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Control strategy for gait transition of an underactuated 3D bipedal robot

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Key words: Gait transition; Underactuated three-dimensional biped; Event-based feedback controller; Adaptive control law

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Motivation

1. Although the full-actuation approach is very effective in physical environments, it is relatively conservative because it requires bipedal robots be balanced at each state.

2. In reality, bipedal robots are often required to perform gait transitions to achieve flexible walking, but the gait characteristics of an underactuated biped cannot be directly controlled or preplanned as they can in fully actuated robots.

3. Compared with underactuated planar bipeds, 3D bipeds have more degrees of underactuation and their stabilization problems make the control of gait transition more challenging.

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Main idea

1. The gait transition problem of a five-link underactuated 3D bipedal robot is studied.

2. A two-layer control strategy is proposed, which consists of an event-based feedback controller and a transition controller.

3. The feedback gain of the present controller in each step is updated by an adaptive control law.

4. The validity and effectiveness of the control strategy are illustrated by numerical simulation.

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Method

1. A two-layer control strategy consists of an event-based feedback controller and a transition controller. The event-based feedback controller is designed to achieve stability of the target gait, and the transition controller is designed to guide the robot from the current gait to a neighboring point of the target gait.

2. To guarantee the physical constraints in the transition process, the transition controller is parameterized and its control parameters are obtained by solving an optimization problem.

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Major results

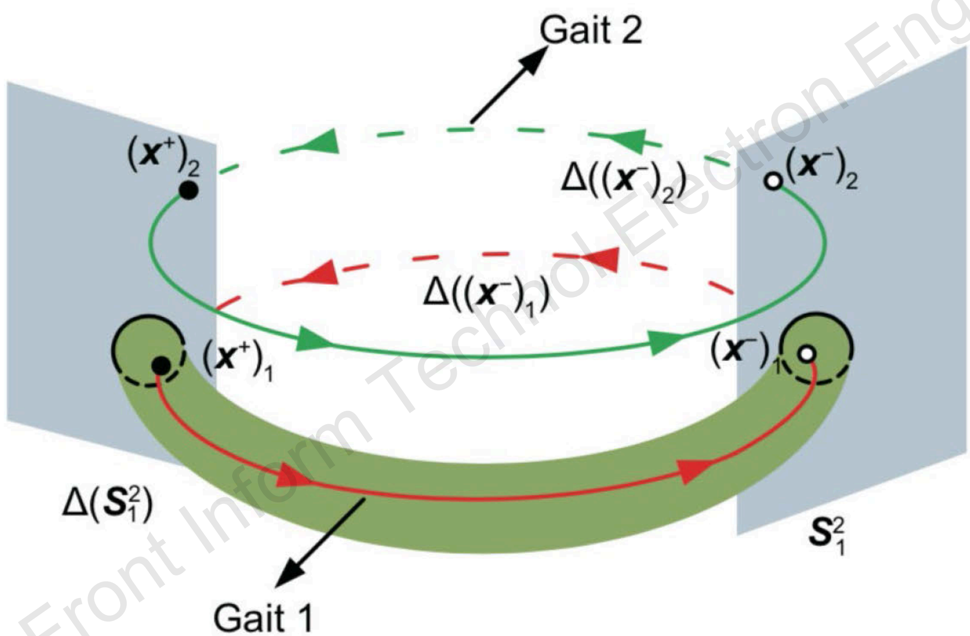

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Fig. 2 Illustration of two periodic gaits for gait transition. References to color refer to the online version of this figure

Major results (Cont'd)

1. To verify the controller, the 3D biped's dynamic model in a closed loop is simulated with an initial state slightly perturbed from the desired final state $(x^{-})_1$.

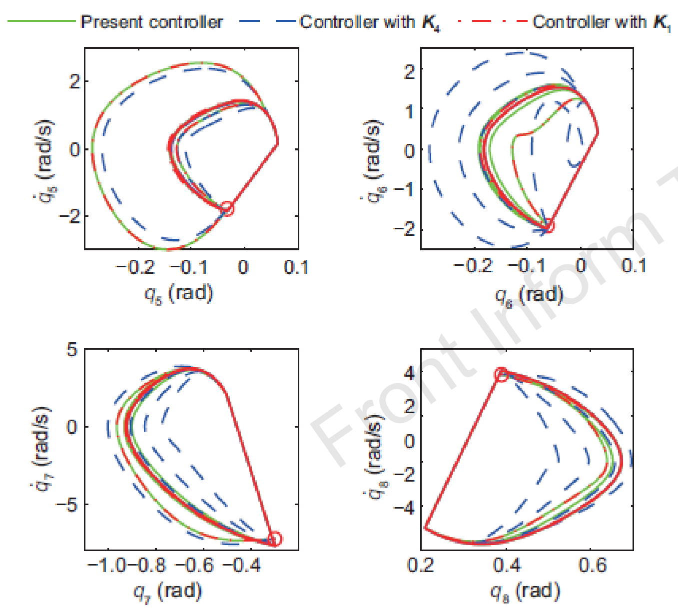

Fig. 3 Phase portraits for q_i ($i = 5, 6, 7, 8$), where the initial condition is represented by a circle. Under the present controller and the controllers with constant gains K_1 and K_4, the robot converges to the desired gait in 5, 12, and 5 steps, respectively

