Karlsruhe Institute of Technology

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Project Type

- ☑ Master Thesis
- ☑ Bachelor Thesis
- ☑ Research Project

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Difficulty

Algorithmic

Math

Application

Model Predictive Control for Deformable Manipulation Tasks

Description

Model Predictive Control (MPC) is a widely used trajectory planning method in robotics. However, its application to deformable object manipulation remains relatively underexplored. Running MPC in such scenarios is computationally expensive due to the need for real-time optimization during execution. While this challenge can be mitigated for tasks involving simple dynamical systems, such as rigid object manipulation, it becomes significantly more difficult for deformable manipulation, such as fluid handling, due to the inherently complex and high-dimensional state space, which slows down simulation speed and the planning algorithm considerably. In this thesis, we investigate methods to address this complexity, including planning using image inputs via latent space [2, 3] or directly through point cloud representations. Although advanced simulators, such as [1, 4], enable relatively fast simulation for these tasks, their speed is still substantially slower than rigid simulations, posing challenges for real-time planning. By developing geometry-aware strategies for MPC, this work seeks to extend its applicability to deformable manipulation, thus bridging the gap between classical planning methods and complex real-world tasks [1].

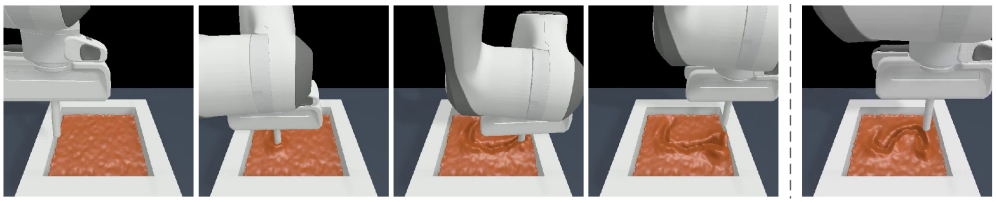

Figure 1: Writing on sand, an example of deformable manipulation tasks from [1].

Tasks

- Get familiar with Maniskill2's *writing on sand* task in Figure 1 and able to control the robot with a random policy.
- Get familiar with Model Predictive Control.
- Implement a full planning pipeline on simple manipulation task and then try it on *writing on sand* task.
- Evaluate the different methods on variously similar tasks.

References

[1] Jiayuan Gu, Fanbo Xiang, Xuanlin Li, Zhan Ling, Xiqiang Liu, Tongzhou Mu, Yihe Tang, Stone Tao, Xinyue Wei, Yunchao Yao, Xiaodi Yuan, Pengwei Xie, Zhiao Huang, Rui Chen, and Hao Su. Maniskill2: A unified benchmark for generalizable manipulation skills. In *The Eleventh International Conference on Learning Representations*, 2023.

[2] Danijar Hafner, Timothy Lillicrap, Ian Fischer, Ruben Villegas, David Ha, Honglak Lee, and James Davidson. Learning latent dynamics for planning from pixels. *arXiv preprint arXiv:1811.04551*, 2018.

[3] Nicklas Hansen, Hao Su, and Xiaolong Wang. Td-mpc2: Scalable, robust world models for continuous control, 2024.

[4] Mayank Mittal, Calvin Yu, Qinxi Yu, Jingzhou Liu, Nikita Rudin, David Hoeller, Jia Lin Yuan, Ritvik Singh, Yunrong Guo, Hammad Mazhar, Ajay Mandlekar, Buck Babich, Gavriel State, Marco Hutter, and Animesh Garg. Orbit: A unified simulation framework for interactive robot learning environments. *IEEE Robotics and Automation Letters*, 8(6):3740–3747, 2023.