Using a Neuromuscular Model of Human Locomotion to Control Bipedal Robots

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1 Motivation

Current walking controllers for bipedal robots do not possess the robustness and the versatility of human locomotion control. Explicitly imitating the human motor control may transfer its advantages to bipedal robots.

2 Our Approach

In a previous study, we have proposed a neuromuscular model of human locomotion that can generate robust and diverse locomotion behaviors in physics simulation [1]. The neural control circuitry of the model consists of a spinal reflex network and a supraspinal system. The spinal reflex network involves feedback modules that produce essential leg functions for stable locomotion; the supraspinal system modulates the reflex pathways for different locomotion behaviors and to react to external disturbances. With different sets of control parameters found through optimization, the human model can walk on terrains with unexpected ground-height changes of $\pm$10 cm, and generate various behaviors, including turning, accelerating and decelerating, negotiating stairs and slopes, deliberately avoiding obstacles, and running.

Here, we investigate the potential of this human neuromuscular model for controlling bipedal robots. To this end, we propose a virtual neuromuscular controller (VNMC) that synchronizes the human model with a bipedal robot and emulates the model to generate desired joint torques for the robot.

So far, we have tested a VNMC on a high-fidelity simulation of the ATRIAS bipedal robot for sagittal plane walking [2]. The control parameters of the VNMC on ATRIAS can be optimized to walk on a terrain with $\pm$7 cm height changes. The optimized controller can adapt to terrains with different ground-height profiles (90% success rate on 30-meter-long terrains with ground-height changes of $\pm$2 cm), and endures external pushes on the trunk (95% of $\pm$30 Ns horizontal impulses) and the swing feet (90% of 6 Ns horizontal impulses) throughout the gait cycle. Furthermore, the optimized VNMC is resilient to modeling errors and sensor noise much larger than the equivalent uncertainties in the real robot.

3 Future Outlook

The simulation results suggest that explicitly emulating a human control model may be a viable strategy for generating robust and diverse locomotion behaviors in bipedal robots. Our immediate goal is to evaluate the proposed VNMC in an experimental setup of ATRIAS constrained to the sagittal plane. Eventually, we plan to extend VNMC to generate robust and diverse 3-D locomotion behaviors in bipedal robots.

In addition to a successful robot controller, the study may provide better understanding of the functional contributions of biomechanical features in human locomotion. For example, since ATRIAS has very light legs, analyzing its behaviors generated by a VNMC can provide insights on the effect of the leg inertia in legged locomotion.

References

[1] S. Song and H. Geyer, "A neural circuitry that emphasizes spinal feedback generates diverse behaviors of human locomotion," *The Journal of Physiology*, in final revision.

[2] Z. Batts, S. Song, and H. Geyer, "Toward a virtual neuromuscular control for robust walking in bipedal robots," in *IEEE/RSJ International Conference on Intelligent Robots and Systems.*, 2015, submitted.

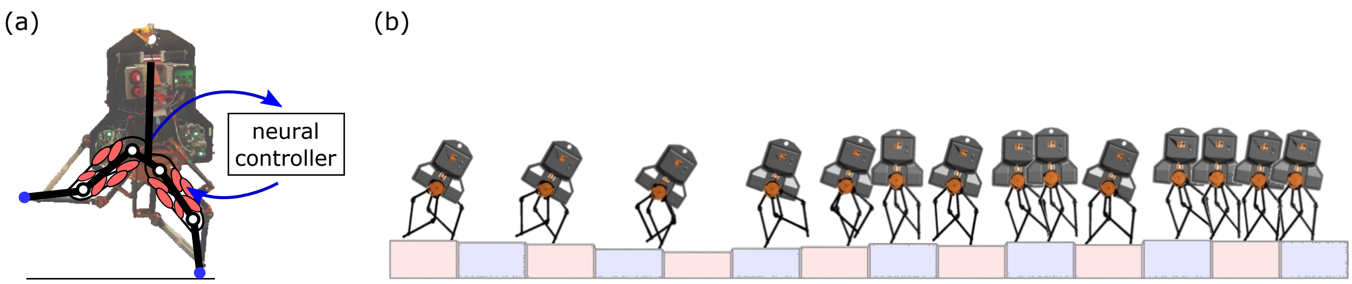

Figure: (a) Virtual neuromuscular control for ATRIAS. (b) ATRIAS walking on a rough terrain in physics simulation (2-D).