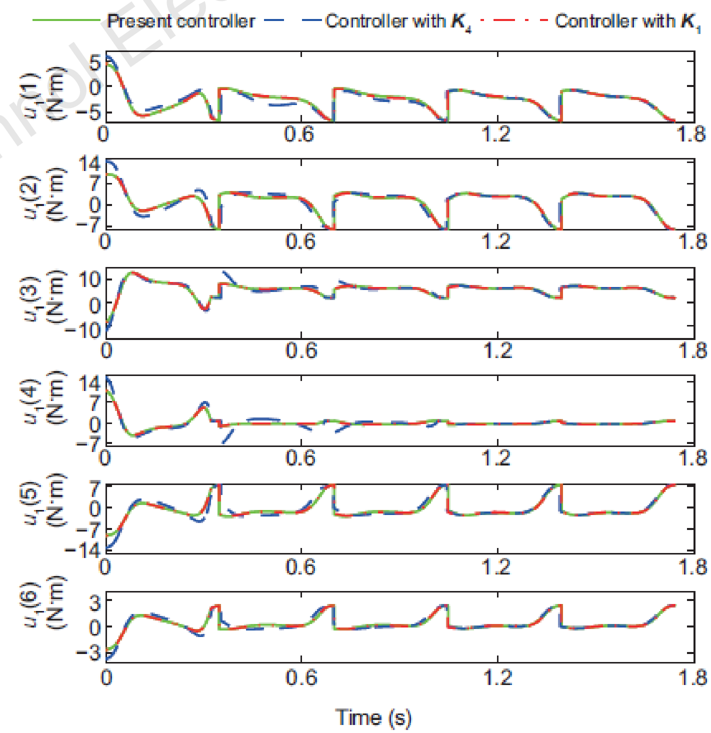

Fig. 4 Torques required for the three controllers in the first five walking steps

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Major results (Cont'd)

2. To achieve a smooth transition, a transition controller is designed by following the method in Section 3.3

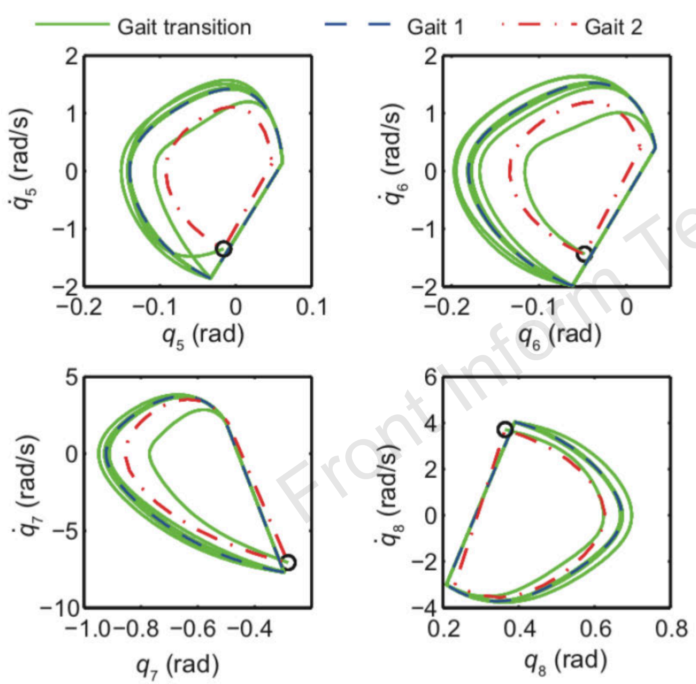

Fig. 5 Phase portraits under gait transition, where the initial condition is represented by a circle, and the walking of the robot transited from gait 2 to gait 1 in six steps

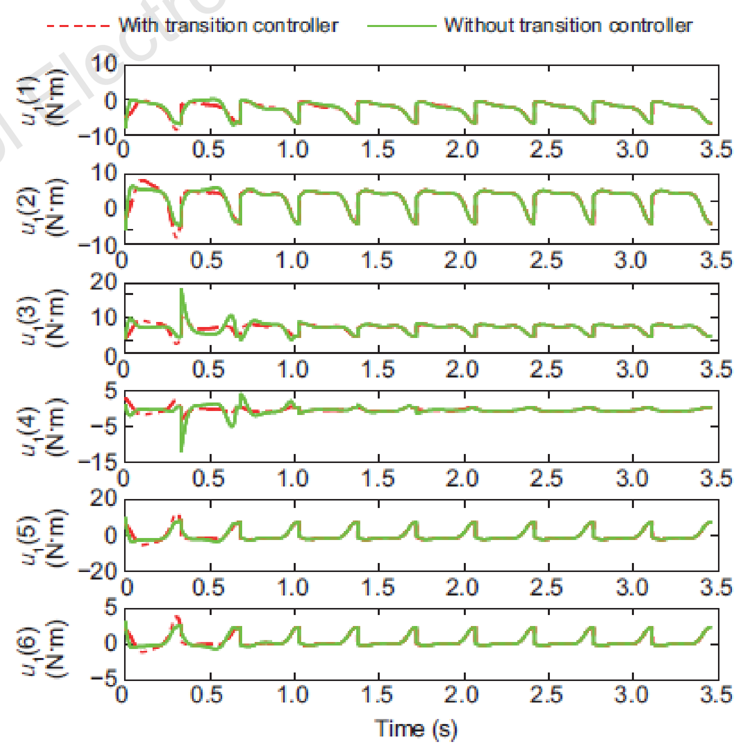

Fig. 6 Torques required for gait transition. The peak values of the torques with and without the transition controller are 12.5 and 22.1 N·m, respectively

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Conclusions

1. A two-layer control strategy that consists of an event-based feedback controller and a transition controller is proposed.
2. Compared with the customary event-based controllers with a constant feedback gain, the present controller exhibits an optimal performance in terms of the balance between the convergence rate and input torques.
3. Under the transition controller, the peak value of the torques can be significantly reduced.

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