# Principles of bipedal locomotion: Sensorimotor and mechanical integration for stability and agility

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Animals must seamlessly integrate mechanics and sensorimotor control to achieve agile and stable locomotion in complex environments. My research team use comparative neuromechanics as a tool to investigate the mechanisms of sensorimotor and mechanical integration in animals, with a focus on revealing fundamental principles that can be applied to bio-inspired robotics. In this talk, I will discuss several examples from our recent studies of bird (avian) locomotor behaviour that highlight the challenges and elegant solutions for adaptive motion in animals: 1) locomotion in uneven terrain [1], 2) rapid kicking strikes of the secretary bird [2], and 3) perching balance control (Fig. 1).

One key challenge for all animal locomotion is sensorimotor delays that inherently limit feedback response times. Humans and birds are bipedal animals that share fundamental movement strategies (Fig. 2), yet have developed different solutions to the fundamental problem of sensorimotor delay. Human sensorimotor control appears to rely heavily on cephalized (brain-dominated) control, involving extensive learning and heavy reliance on predictive planning; however, these processes suffer from long control delays. In contrast, birds have specialised more heavily on spinalized (spinal-cord dominated) control, relying heavily on spinal rhythm generation coupled to robustly stable intrinsic leg mechanics. This is highlighted most obviously by the anecdotal evidence that a headless chicken can walk and balance. More rigorously, there are established fundamental differences in spinal neural networks and leg morphology that enable more local spinalized control in birds compared to humans [3,4]. The control system of birds enables rapid, agile and robustly stable locomotion with minimal control, but may provide limited adaptability for different environments and behavioural contexts. Nonetheless, the locomotor prowess of birds cannot be denied; birds are diverse and athletic animals that inhabit every ecosystem on the earth. Thus, study of the sensorimotor control strategies of birds provides fundamental insights for the development of agile and autonomous robots capable of moving in complex unstructured environments.


**Figure 1:** Bird biomechanics and sensorimotor control studies.

**Figure 2:** Human and ostrich running.

**References**

[1] A. Birn-Jeffery, C. Hubicki, Y. Blum, D. Renjewski, J. Hurst and M. Daley (2014) 'Don't break a leg: Running birds from quail to ostrich prioritise leg safety and economy in uneven terrain.' *Journal of Experimental Biology*, 217, 3786-3796.

[2] S. Portugal, C. Murn, E. Sparkes, and M. Daley (2016) 'The fast and forceful kicking strike of the secretary bird.' *Current Biology*, Volume 26, Issue 2, R58-R59.

[3] Y. Blum, A. Birn-Jeffery, M. Daley and A. Seyfarth (2011) 'Does A Crouched Leg Posture Enhance Running Stability and Robustness?' *Journal of Theoretical Biology*, 281, 97-106.

[4] R. Necker (2006) 'Specializations in the lumbosacral vertebral canal and spinal cord of birds: evidence of a function as a sense organ which is involved in the control of walking.' *Journal of Comparative Physiology A*, 192(5), pp.439-448.