Dynamics Based Integration of Motion Adaptation for a Quadruped Robot 'Tekken'

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1. Introduction

We have been trying to induce a quadruped robot to walk with medium walking speed on irregular terrain based on biological concepts. We propose the necessary conditions for stable dynamic walking on irregular terrain in general, and we design the mechanical system and the neural system by comparing biological concepts with those necessary conditions described in physical terms.

PD-controller at joints can construct the virtual spring-damper system as the visco-elasticity model of a muscle. The neural system model consists of a CPG (central pattern generator) and reflexes. A CPG receives sensory input and changes the period of its own active phase[1]. The desired angle and P-gain of each joint in the virtual spring-damper system is switched based on the phase signal of the CPG. CPGs, the motion of the virtual spring-damper system of each leg and the rolling motion of the body are mutually entrained through the rolling motion feedback to CPGs, and can generate adaptive walking.

In this paper, we define adaptive walking based on biological concepts as "coupled-dynamics-based motion generation", in which a neural system and a mechanical system are coupled and generate motion by interacting with the environment emergently and adaptively according to its own dynamics[2].

2. Experiments

We report our experimental results of dynamic walking on terrains of medium degrees of irregularity in order to verify the effectiveness of the designed neuro-mechanical system(Fig.1). We point out the trade-off problem between the stability and the energy consumption in determining the cyclic period of walking on irregular terrain, and show one example to solve this problem. By detecting the height and the distance to obstacles using vision, the robot can adjust the cyclic period of walking for increasing the stability on terrain of high irregularity while keeping energy consumption low on terrain of low irregularity. In addition, the robot can change the leg length in the swinging phase based on vision in order to prevent the leg from stumbling on obstacles. As a result, Tekken can walk over an obstacle 4 [cm] in height without vision, and an obstacle 5.5 [cm] (28% of the leg length) in height with vision.

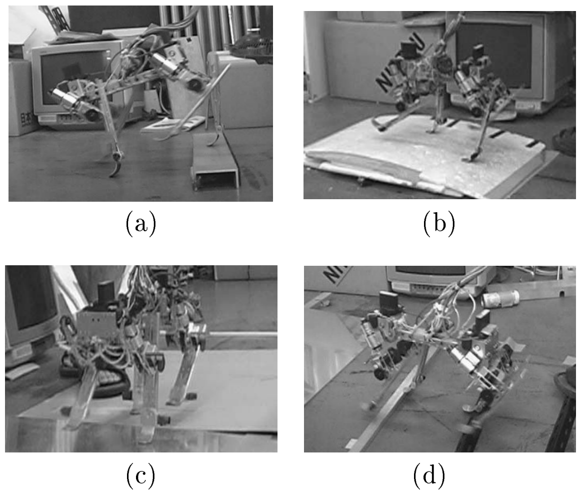

Figure 1: Photos of walking on irregular terrain. (a): walking over a step 4 [cm] in height, (b): walking up and down a slope of 10 [deg] in a forward direction, (c): walking over slopes of 3 and 5 [deg] in a side ways direction, and (d): walking over series of obstacles 2 [cm] in height.

References

[1] Cohen, A. H., and Boothe, D. L. 1999. Sensorimotor interactions during locomotion: principles derived from biological systems. Autonomous Robots 7(3):239–245.

[2] Taga, G., Yamaguchi, Y., and Shimizu, H. 1991. Self-organized control of bipedal locomotion by neural oscillators. Biolog. Cybern. 65:147–159.