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INERTIA TENSOR ESTIMATION OF TETHERED DEBRIS THROUGH TETHER TRACKING

Abstract

A promising method to eliminate debris from the most useful orbits involves tether-based capture of large debris for towing and de-orbiting. However, space debris is by definition uncooperative, unresponsive, and often tumbling. Capture and control without knowledge of the mass and inertia properties of the target object is difficult to achieve. Therefore, there is the need to estimate the moment of inertia parameters in the absence of communication from the debris. To the authors' knowledge, works in the literature often only estimate ratios of the moments of inertia. This study aims to determine the inertia tensor of large space debris after tethered capture.

In previous work by the authors, the individual principal moments of inertia of an uncooperative tethered target were estimated assuming perfect knowledge of the tension in the tether and of the tether attachment point on the debris, as well as measurements of the angular rates of the debris . The present work relaxes these assumptions by assuming that noisy measurements for the tension and relative position of the tether attachment point from the chaser are provided by both a tension sensor and a camera on the chaser. Angular rates of the target are estimated through successive relative position measurements of the tether attachment point. In turn, the estimated angular rates inform the estimation of the inertia tensor of the targeted debris. Thanks to the moments imparted on the debris by the tension in the tether, the inertia tensor can be estimated without any knowledge of the mass of the debris.

The proposed methodology for the estimation of the moments of inertia of tethered debris is applied in simulation of a system formed by a point-mass chaser tethered to a rigid body debris target. This system is simulated in Matlab to generate data for the rotational motion of debris that is affected by the tether tension. An Extended Kalman Filter and an Unscented Kalman Filter are applied to estimate the moments of inertia using simulated sensor measurements. The performances of the filters are analyzed and compared to determine the validity of the proposed method for the estimation of the moment of inertia parameters. Monte Carlo simulations are performed to investigate the mean and standard deviation of the estimated moment of inertia values in the presence of uncertainties in measurements and initial guesses, as well as to evaluate the robustness of the methodology to varying initial guesses.