What is the key to postural stabilization on bipedal walking?

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1 Motivation

Postural stabilization is a fundamental function required for stable bipedal walking. This ability is achieved via "tight" interaction between neural and musculoskeletal systems. The clarification of this mechanism is required in order to design and build more adapable walking robots.

2 State of the Art

Postural stabilization have been investigated in different research areas, *e.g.*, biomechanics and robotics. One of the remarkable concepts is VPP (Virtual Pivot Point) control or DP (Divergent Point) behavior. Maus *et al.* [1] analyzed human walking and running, and proposed the simple VPP control that stabilizes upright posture in SLIP model. Gruben *et al.* [2] analyzed human walking and aimed to decouple the neural and mechanical contribution to a DP behavior. However, further investigations are required to understand how the VPP control (or DP behavior) is achieved through the neural and mechanical systems.

3 Own Approach

In this study, we modeled a biped robot and conducted simulations. Figure 1 (a) shows the skeletal model composed of 7 links (trunk, thighs, shanks, feet) and 6 joints (hips, knees, ankles). The body parameters are set to match the approximate properties of a human.

Coupled phase oscillators are implemented for the generation of rhythmic leg movement:

$$\dot{\phi}_i = \omega + \varepsilon \sin(\phi_j - \phi_i - \pi) + \sigma\{(1-\gamma)N_{hi} + \gamma N_{ti}\}\cos\phi_i. \quad (1)$$

where ω represents the intrinsic angular velocity of the ith oscillator, the second term denotes the interaction between the oscillators, and the third term denotes the local sensory feedback (LSF) [3] from the force sensors on the feet (heel N_{hi} and toe N_{ti}, see Fig. 1 (a)). We designed the LSF such that a leg remains in the stance phase while supporting the body ($(1-\gamma)N_{hi} + \gamma N_{ti} > 0, \gamma > 0$). Actuators at hip joints drive legs according to the oscillator phases.

4 Current results

Here, we analyzed the effect of LSF on the position of effective VPP [1] during steady walking both without and with LSF. Figure 1 (b) and (c) shows the VPP in the local coordinates (origin: hip position and y axis: parallel to the trunk).

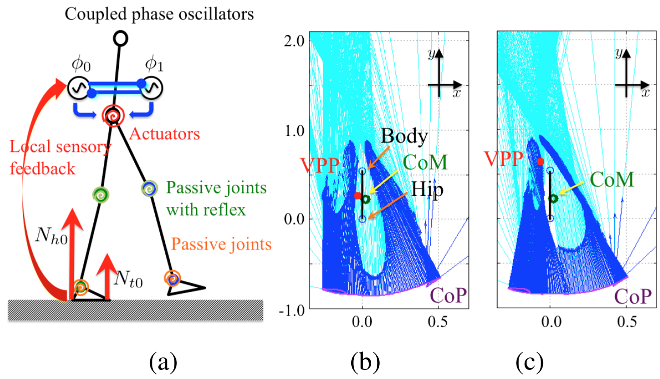

Figure 1: (a) Skeletal model. (b) and (c) VPP in the local coordinates without and with LSF. Blue lines show the GRF vectors from CoP during one period walking.

The result indicates that VPP position with LSF is higher position than without LSF.

5 Outlook

Very interestingly, our LSF "implicitly" affects the position of VPP. It would be important to show how the changed location of the VPP will affect walking stability. In human walking, not only neural system but also physical properties of the body plays an essential role on upright posture stabilization. In future, we would like to investigate the effect of body properties on the VPP position, *e.g.*, ankle elasticities, leading to the clarification of key mechanisms for postural stabilization.

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