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Stability and agility: biped running over varied and unknown terrain

Key words: Underactuated biped running, Dynamic balance , Varied and unknown terrain

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Introduction

- The problem of adapting to complex environments is not well solved for full-actuated biped robot, much less for an unstable point-foot underactuated biped.
- Based on the sustainable running criterion proposed in our previous work , we tackle the problem of stable and agile running over unknown and varied terrain on the underactuated biped.

Non-periodic sustainable running criterion instead of periodic stable running

Lemma: (Running-feasible set) Assume the centroid angular moment is ignored and a running biped is modeled by an inverted pendulum model. The COG state of the biped $[x_c, z_c, \dot{x}_c, \dot{z}_c]^T$ is a running-feasible state if it belongs to the set

$$\Omega(x) = \{x_s \in S_s | x_c < 0, \dot{z}_c < 0, \dot{x}_c^{\min} \leq \dot{x}_c \leq \dot{x}_c^{\max}\},$$

where

$$\dot{x}_c^{\max} = \frac{F^{\max}}{Ml_o} \frac{x_c z_c}{\dot{z}_c} - \frac{x_c g}{\dot{z}_c},$$
$$\dot{x}_c^{\min} = \frac{x_c \dot{z}_c - x_c \sqrt{\dot{z}_c + 4gz_c}}{2z_c}.$$

