Master Thesis Defense Erick Romero Kramer

Date: Friday, May 29th
Time: 10:00am
Room: Webex

Title: Compositional Machine Learning Models for Robotic Manipulation Behaviors

Abstract:

Recently, some robotics researchers have focused on deploying robots in environments with many unknowns and uncontrollable conditions, as they resemble better real-world environments. Manually defining robotic behaviors is unfeasible for such environments. Therefore, approaches that allow robots to autonomously learn behaviors to solve a task are preferred. Certain tasks can be too complex to learn to solve from scratch. One approach would be to decompose the complex task into smaller sub-tasks that are easier to solve. Robotic manipulators are suitable candidates to evaluate those solutions as most manipulation tasks have a hierarchical structure that can be easily decomposed.

In this thesis, we investigated Machine Learning approaches that generate robotic manipulation behaviors that can be composed for picking and placing tasks. From the investigated approaches, we selected a Quality Diversity algorithm named CVT-MAP-Elites to autonomously learn repertoires of diverse, high-performing, and compositional robotic manipulation behaviors. The behaviors are formulated by solving the Inverse Kinematic problem of a simulated 7 Degrees-of-Freedom manipulator, where each behavior brings the end-effector to a single 3D position in the working space. Three methods are used to describe the evolved behaviors in the repertoires, one uses the reached 3D end-effector position, another uses the reached 6D end-effector pose, and the last one uses a 15D end-effector trajectory. The first two repertoires are optimized using two fitness functions, i.e. joints variance and torque consumption, while the last repertoire was optimized only on torque consumption.

We proposed three different frameworks to select and activate the behaviors from the evolved repertoires, named target, planner, and hierarchical. They were evaluated on use-cases concerning targets pre-grasping positions and pre-grasping poses using top-down and front grasping strategies. The proposed frameworks were evaluated based on the distance to the target positions and target poses, the torque consumed, and the distance traveled by the end-effector. An Inverse Kinematics solver was used as baseline for the target and planner frameworks.

The results of our experiments show that repertoires generated using CVT-MAP-Elites can be composed and used to reach targets positions and targets poses reducing either the torque consumed or the distance traveled by the end-effector. In terms of accuracy, the repertoire-based implementations were limited due to their discretization of the manipulation workspace, which could be improved by having a finer discretization at the expense of more computation time during the evolution of the repertoires.

This work shows that Quality Diversity algorithms are a promising approach to autonomously generate fundamental manipulation behaviors, where each is a high performing solution to a sub-problem, and a combination of them can be used to solve a more complex problem.