Attractor Dynamics in Locomotion

Neville Hogan
Massachusetts Institute of Technology

Human agility far exceeds that of modern robots despite vastly slower 'hardware' (e.g. muscle) and 'wetware' (e.g. neurons). This is likely due to control based on dynamic primitives, defined as attractors that emerge from nonlinear neuro-mechanical dynamics. Importantly, these attractors enable highly dynamic behavior with minimal high-level supervision and intervention. Long-range correlations in time-series of stride durations in human level walking have been attributed to a chaotic attractor. I will review studies of entrainment to periodic mechanical perturbation suggesting that a semi-autonomous limit-cycle attractor (incapable of chaos) is sufficient. Simple models reproduce this entrainment as well as the long correlations, indicating that the limit cycle is weakly stable in unimpaired gait. A different kind of attractor, mechanical impedance, mediates physical interaction. Ankle mechanical impedance is especially important during locomotion. I will present recent measurements of ankle mechanical impedance and its time variation during level walking.

This talk will draw from the following articles, in addition to other ongoing work:

Long-Range Correlations in Stride Intervals May Emerge from Non-Chaotic Walking Dynamics. Jooeun Ahn , Neville Hogan. PLoS ONE 8(9): e73239. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0073239

Ahn J, Hogan N (2012) A Simple State-Determined Model Reproduces Entrainment and Phase-Locking of Human Walking. PLoS ONE 7(11): e47963. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0047963

Walking Is Not Like Reaching: Evidence from Periodic Mechanical Perturbations. PLoS ONE 7(3): e31767. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0031767

Multivariable Dynamic Ankle Mechanical Impedance With Active Muscles. Hyunglae Lee and Neville Hogan. IEEE transactions on neural systems and rehabilitation engineering, 22, 2014. http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6825865

Time-Varying Ankle Mechanical Impedance during Human Locomotion. Hyunglae Lee and Neville Hogan. IEEE transactions on neural systems and rehabilitation engineering, http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6879304