[27.12.2020]

[Whole-Body Nonlinear Model Predictive Control Through Contacts for Quadrupeds]

Summary

The interesting part of this paper is that it treats the contact force differently, normally we use complementary condition for contacting/not contacting with the ground. For computational reasons, such methods is not nice for commercial solvers. By decomposing the contact force into a damping part and a spring part, the model is then differentiable and can be solved quite efficiently.

Some key points of this paper:

- Using numerical and software solvers can reach at a rate up to 190 Hz for a time horizon of half a second.
- Formulate the problem as an unconstrained optimal control problem
- a family of iterative Gaussian-Newton NLOC algorithms that use fist order method to locally approximate NLOC problem as a linear quadratic optimal control problem. (basically use Gaussian-Newton Hessain approximation)

Major Analysis and Comparison

1) Question: if the contact force is defined as function of p(z) and \dot p(z), how do you determine the gait then?
   - No need for per-specified contact sequences, locations or timings. The gaits are discovered automatically by introducing a cost to the periodically behavior of the optimization variables.

$$
\begin{aligned}
{}_C\boldsymbol{\lambda}(\boldsymbol{q}, \dot{\boldsymbol{q}}) = \; & -k \exp(\alpha_k \, {}_C\boldsymbol{p}_z(\boldsymbol{q})) \\
& -d \, \mathrm{sig}(\alpha_d \, {}_C\boldsymbol{p}_z(\boldsymbol{q})) \, {}_C\dot{\boldsymbol{p}}(\boldsymbol{q}, \dot{\boldsymbol{q}})
\end{aligned}
$$

2) A major difference compared to MIT model is that here we accept the non-linearity of the model and do not simplify the model too much, unlike in MIT, basically the orientation model is simplified a lot.

Thoughts

1) contact forces optimization is a problem. It depends on how we are going to compute the contact force, two ways currently:
    1. Use MPC, put contact force as a optimization variable, compute it (the most intuitively one use MPC)
    2. Like in towr and ocs2, MPC-feedback, the contact force are actually first optimized by planning, and use MPC to track it. MPC is in fact playing the role of smoothing the performance of actuators instead of the high level trajectory.
2) https://www.youtube.com/watch?feature=player_embedded&v=vuCSKtP67E4
3)