Using a Neuromuscular Model of Human Locomotion to Control Bipedal Robots

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

Our Approach
We seek to control bipedal robots with a specific neuromuscular human walking model proposed previously. Here, we present a virtual neuromuscular controller, VNMC, that emulates this neuromuscular model to generate desired motor torques for a bipedal robot.

Current Results and Future Plan
We have shown in simulation that VNMC can generate robust walking for ATRIAS in the sagittal plane. We plan to extend VNMC for robust 3D walking and validate it on hardware.

Neuromuscular Control Model[1]
Our neuromuscular control model generates robust and diverse human locomotion behaviors.

Virtual Neuromuscular Control (VNMC)[2]
VNMC maps the NM control to the bipedal robot ATRIAS.

3. An emulated neuromuscular model is mapped to a robot topology to generate desired motor torques. We use a high-fidelity simulation of the ATRIAS platform constrained in the sagittal plane. The simulation model includes the SEA dynamics, joint frictions, and stick-slip ground contact modes.

Reflex Control Modules
The neural controller consists of 10 reflex modules.

2. The control modules compose the spinal control. These modules are modulated by the supraspinal (brain) control through the high-level commands. The current high-level commands are target swing leg placement, swing foot-ground clearance, and trunk lean.

Simulation Results
We optimize the control parameters in simulation.

4. With the original neuromuscular model, VNMC adapts to 90% of random terrains with height-changes of ±2 cm, and endures 95% of ±30 Ns horizontal pushes on the trunk, and 90% of 8 Ns backward and 4 Ns forward impulses on the swing foot throughout the gait cycle. We expect more robust locomotion with the updated VNMC.

Hardware Experiments in Progress
We are currently testing each control modules on ATRIAS hardware.

Open Questions
Do humans and animals take advantage of the muscle properties in locomotion? Should robotic controllers capture these properties?

Currently, the virtual muscles in VNMC are identical to those used in the original human model. However, the segment dynamics of ATRIAS are much different from those of humans. How can we tune the muscles specific for the given robot?

In simulation, the neural controller can tolerate about ±20 cm ground height disturbances in both the human and the ATRIAS model in the sagittal plane. This is somewhat unexpected considering that ATRIAS does not have feet. How can we further analyze this result to gain fundamental understanding on the function of the ankle-foot complex?

Dynamic Walking 2015
7. 21 ~ 24  The Ohio State University