STABLE LOCOMOTION OF FEEDFORWARD CONTROLLED ONE-LEGGED ROBOT

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INTRODUCTION

An accepted model for understanding the dynamics of legged locomotion is the simple spring-mass model introduced by Blickhan [1] and further researched by Seyfarth, et. al. [3]. In reality, however, humans and animals use segmented legs for locomtion instead of simple springs. The combination of both in a motor-driven mechanical application should therefore be more biologically inspired. The aim of this study was to investigate, wether an actuated mechanical system allows stable locomotion without sensory feedback.

METHODS

The mechanical application used in this investigation is a one-legged robot with two segments. The robot body is 150 mm in length, 50 mm in width and 155 mm in height. One motor at the hip actuates a connected thigh segment, that is elastically joined with a shank segment. Two elements of rubber serve as dampers when hitting the ground.

According to Raibert [2], a retaining mechanism constrains motion leaving just two degrees of freedom (vertical and horizontal direction). Rotation about the pitch axis is disabled. Therefore, other stabilizing the robot body is not required.

The hip actuator is realized by a position controlled motor. Here, we used a simple sine oscillation as position signal as follows:

$$P(t) = \alpha \cdot \sin(2\pi \cdot f \cdot t) + \alpha_0 \qquad (1)$$

Frequency f and bias angle α_0 are independent parameters and were varied in experiments (f = 1.5…8 Hz and α_0 = -25…+25 deg) . The amplitude α depends on frequency. This control strategy did not need global sensory feedback.

During experiments, the robot moved in a circle on a wooden plate for 30 seconds for every parameter set and were repeated 3 times. For kinematic analysis of robot movement we attached reflective markers. A high-speed (240 Hz) motion capture system measured and tracked 3D-trajectories of the markers. The Trajectories were split into cycles defined by motor oscillation. For every parameter set, 120 movement cycles were randomly selected for analysis.

The stability of resultant locomotion will be described as equal patterns in horizontal direction whereas standard deviation is used as an opposing reference number in this study.

RESULTS AND DISCUSSION

As shown in figure 1, there are two significant regions with a mean speed of 0.3 m/s in positive horizontal direction. For frequencies between 4 and 6 Hz and bias angles with a range of 0 to 20 deg the robot has a local maximum in speed by using mostly one support point. More important is, that this gait describes a local minimum in variability of speed as shown in figure 2. In the range of the second maximum (f = 2…5 Hz, α_0 < 0 deg), the robot uses two point contacts. There, horizontal velocity increases and causes low variance in locomotion for a wide area (Fig. 2)

CONCLUSIONS

In this study we observed that feed-forward controlled one-legged locomotion is possible. In two cases we found stable ranges with a remarkable speed.

REFERENCES

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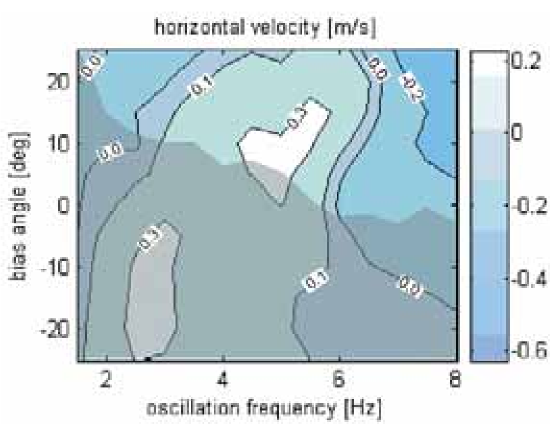

Figure 1: Horizontal speed of robot. Gray layered area shows, where two points touches the ground.

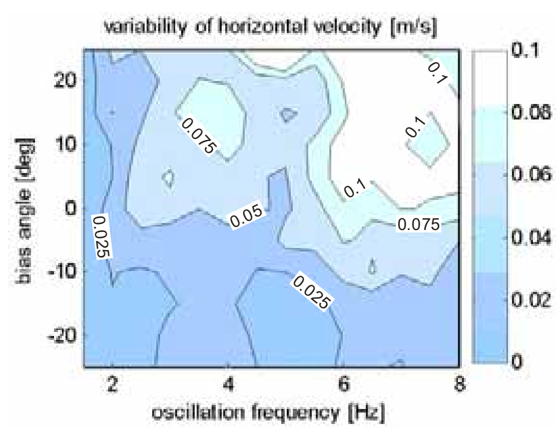

Figure 2: Variation of speed as opposite parameter for stability of motion cycles.