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IN-SPACE ROBOTIC ASSEMBLY AND SERVICING OF HIGH-VALUE INFRASTRUCTURE

Abstract

Advances in Robotics, Automation and Autonomous Systems (RAAS) have widened the horizon of space exploration, allowing robots to be deployed in extremely harsh environments. Building upon the heritage of successful surface exploration rover and lander missions to the Moon, Mars and Asteroids, the space community worldwide is now pushing the frontiers of in-orbit robotics. Doubtlessly, RAAS will facilitate a range of assembly, manufacturing, servicing and active debris removal missions. Resources published by space agencies and major companies worldwide clearly indicates that mankind will start witnessing in-orbit robotic missions within the next decade. This includes but not limited to building modular large aperture space telescopes, synthetic aperture radar, radiofrequency antennae, in-space power generation station, mobile servicing stations for repairing and maintenance of satellites and possibly large-scale infrastructure for space tourism. Out of the many potential missions RAAS could support, assembly and construction of large space telescopes are gaining more popularity. However, there are numerous technical challenges to address before such adventurous in-space missions could be realised. One such impediment is the design of space robots itself, which needs to operate autonomously or semi-autonomously in remote and extreme conditions. Further, the Guidance, Navigation and Control (GNC) of the space robot, both in Earth orbits and beyond, is also more convoluted than conventional satellites which do not have any robotic manipulation capability. This paper focuses on these two critical problems, with an emphasis on robotic assembly and servicing mission scenarios. More specifically, this paper is aimed at providing new insight into the architectural and design engineering aspects, alongside presenting GNC solutions for close proximity operations of the space robot with its target. For in-space assembly and construction missions, the design choices ranging from a base spacecraft with a single arm and dual arms to an End-Over-End Walker (E-Walker) will be presented. Further, this paper will cover an in-depth analysis of the motion dynamics and control of the E-Walker for Space telescope assembly mission. A detailed system-level trade-off will be presented in addition to an in-depth evaluation of precise trajectory tracking and robust pose control of the space robot. Unlike the traditional free-flyer and free-floating modes of operation, the space robot will be operated in the controlled floating mode. Extensive simulation-based results covered in this paper will invariably improve the current understanding and advance the state-of-the-art of designing and controlling space robots for structural assembly and sustained servicing

operations.