Blueprints in Legged Animals and their Importance for Legged Machines

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1 Abstract

The dynamic performance and versatility of legged locomoting animals is neither reached nor sufficiently understood, and presents a fascinating goal also in robotics. Research from Biology, Paleontology, and Biomechanics indicates the existence of design blueprints common throughout many legged animals. Such blueprints are found e.g. in the mechanical design of mammalian legs as leg segmentation ratios, pantographic leg structures, multiarticulate muscles-tendons, and muscle-tendon structures with pronounced physical compliance. A blueprint example from animal neuromuscular control are robust pattern generators responsible for locomotion rhythm generation. Blueprints might present a strategy ("recipe") to counter performance-limiting effects caused by intrinsic properties of body structure, actuators, sensing and acting in running animals.

We base our discussion on findings and insights from implementing biomechanical and control blueprints into dynamic, legged robots. I.e. Cheetah-cub robot is the first quadruped robot between 0.5kg and 30kg to reach a dynamic speed of Froude 1.3, while trotting in 3D, and in a feed-forward control mode. We apply bioinspired robot- and controller designs to produce rich and biomechanically relevant locomotion data. Recordings from running robotic experiments help us analyzing and comparing robotic and biological legged systems, and allow us to hypothesize further about animal locomotion.

We will discuss these and other examples also from Biology and Biomechanics indicating the existence of dynamic legged locomotion modes which can heavily rely on feed-forward control patters, in combination with potentially bioinspired leg and robot designs.

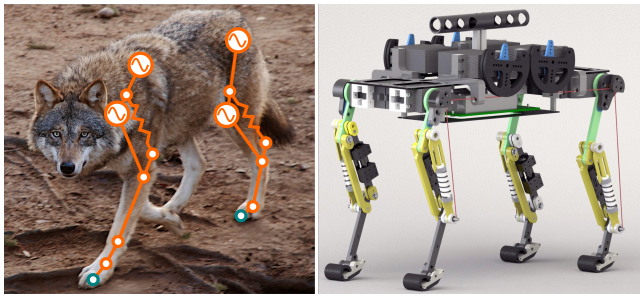

Figure 1: Pantographic leg segment structure, and the Cheetah-cub quadruped robot platform for legged robot locomotion testing.

References

[1] Dynamic Locomotion Group, Website: http://is.mpg.de/dlg

[2] Dynamic Locomotion Group Youtube Channel: https://www.youtube.com/channel/UCuL-PnIqf4ZsAO1qV99ohwA

[3] A. Spröwitz, A. Tuleu, M. Vespignani, M. Ajallooeian, E. Badri, and A. Ijspeert. "Towards Dynamic Trot Gait Locomotion: Design, Control and Experiments with Cheetah-Cub, a Compliant Quadruped Robot." *International Journal of Robotics Research 32*, no. 8 (2013): 932 950. doi:10.1177/0278364913489205.

[4] M. Khoramshahi, A. Spröwitz, A. Tuleu, M. N. Ahmadabadi, and A. Ijspeert. "Benefits of an Active Spine Supported Bounding Locomotion With a Small Compliant Quadruped Robot." *In Proceedings of 2013 IEEE International Conference on Robotics and Automation*, 3329–3334. Karlsruhe, Germany, 2013. doi:10.1109/ICRA.2013.6631041.

[5] M. A. Daley, "Biomechanics: Running Over Uneven Terrain Is a No-Brainer." *Current Biology 18*, no. 22 (November 2008): R106466. doi:10.1016/j.cub.2008.09.050.

[6] A. J. Ijspeert, A. Crespi, D. Ryczko, and J.-M. Cabelguen. "From Swimming to Walking with a Salamander Robot Driven by a Spinal Cord Model." *Science 315*, no. 5817 (March 9, 2007): 141620. doi:10.1126/science.1138353.

[7] H. Witte, R. Hackert, K.E. Lilje, N. Schilling, D. Voges, G. Klauer, W. Ilg, et al. "Transfer of Biological Principles into the Construction of Quadruped Walking Machines." *In Robot Motion and Control*, 2001 Proceedings of the Second International Workshop on, 24549, 2001. doi:10.1109/ROMOCO.2001.973462.

[8] X. Liu,Y. Duan, A. Rosendo, S. Ikemoto, and K. Hosoda. "Higher Jumping of a Biped Musculoskeletal Robot with Foot Windlass Mechanism." *In Intelligent Autonomous Systems 14*, 34356. Springer, Cham, 2016.

[9] D. Owaki, T. Kano, K. Nagasawa, A. Tero, and A. Ishiguro. "Simple Robot Suggests Physical Interlimb Communication Is Essential for Quadruped Walking." *Journal of The Royal Society Interface 10*, no. 78 (January 6, 2013). doi:10.1098/rsif.2012.0669.

[10] R. Tedrake, T. W. Zhang, M. Fong, and H. S. Seung. "Actuating a Simple 3D Passive Dynamic Walker." *In Robotics and Automation*, 2004. Proceedings. ICRA04. 2004 IEEE International Conference on, 5:46564661. IEEE, 2004. http://ieeexplore.ieee.org/abstract/document/1302452/.