Introduction and Objective

- We develop a versatile hierarchical offline planning algorithm, along with an online control pipeline for agile quadrupedal locomotion.
- Propose an optimization scheme that alternates between centroidal and whole-body optimization, to generate a wide range of motions, including inertia shaping behaviors.
- Formulate a convex model predictive controller through a novel linear transformation of full centroidal dynamics to efficiently track momentum-rich motions.

Alternating CEN-WBD Optimization

- The dynamic consensus [1] is enforced by adding equality consistency constraints for Center of Mass (CoM) positions, centroidal momentum, and footholds. The Moment of Inertia (MoI) is directly computed from whole-body composite rigid body Mol.
- Centroidal optimization [2] utilizes an equimomental-ellipsoid parameterization to capture the change of MoI [3].

Model Predictive Control with Centroidal Dynamics

- An online full centroidal convex MPC re-computes foot contact forces and joint accelerations based on state feedback from the robot, and allows an explicit momentum tracking compared with original convex MPC [5].
- Based on the assumption that the robot follows the desired reference trajectory, we can pre-compute the matrix H and G inside the dynamics equation, which simplifies to a linear time-varying system.

Results

- Simulated and hardware tests conducted
- Simulated “parkour” maneuver, where the robot leaps between platforms (Fig. 1)
- Equimomental ellipsoid semi-axes changes (left) and centroidal AM in z direction (right) generated by CEN-WBD and SRBM+IK

Future Work

- Future works include optimizing over foot placements and contact timings for both offline and online parts
- MPC controller that realizes cantering and “parkour” on hardware.

References