Paper Review
Online Movement Adaptation Based on Previous Sensor Experiences

Alvin Sun

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1 Paper Summary

This paper presents an online adaptation algorithm that can effectively generate robust robotic arm control by leveraging sensor readings from previous successful trial runs. Their method first learns some human demonstrated trajectories as a DMP (Dynamic Movement Primitives) system. It then uses this learned DMP model to generate predictive sensor responses in subsequent runs. Using this predictive model and the actual sensor feedback, they can modify the trajectory by adding the feedback to the transformation system in the DMP. Fianlly, using this adapted trajectory plan, a low-level position and force controller is applied for the robotic arm and fingers to track the generated trajectories. In parallel, the authors also proposed a mathematically correct DMP formulation that deals with quaternion trajectories. Their experiments demonstrated that the grasping can handle much more perturbed initial condition using their proposed adaptation algorithm.

2 What I Learned

1. A goal directed trajectory can be efficiently learned with a DMP model that has nice guarantees of convergence and stability properties.

2. Sensory feedback, in additional to the dynamical system itself, can contain some predictive information about the executed control.

3 Opinions

3.1 Up Votes

- I strongly agree with their proposed re-formulation of DMP for quaternion trajectories. The formulation effectively ensures that the derivatives lives in the tangent space of current quaternion state. I think this can also be generalized to other constrained manifolds such as $SE3$, so that the DMP can jointly consider translation and rotation.

- I also like how they formulate the robotic arm controller in a way that the position control and force control is decoupled, and can be simply additive in the overall controller.

3.2 Down Votes

I don't this work conducted enough experiments to show the effectiveness of their proposed adaption method. They only showed the successful grasp on a simple cylinder shaped cup, and a laid-down bottle. The latter experiment also neglects the contact dynamic between the gripper and the table due to fear of collision. The demonstrated examples are quite limited when comparing to real-world demands for robotic grasping tasks.

4 Evaluations

The goal of this paper is to exploit the predictive information present in sensor experiences for robotic grasping problems and to find out how those information can be converted to useful grasp plans that can be robust against unforeseen perturbations. This is a perfectly valid objective as few work before this paper has exploited the fact that successful execution of robot manipulation can generate some *expected* sensor readings that can be useful for adjusting subsequent executions that deviates from the expectation. This paper also achieves their objective by demonstrating how incorporating the adaptation helps improve the control robustness against initial condition perturbation.

The overall quality of this paper is great. They made a few assumptions for their proposed method. One of them is that that some expert demonstration, or some successful grasp execution is available. Another one is that a successful execution should map to some expected sensor experience. Under these assumptions, their experiments show that the system works as expected. However, the assumptions could be unrealistic if the robotic manipulator has too many DoF such that even for human it is unintuitive to control. For the second assumption, there might be multiple different but all successful grasps that can map to drastically different sensor responses. Under such condition, it becomes unclear about how to generate feedback trajectory corrections given those different "correct" sensor experiences.

5 Questions

1. What is the J_{sensor} in Equation (8)? And how does that relates to the intuition of what K_1 and K_2 means.

2. Their methods seem to naturally generate this compliant behavior given the adaptation. Why are they still concerned that the robotic manipulator might collide with the table and break the fingers?