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AUTONOMOUS CONTROL ALGORITHM DEVELOPMENT FOR ON-ORBIT SERVICING MISSIONS

Abstract

Extending our spacefaring reach beyond Earth orbit carries with it the need for increased autonomy. As physics limits our ability to communicate in real-time with distant spacecraft, instantaneous decisions will need to be made on-board the spacecraft. On-orbit Servicing, Assembly and Manufacturing (OSAM) tasks are ideal candidates to incorporate autonomous operations. Maintaining the necessary relative pose between a servicing spacecraft and a client requires continuous effort and pausing to await instruction from the ground could significantly lower the efficiency of the operation. This paper highlights the acquisition phase of OSAM mission: specifically positioning a robotic arm in preparation for grasping a satellite, referred to herein as the “approach-to-grapple” maneuver. This is a time-critical procedure that will benefit from autonomous control. The approach-to-grapple task consists of three primary steps: (1) identifying the location of the grapple point, (2) moving the servicing spacecraft within the operational envelope of the robotic arm, and (3) extending the robotic arm to the grapple point. The task will terminate just prior to contact and represents an essential first step for follow-on analysis of the contact dynamic and control problem.

Autonomous control algorithms were developed through an exploratory study to determine the potential benefits of using machine learning approaches, in particular a Double Deep-Q Network, versus more traditional model-based optimization techniques. Leaning-based control methods remove the burden of evaluating the dynamics model in the on-board software through off-line learning conducted prior to the mission. Tasks such as scanning the client to identify the grapple fixture location and control of the robotic arm are especially inviting areas to introduce machine learning into spacecraft control, similar to how they are currently being used for control of ground robots. A six-degree-of-freedom simulation was developed using the Robot Operating System and Gazebo toolsets with a configurable environment which can be used for both training the machine learning algorithm and evaluation against the model-based algorithm. The algorithms were evaluated using several criteria in order to determine which aspects of the mission may benefit most from incorporating machine learning. Evaluation criteria used include: mission success, efficiency in terms of control effort and time, resilience to uncertainties, and safety in the event of a failure.