Momentum-based whole-body control framework – Application to the humanoid robots Atlas and Valkyrie

In this talk we will present our whole-body control framework that was successfully implemented on the humanoid robot Atlas and used to achieve second place at the DARPA Robotics Challenge Trials. We will discuss our work in progress on push recovery, multi-contact behavior, and on the application of the control algorithm to Valkyrie, the humanoid robot developed by the NASA Johnson Space Center.

Our whole-body control framework has been designed around a convex quadratic program (QP). Given a set of motion constraints, rate of change of momentum, and contact information, the QP finds a desired joint acceleration vector and external contact forces. The QP output is then used with a recursive Newton-Euler algorithm to compute the desired joint torque vector to apply to the robot. A high-level motion plan based on the capture point is used to compute the QP's inputs.

The performance obtained using this control framework was satisfactory during the Virtual Robotics Challenge, i.e. simulation phase of the DARPA Robotics Challenge, and allowed IHMC to achieve first place. However, the implementation on the real humanoid robot Atlas was very challenging. We quickly discovered a lot of instances where our controller was not very robust to real world imperfections, requiring both an adaptation to real world constraints and modifications of the simulation environment. We will present the approach we have been using on both Atlas and Valkyrie to improve the controller reliability.

The improvements made on the controller allowed us to successfully control the humanoid robot Atlas to achieve second place at the DARPA Robotics Challenge, and to show optimistic preliminary results on Valkyrie. We are currently improving the algorithm's performance on Valkyrie, and are also extending the control to include new features. Relying on previous work on capturability, we added a push recovery control module. When subject to a strong disturbance that could lead to a fall, the robot is able to recover by replanning the current desired footstep when walking. Looking towards the finals of the DARPA Robotics Challenge, especially the tasks of getting out of a vehicle and stair climbing, we are extending our walking controller so that as well as the feet, the hands can be used to help support and balance the robot.