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# TETHER-BASED SOFT RENDEZVOUS AND DOCKING FOR MICROSATELLITES: DESIGN, CONTROL AND EXPERIMENT

**Abstract**

The rapid development and maturation of microsatellites has led to their increasing involvement in space on-orbit service missions. The primary prerequisite for on-orbit service is the contact and connection of service satellite to the surface of target spacecraft through rendezvous and docking. On-orbit rendezvous and docking, requiring high precision relative motion control, is a challenging task, especially for microsatellites with limited volume and devices. Existing mature rendezvous and docking technologies, developed for large facilities (such as space station), demand complex cooperative or non-cooperative relative state measurement equipments during implementation, and even require specialized robotic arms to complete capture and docking. They not only put forward cooperation requirements for the target spacecraft, but also significantly increase the mass and complexity of the service satellite, which results in their inability to be directly applied to microsatellites.

In order to deal with the gap caused by the miniaturization of spacecraft, a tether-based soft rendezvous and docking scheme for microsatellites is conceived in this paper, which is applicable to both cooperative and non-cooperative targets. The scheme is characterized with notable features of miniaturized structure, easy reusability and cost effectiveness, which can meet the docking needs of microsatellite and provide guarantees for the on-orbit micro-manipulation of service satellite. We first describe in detail the rendezvous and docking mechanism design, which mainly consists of three parts: tether reel, launcher and capturer, and give a typical mission implementation scenario. As a specific application of the space tether system, the tether retrieval control is a core aspect to ensure safe rendezvous and docking. We establish the relative dynamics model with tether-based tension and propose a tether length control method based on fractional-order observer to cope with the modelling error. The proposed law takes full advantage of the unique historical memory effect of fractional-order control to track the modelling error and improves its robustness by error compensation. Finally, we jointly use numerical simulation experiments and hardware-in-loop semi-physical experiments to verify that the proposed scheme and control law are feasible solutions for rendezvous and docking. The experimental results show that the tether-based soft rendezvous and docking scheme can ensure the service satellite simulator to approach and dock to the target. In addition, the robust control law based on fractional-order observer can deal with the uncertainty of the environment with small overshoot, short convergence time and high accuracy.