Verification Procedures and Results of the Spacecraft Docking Emulation Test Bed

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Abstract

Satellite servicing represents a considerable challenge for space engineering. Each mission requires important investments in terms of human and financial resources, and thus several space agencies are trying to find an efficient way to restore satellites by unmanned missions, using autonomous repair spacecrafts. However, there are specific complications related to this type of operation, one of them being the critical nature of the docking stage that, if not done in strict accordance to the set parameters of velocity and angle of approach, can jeopardize the entire mission, hence the extensive research that is presently being conducted in the field of contact dynamics.

The focus of this research is to find alternatives to the methods that are currently in use for dynamic estimates, as they do not deliver reliable results particularly in complex situations. This behavior is mainly due to the fact that dynamic results change drastically with each variation of the calculation parameters. In an effort to solve this problem, researchers have developed experimental setups that can help generate more realistic results.

Such experimental systems are common place in space robotic applications, as they are often used for ground based systems testing. For example, the Japanese space agency (JAXA), uses air-bearing pads to simulate the docking of two satellites in a space environment [1]. There are, however, downsides to this approach, such as the complexity of six-degrees-of-freedom (DOF) movement, and the work involved in the creation of realistic mock-ups.

To cope with this problem, intensive research is being conducted at the Canadian Space Agency (CSA) on the Special Purpose Dextrous Manipulator (SPDM) Task Verification Facility (STVF) [2]. This Hardware-in-the-Loop simulation (HLS) facility was developed for functional task verifications, such as the extraction of the Orbital Replacement Unit (ORU)

of the SPDM. In this setup, real forces on the ORU are measured and applied like external forces on the simulated robot. The CSA is extending the capabilities of this facility in order to study the docking of two spacecrafts. In this case, the STVF robot, shown in Figure 1, is driven by a docking simulator of two spacecrafts with a docking interface, developed in the Matlab/Simulink environment [3]. An important aspect of this docking simulator is that it allows for a variety of target/chaser geometry configurations; the inertial property of the satellites and the position of the end-effectors need only be defined.

Figure 1: MDR end-effector mounted on STVF test bed

An end-effector developed by MD Robotics (MDR) is fixed to the gripper of the STVF robot (see Figure 1) in order to emulate the end-effector of the chaser satellite, which is retained to the outboard frame by a six DOF spring/damper system. The two satellites and their controller are modelled using Symofros (Symbolic Modelling of Flexible Robots & Simulation). The end-effector of the STVF robot is ordered to follow the relative position of the target/chaser system. This test bed can be used to determine the docking capability of the satellites, in a variety of velocities and angles of approach.

This paper will present the tests that were performed to verify the dynamic behavior of the CSA's docking test bed, along with preliminary test data for practical applications. In addition, the paper will introduce the STVF facility, and provide a description of the docking simulator as well as the general architecture of the docking test bed.

References

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