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DESIGN, CONSTRUCTION AND VALIDATION OF AN AUTONOMOUS, INTELLIGENT, ROBOTIC ARM FOR ON ORBIT SATELLITE CAPTURE

Abstract

On-orbit servicing (OOS) of failed or failing spacecrafts is becoming an increasingly important role for robotics in space. One of the most important phases of OOS mission with the highest risk is the spacecraft capturing operation by a space robot, because it involves contact between the two spacecrafts and typically requires a timely cooperation of the control systems on both satellites, which is impossible for a tumbling (non-cooperative) satellite. In this phase, the chaser's robotic arm approaches the free-floating target satellite and grasps it. During the contact between the end-effector and grasping point, there is risk that the target and the robot may be pushed away from each other or the end-effecter/target may be damaged by the contact force, if it is not properly controlled.

Previous efforts, including those of Papadopoulos Duowsky [1990], Wee Walker [1993], and Shibli et al. [2006] have focused on 2D and 3D contact mechanics of rigid bodies and the related control strategies to minimize the contact force with grossly simplified assumptions. These include (1) zero external applied force; (2) contact duration is instantaneous; (3) generalized coordinates remain unchanged during contact; (4) contact occurs at a point rather than a time-varying area. Further work by Kim et al. [1999] and Wang et al. [2006] have abandoned some of the above assumptions and adopted the finite element method to model the local flexibility of contact area. However, all of these approaches face complications from their simplifications.

This paper will present the development of a generic approach to treat the contact dynamics of two flexible multi-body system and the contact force control scheme for capture operation of the free-flying satellite without the above assumptions, The new model will be implemented by hybrid formulating which integrates the contact dynamics, rigid/flexible multi-body system dynamics, and finite element method based on the global nodal coordinate method. Furthermore, the entire procedure will be validated experimentally on a specially constructed robotic manipulator built for this purpose and the generalized method will be applied to design contact force control scheme to minimize the dynamic contact force during the capture operation.