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IMPROVING ROBUSTNESS AND FAULT DETECTION, IDENTIFICATION, AND RECOVERY FOR DOUBLE-GIMBAL SCISSORED-PAIR CONTROL MOMENT GYROS USING UNSCENTED KALMAN FILTER

Abstract

Since fuel cannot be replenished in space, attitude control actuators that do not require fuel and can be operated continuously are essential. There are two types of angular momentum exchange actuators for spacecraft attitude control that are not restricted by fuel: control moment gyros (CMGs) and reaction wheels (RWs). Conventional CMG systems require multiple CMG unit to achieve three-axis attitude control. However, when multiple CMGs are combined, the complexity of system rises which leads to complicated singularity issue. Variable-speed CMG (VSCMG), which generates torque about three axes by changing the rotation speed of the wheels, can also generate torque about three axes, but the torque generated by changing the rotation speed of the wheels is in principle the same as RW, which is much smaller than the torque generated by gyroscopic effect. To overcome the above drawbacks, in this study, double-gimbal scissored-pair CMG (DGSPCMG) proposed by Kojima et al. was considered as the CMG system. In the previous study, the inverse kinematics steering law , which calculates the gimbal rate backward from the kinematic relationship between angular momentum and gimbal angle, was applied to the DGSPCM. In case that the inner or outer gimbal fails, the DGSPCMG has only three degrees of freedom, thus the redundancy is not ensured. To solve this issue of the DGSPCMG, the authors group also proposed the inverse kinematic steering law that removes the equivalence of the scissored-pair angle to ensure redundancy. While this steering law can realize stable control without explicitly considering the internal singularities, it lacks robustness because it requires the precise information on the malfunctioning status of gimbal angles. Furthermore, the failure detection and identification, which are necessary for practical applications, must be studied. This study proposes the use of Unscented Kalman Filter (UKF) to estimate the state parameters, to reduce the number of parameters that should be known, and to perform fault detection identification and recovery (FDIR) using the estimated parameters. The results of numerical simulations show that the values estimated by the UKF follow the true values sufficiently, thus the proposed control scheme that combines the inverse kinematic steering law and FDIR provides several advantages, such as elimination of internal singularity, three-axis attitude control with a single unit, high robustness, and recovery of degrees of freedom by removing equivalence of Scissored-Pair gimbal angle in case of gimbal axis failure.