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AN ALGEBRAIC APPROACH FOR THE MOTION ESTIMATION OF A NON-COOPERATIVE SPACE DEBRIS TARGET

Abstract

A large amount of space debris around the Earth poses a significant threat to future near-Earth space activities. One of the definitive solutions to this problem is the removal of space debris from orbit. A key technology for the active removal of space debris is to accurately estimate the state of the target motion. Many strategies have been extensively studied for relative motion estimation of a non-cooperative target, but problems have remained concerning conducting precise and robust estimation in real-time. This paper proposes a novel strategy to solve this issue via a real-time, robust, and practical method.

Many strategies proposed until now have mostly adopted filtering methods utilizing differential equations of motion. Although these methods can estimate the target motion when an appropriate initial guess and reference models are given, assuming that the reference models are known would be unrealistic in some cases. Besides, such methods cannot conduct precise estimation when the target changes motion, as in the case when an unexpected external torque is applied to the target inadvertently.

To cope with these problems, we propose an algebraic approach for non-cooperative target motion estimation. One advantage of our method is that it does not need a-priori reference models, as it can estimate the target motion and the target inertia tensor at the same time without the a-priori knowledge of the target itself. Another advantage of the method is that it can estimate the motion even when the chaser fails to capture the target and applies an inadvertent change to the target's motion. The proposed method consists of relative position estimation based on an optical navigation and the algebraic estimation of the angular momentum vector and inertia tensor. The relative position estimation utilizes camera geometric constraints, resulting in a low-cost calculation. As for the estimation of the angular momentum vector, an algebraic equation is proposed simply from the angular momentum vector conservation law. As this method refers only to the kinematic equations, the parameters of motion can be computed whenever a new observation is obtained. The validity and efficacy of the method is demonstrated using numerical simulations.

The simulation results demonstrate that the proposed method can estimate the angular momentum vector direction with 1.15 deg accuracy and that the method is robust to any target motion alteration that may occur, confirming that the proposed method provides a viable and robust strategy for the capture of non-cooperative space debris targets.