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MACHINE LEARNING APPROACH TO SPACE-BASED MANIPULATOR CONTROL

Abstract

With an ever increasing number of satellite operations in Earth's orbit, the demand for space debris removal and on-orbit servicing has become a necessity. As a result, there has been extensive research in this area to increase efficiency and safety when conducting space operations. Many newly published and existing studies focus on the path planning and trajectory of an end-effector to a target using classical control techniques. Within these studies there is often a neglect to consider a tumbling target or a method to avoid collisions in space. In terrestrial fixed-base manipulators, simple machine learning techniques have been proposed to determine optimal trajectories for the end-effector to reach the target in a static environment. Within these studies the target is a stationary object that maintains a stable attitude during contact. In the case of a tumbling target, these studies do not account for maneuvers or protocols to avoid collisions. However, a deep reinforcement learning-based controller has the potential to avoid collisions with a tumbling target by effectively learning through interactions in a simulated dynamic environment. The purpose of this research is to apply deep reinforcement learning algorithms to the control of a robotic manipulator with the intent of capturing a noncooperative target. The dynamics and kinematics of the manipulator arm and the target object are modelled in order to establish the simulation environment and action space. The normalized advantage function (NAF) algorithm is used to learn torque control policies for manipulator motion while avoiding collision with the tumbling target. The inertial and geometric properties of a representative target tumbling object will be employed in the simulation. Actions that lead to manipulator trajectories that avoid collision and minimize interaction forces between the end-effector and tumbling target will be rewarded. After the agent is trained in the virtual environment, a set of simulated experiments will be conducted with a manipulator arm and different target characteristics to validate the robustness of the controller. The results will be discussed in light of applications to autonomous debris removal and on-orbit servicing. Reducing the risks that accompany these tasks is essential for future space operations as well as ensuring the safety of astronauts and operational spacecraft.