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Non-cooperative Maneuvering Spacecraft Tracking via a Variable Structure Estimator

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***Abstract*—*A spacecraft performing unknown maneuvers significantly increases the probability of a collision between spacecraft with neighboring orbits. Traditional orbit determination filters cannot robustly cope with unknown maneuvers. To track non-cooperative, unknowingly maneuvering spacecraft, a novel variable structure estimator is proposed based on the input compensation to a normal filter. We develop an observer to estimate the unknown maneuver and then analyze the estimated maneuver performance based on error propagation. Once the maneuver detector declares the occurrence of an unknown maneuver, the estimated maneuver is fed to an extended Kalman filter as compensation, which enables the estimator to work adaptively. Finally, a series of numerical simulations are carried out to demonstrate the effectiveness of the proposed variable structure estimator, and the estimation performances in the cases of constant and time-varying maneuvers are analyzed based on the simulation results.*

Index Terms—Orbit determination; Non-cooperative target; Unknown maneuver; Observer; Extended Kalman filter; Variable structure estimator.

I.Introduction

The techniques of tracking, predicting and estimating the orbit states of non-cooperative spacecraft are critically important for Space Situational Awareness (SSA). Due to the rapid growth of the spacecraft population, possible collisions between spacecraft in neighboring orbits are attracting increasing attention [1]. To guarantee the safety of operational space assets, satellite operators must have a clear picture of all space objects. In general, Kalman filter has been wildly used for orbit determination, it is not difficult to track a cooperative spacecraft given a well-known, planned maneuver sequence [2-4]. However, if the maneuver sequence is unknown to the tracking system, the estimation performance of a traditional filter will be significantly degraded, and sometimes the estimator even diverges [5].

In general, the divergence problem caused by unknown maneuvers could be solved by inflating the covariance [6,7]. The one-time covariance inflation method has been proved effective for coping with the impulsive maneuvers performed by non-cooperative spacecraft. To prevent filter estimation divergence, this algorithm inflates the covariance to increase the weight of fresh observation during the state update stage, which allows the estimation to converge on the post-maneuver trajectory. However, this approach becomes limited if the unknown maneuvers are continuous. In contrast, the fading memory filter continuously increases the weight of the current measurement through covariance inflation [8,9], but it also increases the

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