Optimal Reduced-order Model Embedding for Cassie

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I. Summary

State-of-the-art approaches to legged locomotion are widely dependent on the use of reduced-order models such as the linear inverted pendulum and the spring-loaded inverted pendulum, popular because their simplicity enables realtime planning [1] and analysis of legged robots. However, they inevitably limit the ability to execute complex tasks or agile maneuvers. Many has sought more expressive yet relatively simple models, but these model extensions all required human intuition [2].

We previously synthesized low-dimensional models that optimized the model performance [3]. In our most recent work, we implemented a realtime model predictive control (MPC) that used the optimal models derived from our model synthesis. We implemented this MPC on a bipedal robot Cassie in Drake simulation [4] and showed that the performance of Cassie was improved by 50% when using the optimized model.

II. MPC with Optimal Models

Our MPC consists of a high-level planner which is extended from the one in [3] and a low-level quadratic-programming-based whole body controller [5]. The planner has a horizon of 2 footsteps, and the period per step is fixed to 0.4 seconds. We solve the planner with SNOPT, and the loop runs at 5-15Hz.

In the experiment, Cassie had to walk at a speed of 0.5 m/s and with a stride length of 0.21 m. We initialized the robot with a standing pose, and after the robot reached a periodic steady state we started evaluating the performance using a cost function from the trajectory optimization of the model optimization stage. We repeated the simulation using different models along a model optimization, and the result is shown in Fig. 2. We can see that the cost went down by about 50% after using an optimized model.

As a part of the ongoing work, we are currently putting the MPC on the real Cassie. We also plan to run more simulation experiments of Cassie with different tasks to evaluate the model performance.

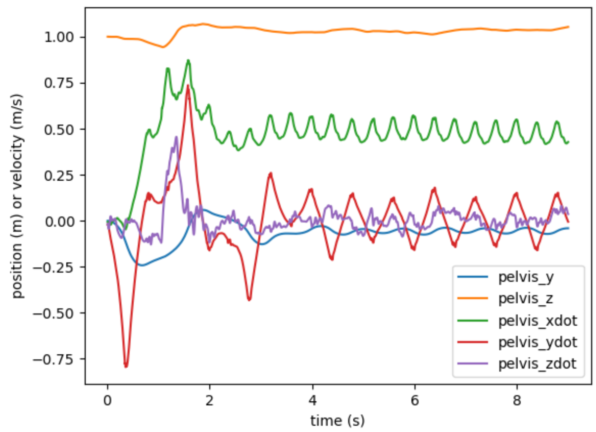

Fig. 1: Floating-base trajectories from a Drake simulation when the MPC used an optimized model.

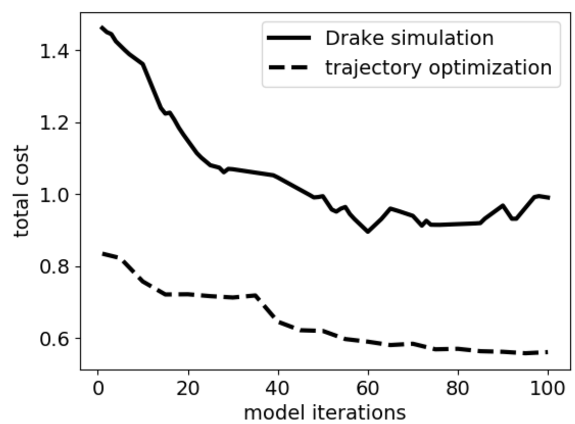

Fig. 2: Cost over model iterations. The cost is a function of the full model's state and input. Model iteration 1 corresponds to a 3D linear inverted pendulum, and iteration 100 corresponds to an optimized model. We also plotted the cost of trajectory optimizations which roughly shows the minimal cost over all possible controllers.

References

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