Why do quadrupeds exhibit exclusively either trot or pace gaits?

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1 Motivation

Quadrupeds exhibit versatile gait patterns (walk, trot, pace, bound, *etc.*), in response to the locomotion speed and environmental conditions [1]. Furthermore, in the middle speed locomotion, quadrupeds exhibit "exclusively" either trot or pace gaits; horses exhibit a tort gait, whereas camels exhibit a pace gait. These locomotor patterns are generated via the coordination of limb movements, *i.e.*, *interlimb coordination*. However, the interlimb coordination mechanism that generates such locomotor patterns is not yet clear. Thus, it requires further clarification in order to design more adaptable and multifunctional quadruped robots.

2 State of the Art

Well-known experiments using decerebrated cats have provided us with important insights into the locomotion control of quadruped animals [2]. The corresponding results suggest that locomotion is partially controlled by an intraspinal neural network called the *central pattern generator* (CPG), which is capable of self-organizing coordinated movement patterns between legs. These biological findings have prompted many researchers to incorporate artificial CPGs into legged robots to generate highly adaptive locomotion. However, the interlimb coordination has been achieved by focusing particularly on the structure of the CPG network. Hence, the interlimb neural connections thus far have been designed on a completely ad hoc basis to obtain the desired locomotor patterns.

3 Own Approach

To address these issues, we have proposed an unconventional CPG model [3] by focusing on the "physical" interaction between the legs. Our CPG was modeled by using phase oscillators that were completely "decoupled"; instead, their phases were modified according to the ground reaction forces N_i acting on the ith leg:

$$\dot{\phi}_i = \omega - \sigma N_i \cos\phi_i, \tag{1}$$

where ω is the intrinsic angular velocity, and the second term denotes the local sensory feedback. The positive constant σ denotes the magnitude of the feedback to the corresponding oscillator. Our previous robot exhibits good adaptability to changes in weight distribution and walking speed simply by responding to local sensory feedback, even in the absence of a "direct neural connection" between the different limb oscillators [3].

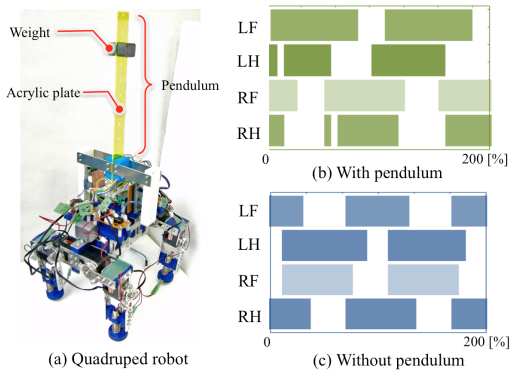

Figure 1: Our robot exclusively exhibits either tort or pace gaits according to their physical properties.

4 Current results

In this study, we aim to clarify the exclusive generation mechanism of trot or pace gaits in middle speed quadruped locomotion. To this end, we developed a simple-structured quadruped robot *OSCILLEX* [3] with a pendulum composed of weights and acrylic plate as shown in Fig. 1 (a). This pendulum generates oscillating motion in the roll axis according to their physical properties. We investigated the effect of the pendulum on gaits obtained. Figure 1 (b) and (c) show the gaits with and without the pendulum, respectively. These results indicate that our robot exclusively exhibits trot or pace gaits in response to their physical properties with the exactly same CPGs.

5 Best Possible Outcome

Our results suggests that oscillating motion in the roll axis enables quadrupeds to exhibit pace gait, and they strongly support that physical properties play a crucial role to exclusively generate either trot or pace gaits. The proposed model may provide a useful starting point to establish a design principle of CPG that can mimic versatile gaits of quadrupeds.

References

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