Paper ID: 65061
student

IAF SPACE SYSTEMS SYMPOSIUM (D1)
Cooperative and Robotic Space Systems (6)

Author: Mr. Kuldeep Rambhai Barad
University of Luxembourg, Luxembourg

Dr. Carol Martinez
University of Luxembourg, Luxembourg
Dr. Jan Dentler
Made In Space Europe S.a.r.l., Luxembourg
Prof.Dr. Miguel Olivares-Mendez
University of Luxembourg, Luxembourg

TOWARDS INCREMENTAL AUTONOMY FRAMEWORK FOR ON-ORBIT VISION-BASED GRASPING

Abstract

Advanced robotic capabilities and operational autonomy are crucial enabling technologies for the envisioned progress in on-orbit servicing, assembly, and manufacturing (OSAM). While the use of robotic manipulation has been deemed central for these applications, the conventional methods and techniques present limitations in handling uncooperative objects, arbitrary geometries and materials, high uncertainty of state knowledge and task failure handling. This hinders wide-range adaptation of such approaches and ultimately motivates the need for newer solutions. In this work, inspired by the recent advances in machine learning for computer vision and robotic manipulation, an incremental framework is presented to assess how space-borne vision-based grasping systems need to be developed to move from basic to full autonomy in operations. It is noted that learning-based approaches for vision and especially manipulation present unique challenges like explainability, robustness, real-time implementation and performance transfer from training environments to the operational environment, which must be critically analyzed. It is therefore essential to build a framework under which progress in terrestrial robotics can be harnessed for use in space applications, aligned with the long term goal of building fully autonomous spacecraft manipulation systems for advanced OSAM infrastructure.

Along this direction, we evaluate the prospects of novel state-of-the-art methods and techniques applicable to on-board robotic manipulation systems. In particular, the scope utilizing machine learning elements in the conventional vision or control systems is investigated for monocular vision-based grasping in unstructured and uncertain working environments. At each level from basic to full autonomy, the expected behavior is described along with the definition of its time horizon and task complexity domain. Coarse system constraints are subsequently incorporated to assess feasibility, scalability and real-time implementability for on-board pose estimation, grasp estimation, grasp detection and grasp execution subtasks. Next, the expected behavior description is broken down at each autonomy level into objectives of perception, prediction, planning and control subsystems along with their interfaces. Finally, algorithmic generalization aspect is briefly reviewed to assess how to adapt the same task to newer environments or objects. Overall, this work presents a foundational top-level framework for the vision-based dynamic grasping capability and lays down a guiding roadmap towards generalizable full-autonomy.