Gait Synthesis with Reduced Proprioceptive Requirements

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Abstract

Sensory and motor neural signaling is comparatively limited in bandwidth and irregular in timing compared to human-designed electronic channels. Despite this, legged animals routinely out-perform robots in legged-locomotion tasks. One possible contributor to the performance differential is predicted by event-selected systems. Event-selected vector fields, recently formalized by Burden and Revzen [1] to model simultaneous contacts in legged systems, predict a strategy to synthesize a gait as a function of the limb states that is structurally persistent despite irregular or imperfect knowledge in ground contact events, and has looser bandwidth requirements than reference-signal policies that are widely used to drive robots. Empirical analysis of trotting horses by Yuan et. al [2] suggested that event-selected phenomena were contributing to the stability of a horse gait, but left open the possibly that other mechanisms were at work. In order to show that the regime may not just be contributory, but be entirely sufficient to generate a rhythmic stride, an event-selected control scheme was implemented on a Robotic Hexapod (RHex) robot, a six-limbed legged device. A RHex was chosen as RHex robots have been shown to be capable dynamic locomotor when driven [3], [4] with a reference trajectory - the Buehler clock, which generates an alternating sequence of footfalls in a prescribed pattern regardless of the environment. Using the solution curve of an event-selected vector field, an analogous, but interactive, gait created was with low (10-20 Hz) closed loop bandwidth between the actuators and the central authority commanding the limbs. The relaxed tracking requirements, structural stability, and timing characteristics results of event-selected synchronization theory suggest a possible resolution, compatible with musculoskeletal signaling limitations, to how animals are able to achieve remarkable performance on rugged terrain.

References

[1] Samuel A Burden, S Shankar Sastry, Daniel E Koditschek, and Shai Revzen. Event-selected vector field discontinuities yield piecewise-differentiable flows. *SIAM Journal on Applied Dynamical Systems*.

[2] Ming Yuan, Shai Revzen, and A. Liedtk. Trotting horses synchronize their legs during the second half of stance. In *Society for Integrative and Comparative Biology 2016*. SICB, 2016.

[3] Kevin C. Galloway, G. C. Haynes, B. Deniz Ilhan, Aaron M. Johnson, Ryan Knopf, Goran Lynch, Benjamin Plotnick, Mackenzie White, and D. E. Koditschek. X-rhex: A highly mobile hexapedal robot for sensorimotor tasks. Technical report, University of Pennsylvania, 2010.

[4] Uluc Saranli, Martin Buehler, and Daniel E Koditschek. Rhex: A simple and highly mobile hexapod robot. *The International Journal of Robotics Research*, 20(7):616–631, 2001.

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