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A LEARNING-BASED ROBOTIC REFUELING CONTROL SYSTEM FOR ON-ORBIT SERVICE

Abstract

On-orbit service (OOS) is a type of operation that the human or robot server carries out on the client spacecraft in the space environment. Typical OOS includes propellant replenishment, component replacement, maintenance, etc. Among them, robotic refueling is a long-studied yet promising technology to increment a spacecraft's service duration. The main difficulty in space robotic refueling is the high requirement of manipulation versatility in an unstructured on-orbit environment. Learning-based methods, especially deep learning with highly expressive deep neural networks, can be leveraged to upgrade the autonomy of robotic refueling. In this paper, we design and implement an autonomous robotic refueling control system based on deep reinforcement leaming. This paper depicts the framework including intelligent perception, autonomous planning and visual servo control, and the physical experiment system. Validation in both simulation and real environments shows that the system is able to execute numerous basic manipulation tasks like lid opening, injector docking, and refueling. Robustness and adaptability to an active interaction with dynamic time-varying environments are also demonstrated. The paper has three main technical contributions: (1) Overcoming sparse reward by learning sequential generative subgoals. The method shows generalization over a variety of elementary tasks for space robotic refueling including lid opening, injector docking, refueling, etc; (2) Design of a laboratory learning/training platform for space operation for efficient learning data sampling, which has high similarity with the on-orbit environment. The learned policy has a good property of Sim-to-Real(Sim2Real) transfer, verifying the possibility that further application in the practical on-orbit environment; (3) A sufficient validation of robustness to robot base/goal perturbation and luminance intensity change, meeting the practical needs in engineering.