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THE DETECTION AND CHARACTERISATION OF UNKNOWN MANEUVERS IN SPACECRAFT

Abstract

Space debris detection and characterisation is an important and pressing field, as the amount of space debris is growing due to the increase in spacecraft launches and increasing interests for space uses. Space agencies like NASA and ESA keep track of over 5,000 spacecraft and 20,000 spacecraft-related debris objects currently orbiting the Earth. An active spacecraft may undergo trajectory changes through an impulsive maneuver, or an inactive spacecraft may change its trajectory because of uncontrolled explosions due to residual fuel without warning. These pose risks to operational satellites. In addition, measurement data from tracking and detection consists of uncertainties, causing maneuver detection and characterisation methods to become computationally expensive.

Thus, the goal of this work was to develop a quick, reliable, computationally inexpensive method for spacecraft maneuver detection and characterization to be used by satellite operators and assist in collision avoidance measures. This paper presents such a technique, which is applied to simulated measurement data of an orbiting spacecraft taken from one ground site. With these objectives, a method using a modified Extended Kalman Filter (EKF) with covariance inflation from previous studies was explored and simplified. A new parameter definition is presented for maneuver detection and characterization, named K, with focus on transverse apogee and perigee maneuvers. A relationship was then found between the detection parameter and the magnitude of the impulsive artificial maneuver. The detection and characterization method were tested in several different scenarios, varying Δv magnitude and scale, Δv direction, maneuver orbital location, orbit geometry, noise covariance, detection parameter threshold, state covariance inflation threshold, and maneuver duration.

In general, it was found that as the Δv magnitude increases, the magnitude of the detection parameter also increases. This relationship was found to be a nonlinear logarithmic relationship through best fit curve testing. Possible expansions of this work in the future can include: testing multi-maneuver scenarios, multi-sensor data collection and fusion, break-up or berthing events, rendezvous or mating events, MATLAB EKF protocol implementation.