of pronking both on the robot and in simulation [6, 1], with some success at moderate speeds using a variety of controllers to stabilize the pitch of the robot.

II. Gait Design

Self–manipulation analysis [4] provides three levels of insight into the design of this new pronking gait. First, at the behavioral level, this analysis reveals the importance of a nominally positive pitch and the inertial effects leg recirculation. Second, at the level of controller design, the self–manipulation framework underscores the great affordance given by stubbing the toes. Finally, at the level of platform design, self–manipulation analysis demonstrates that rolling contact of the legs enables a higher forward speed bound, as compared to a point toe. These ideas were previously used to design better leaping behaviors [5], but here they further provide the necessary insight to stabilize steady-state pronking.

III. Results

Using these insights, an open–loop stable pronk is shown in Fig. 1, where the legs of the robot are slightly splayed on average resulting in a net upward pitch. It appears that there is no “level” pitched limit–cycle (stable or unstable) for this system, and requiring a level pitch would overconstrain the task. The robot ran at up to 1.68m/s on outdoors on bricks (about 73% faster than [6]), with 26% duty factor (i.e. the robot is in the air 74% of the time). Indoors on smooth tiles, as shown in Fig. 1, the resulting behavior was a little slower at about 1.25 m/s. In these trials it appears that the rear leg begins to slow down before it reaches the end of stance, suggesting that some slight toe stubbing is aiding the pitch stability in an open–loop manor. These results are preliminary and additional tuning and testing is required to fully characterize the efficiency, stability, and robustness of the behavior.

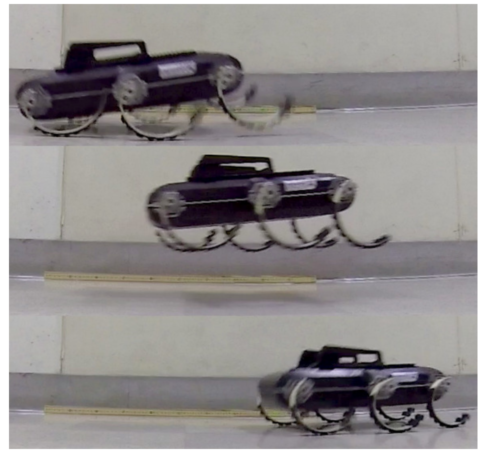

Fig. 1: RHex pronking on smooth tiles. Frames taken .2s apart.

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