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PRESCRIBED PERFORMANCE ADAPTIVE CONTROL WITH FAULT-TOLERANCE CAPABILITY FOR A SUN-POINTING SPACECRAFT ON HALO ORBIT

Abstract

The Aditya mission is India's first dedicated scientific mission to study the Sun by placing a spacecraft in the Sun–Earth L_1 Halo orbit. The location has the major advantage of continuously viewing the Sun without any occultations/eclipses. During the mission, the spacecraft switches between two attitude modes. The first is the Sun acquisition mode, which enables the Visible Emission Line Coronagraph (VELC) payload to image solar corona as close as 1.05 times the Sun's radius and requires precise Sun-pointing accuracy of 25 arc seconds. The second is the Station-keeping (SK) mode, which enables the spacecraft thrusters to perform orbital corrections. The spacecraft uses a set of four reaction wheels to enable the desired attitude re-orientation. An inaccuracy in achieving and maintaining the desired attitude will lead to degraded observations and orbital deviation due to unwarranted residual velocities. In addition, a continuous disturbance torque due to solar radiation pressure (SRP), parametric uncertainties (moment of inertia, centre of mass location, actuator mounting and SRP coefficients) and fixed-time tracking requirements pose additional control design challenges.

To address the above objectives, this paper synthesizes a novel fixed-time prescribed performance based adaptive control law by blending the philosophies of model-following neuro-adaptive control and output-constrained design using Barrier Lyapunov functions (BLFs). The field-of-view constraints on VELC are imposed by modelling the Sun-pointing errors using a set of cone angles. An appropriate error transformation is carried out to obtain the equivalent output constraints on the quaternion error. Subsequently, a strictly convex-BLF is constructed and Lyapunov analysis is carried out to result in an adaptive control law that ensures precise attitude tracking in the presence of parametric uncertainties, exogenous disturbances, actuator saturation and a class of actuator faults. The desired transient and steady-state behavior is guaranteed to be achieved in a fixed time (pre-selected and user-defined) by constraining the attitude errors within a novel fixed-time prescribed performance function. The actuator constraints and faults are handled by approximating the saturation phenomenon using a smooth hyperbolic tangent function and Nussbaum gains. The controller formulation does not require explicit knowledge of the bounds on uncertainties, faults and disturbances. Further, the formulation does not consider the rigorous sufficient conditions with fractional powers typically required for fixed-time Lyapunov analysis, thereby simplifying the design process. Finally, the efficacy of the control law is verified by conducting extensive simulation studies, including comparisons with traditional adaptive control design schemes.