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CAPTURING METHOD OF TUMBLING SPACE DEBRIS BASED ON ASSEMBLED MULTIPLE MICRO-SATELLITES

Abstract

Typical methods to manipulate dysfunctional spacecrafts are based on multi-DOF space manipulator or flexible gripper as flying net, but these methods are not sufficient when faced with high-speed tumbling debris. While a lot of ideas focus on swarm of micro-satellites, which are more and more studied and demonstrated recently. Micro-satellites, when used in On-Orbit Service, show advantages as, flexibility, modularization, thus may achieve more autonomy and maneuverability. Unfortunately, slack organization of swarms makes many problems within GNC system unsettled.

This paper presents a novel method based on assembled multiple micro-satellites, which are used as a whole to capture tumbling debris. It's assembled on-orbit from 3 rods, 3 micro-satellites deployed with orbital/attitude control system, and the buffer mechanism to execute capturing. Each rod goes through one micro-satellite, and meanwhile, the micro-satellite has 1 DOF along the rod, and hinged to another rod. The overall structure of the rod-assembled micro-satellites is a contractible triangle.

The preferred execution schedule should consist the following 4 phases, proximity, relative spinning decrease, motion synchronization and capturing. The assembled micro-satellites are put down near debris by large satellite, and approach it by itself. For the reason that most targets spin or tumble, it surrounds the target in the middle of the assembly firstly. Then the relative transitional/rotational velocities are both decreased with the work of attitude/orbital actuator, measurement equipment, as well as computer on board the micro-satellites. Finally, micro-satellites move inward along rods, causing the structure contracts and buffer mechanism fixes the assembly to the target. In this way, the target will be controlled temporarily or de-orbited.

This paper studies the autonomous control of attitude/orbit of the assembled micro-satellites, after it's put down, and before it touches the target. The micro-satellite uses impulse thruster and three-axis stable wheel as its actuator, and Model Predictive Control is applied to attain 6-DOF motion synchronization. Considering the contraction of structure causes its angular velocity increases, principle of conservation of momentum is used to get optimal control during these phases. Collision avoidance constraint with target, bias/noise of measurement of position/attitude information and bias of actuators are considered in the numerical simulations. The result indicates that the control method could attain acceptable relative static, and decreases relative angular velocity, which establish necessary condition for capturing a tumbling target. Further ground experiment shows that the assembled micro-satellites are technical feasible and have certain potential to be used in Active Debris Removal.