Decoding the locomotion control circuits in the spinal cord using robots and mathematical models

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Animal locomotion is amazing in its agility and diversity. Animals have conquered different ecological niches, with a large diversity of different morphologies and modes of locomotion. Despite this diversity, animals use similar building blocks: neurons, muscles, and structural parts, and similar physical principles: periodic generation of forces, and asymmetric interaction forces to move in particular directions. There is also similarity in the motor control circuitry: most animals control their movements thanks to a combination of neural oscillatory circuits (central pattern generators, CPGs), reflexes, and descending modulation from higher control centers. But because of the complex nonlinear interactions between different components, the control principles underlying locomotion are not yet completely understood, nor are how they have evolved to adapt to different ecological niches and different modes of locomotion.

In this talk, I will present how robots and mathematical models of the spinal cord (as well as neuromechanical simulations) can be used to investigate the principles of locomotion control in vertebrate animals [1]. Simple models made of networks of coupled oscillators and sensory feedback loops will be presented for different types of locomotion from swimming in the lamprey, to sprawling locomotion in the salamander, up to walking in humans [2,3]. I will also present how the models are tested in swimming, legged, and humanoid robots (Fig. 1), and compared to biological data. The models and robots are instrumental in testing hypotheses concerning the mechanisms of gait transition, sensory feedback integration, and generation of rich motor skills in vertebrate animals. In particular, the models allow one to investigate the respective roles of central pattern generators versus sensory feedback in rhythm generation and coordination [4], and how these respective roles have changed during evolution from fish to mammals.

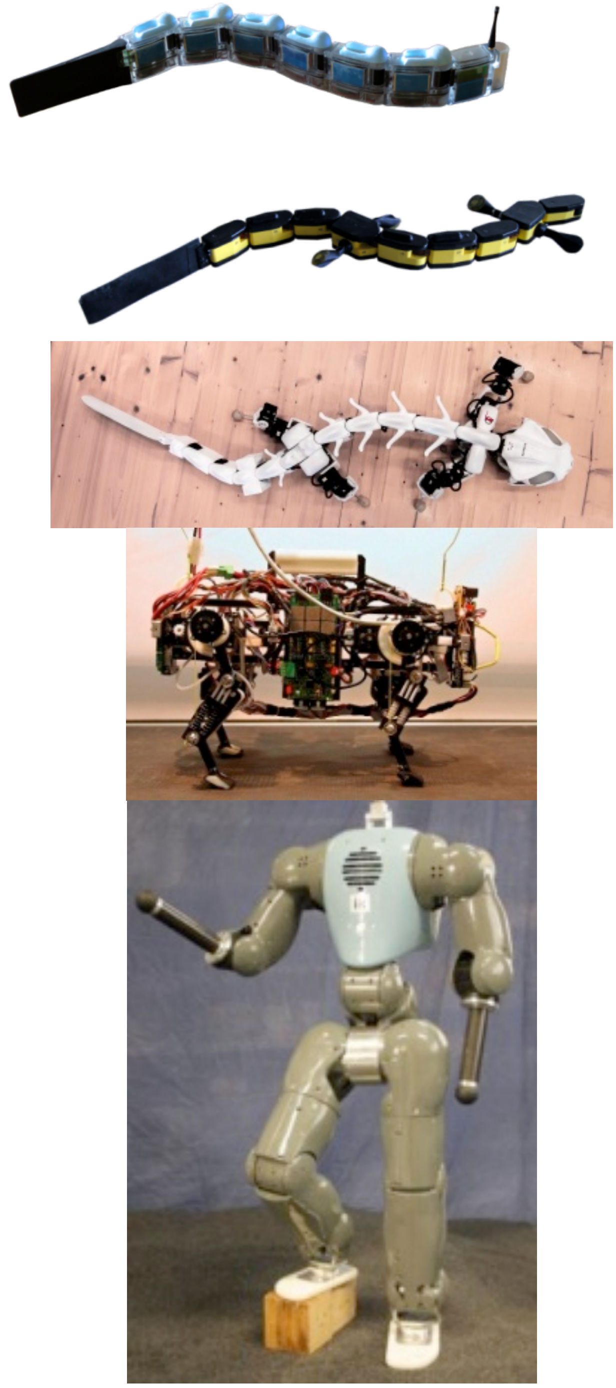

Figure 1: Different robots used to investigate vertebrate locomotion in the Biorobotics Laboratory at EPFL.

References

[1] Ijspeert, A., Biorobotics: Using robots to emulate and investigate agile animal locomotion. Science, vol. 346, num. 6206, p. 196-203, 2014.

[2] Dzeladini, F., Van Den Kieboom, J., and Ijspeert, A.. The contribution of a central pattern generator in a reflex-based neuromuscular model, Frontiers in Human Neuroscience, vol. 8, 2014.

[3] Ijspeert A.J., Crespi A., Ryczko D., and Cabelguen J.M.. From swimming to walking with a salamander robot driven by a spinal cord model. Science, 315(5817):1416-1420, 2007.

[4] Minassian, Karen, et al. "The Human Central Pattern Generator for Locomotion: Does It Exist and Contribute to Walking?." The Neuroscientist (2017): 1073858417699790.