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SIMULATION AND TENSION CONTROL OF A TETHER-ACTUATED CLOSING MECHANISM FOR NET-BASED CAPTURE OF SPACE DEBRIS

Abstract

The growth of space debris in Earth's orbit is recognized as a serious threat to future space missions. To contain the growth of space debris in the long term, active removal of large defunct spacecraft is needed. A promising solution to this problem is the use of tethered-nets. In the envisaged mission, a net is released from a chaser spacecraft toward a target debris; the net entangles the debris and the tether provides a flexible link between chaser and debris to tug the debris to a disposal orbit. This work is focused on the simulation and control of a tether-actuated closing mechanism. In this concept, proposed only recently, the tether is looped through the center of the net and around the perimeter, and spooling the tether in draws the net perimeter closed. A four-tether-actuated closing mechanism was considered in previous research, but having four separate tethers is impractical and increases the complexity of the system.

In this research, improved models for a tether-actuated closing mechanism for net-based capture of space debris are developed, considering both single-tether and double-tether configurations. The model of the winch, which is key to the control of the closing mechanism, is established based on literature on the design of reeling mechanisms for tethered-nets. The rest of the system, including chaser, net, and target, is modeled based on previous work on the dynamics of tether-nets for ADR.

Through simulations, the deployment of the tethered-net in presence of either closing mechanism is evaluated and the characteristics of deployment are used to determine a nominal capture scenario. The results indicate that the tension in the single-tether-actuated closing mechanism hinders the deployment significantly, and therefore the single-tether configuration is deemed a non-feasible option.

Open-loop and closed-loop control strategies are employed for the capture and containment of a desired target debris with the double-tether configuration. The outcome of simulation with the open-loop control manifests the need for tension control to ensure containment of the debris. In light of this result, a PD tension control law with gain scheduling, as well as emulated thruster control on the chaser spacecraft, is applied. The proposed control strategy is designed with a view to the measurable parameters and performance limits that would be present in a real tethered-net ADR system. This novel control law demonstrates capture and containment of the target debris while keeping the tension and spooling rate of the tether within realistic limits.