Non-periodic sustainable running instead of periodic stable running

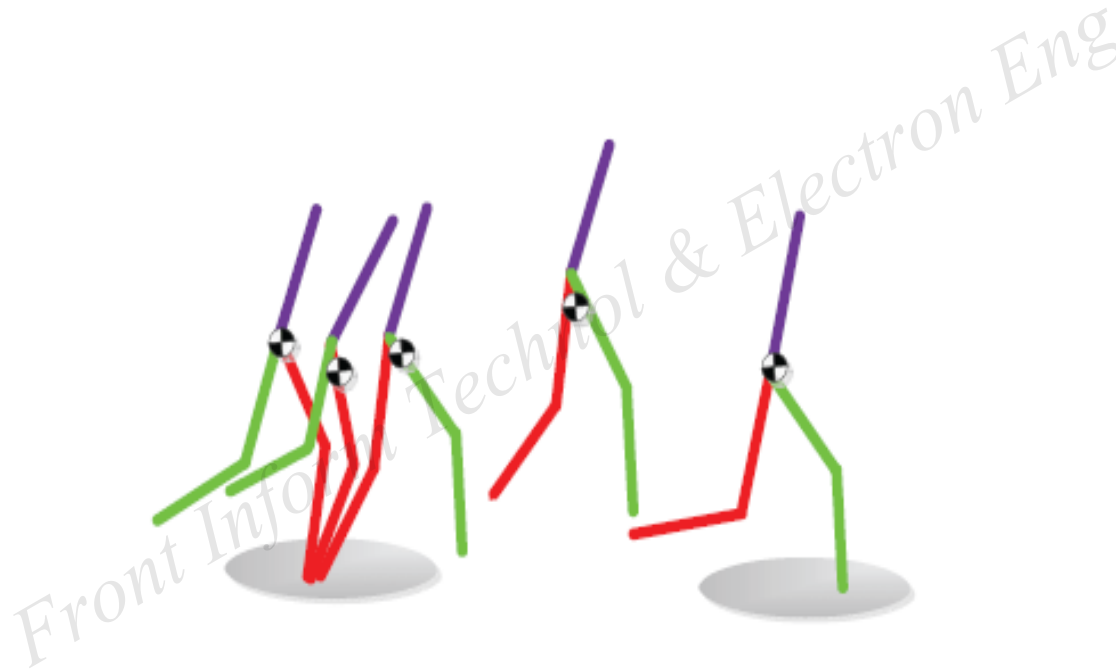


Fig. 3 A running biped with a pre-known safe area

Non-periodic trajectories of the biped joints and the center of gravity

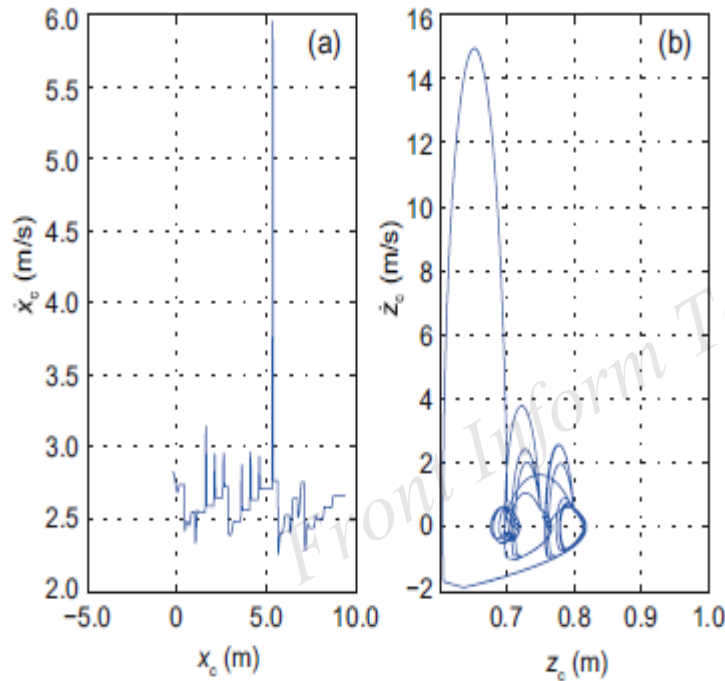


Fig. 7 The dynamics of the COG in the horizontal (a) and vertical (b) directions

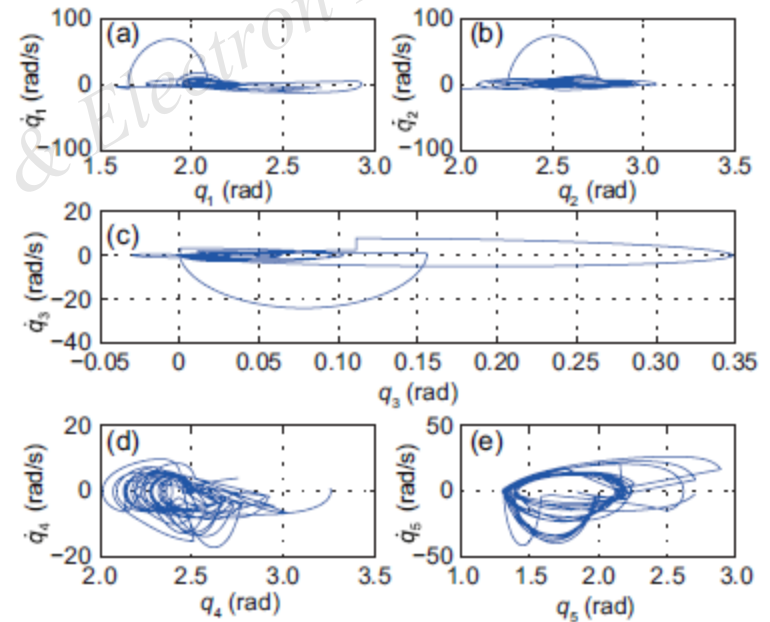
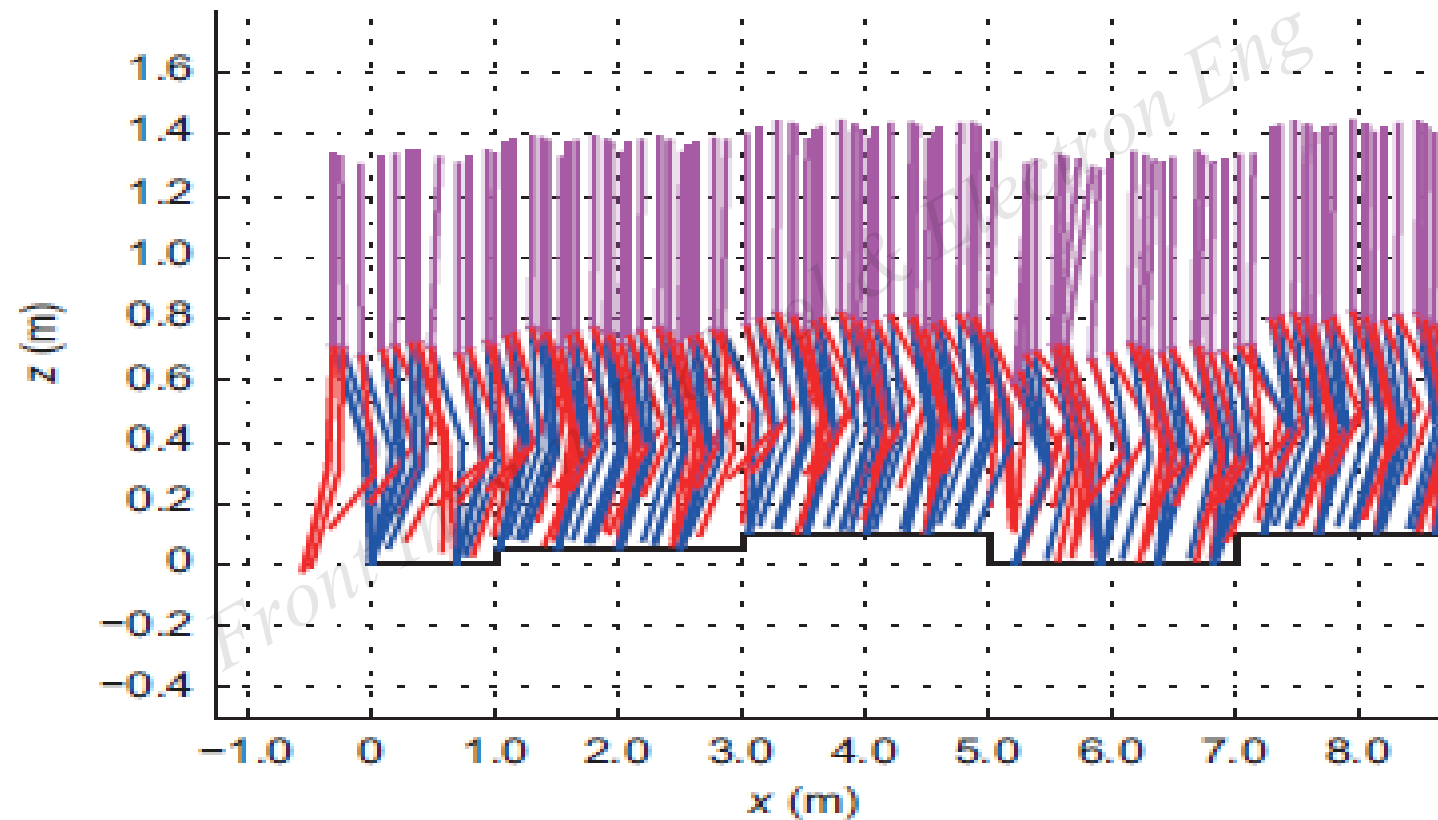


Fig. 8 The non-period trajectories of q_1 with respect to $\dot{q}_1$ (a), q_2 with respect to $\dot{q}_2$ (b), q_3 with respect to $\dot{q}_3$ (c), q_4 with respect to $\dot{q}_4$ (d), and q_5 with respect to $\dot{q}_5$ (e)

Running over unknown and varied terrain



Conclusions

- A control law for incorporating the environmental change into the running velocity is proposed for an underactuated running biped in the presence of terrain variation.
- A strategy of proper foot velocity before touchdown is proposed to make an underactuated biped sustain a non-periodic running motion in the presence of unknown environment.