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A FRAMEWORK FOR HARDWARE-IN-THE-LOOP SIMULATION OF RELATIVE ORBIT DYNAMICS

Abstract

The current need for developing enabling technologies for space rendezvous missions has led to the development of hardware-in-the-loop facilities for simulating the closest phases of on-orbit servicing and/or space debris removal missions. Such testbeds are generally used for validating guidance and navigation algorithms while utilizing different typologies of sensors (gyroscopes, accelerometers, cameras, lidars), as well as for testing different typologies of docking and grasping mechanisms. Different kinds of testbeds have been developed, utilizing either frictionless tables with platforms floating over air-bearings or robotic arms holding spacecraft mockups with specific sensors and mechanisms to be tested. The key incentive for developing such facilities is not just limited to the pure mechanical on-ground simulation of some of the space conditions; it is also extended to the possibility of having a versatile tool that can emulate different environmental and spacecraft conditions within an integrated software/hardware framework.

The aim of this paper is to discuss a scale unification theory that allows for the utilization of robotic platforms for the simulation of the relative dynamics of two spacecraft in orbit. The theory utilizes the Pi theorem for scaling down the equations of motion as well as the physical dimension of a space close rendezvous scenario to be properly simulated by a ground testbed with limitations in size and degrees of freedom. The theory also takes into account the limitations on the joint movements of the robotic arms that hold and move the two mockups of the chaser and target spacecraft. As a result, a framework is presented for defining the scaling factors to apply to the test requirements and performances in order to have genuine simulations of real-life scenarios. Some experimentations demonstrate the validity of the proposed framework.