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THREE-AXIS ATTITUDE CONTROL OF AGILE SATELLITE USING FRACTIONAL ORDER PROPORTIONAL-DERIVATIVE CONTROLLER

Abstract

In this research paper, a fractional order proportional-derivative controller has been designed and developed for three-axis attitude control of an agile spacecraft. To achieve agility of the spacecraft, control-moment-gyros (CMG) are used as actuator in pyramid configuration. As is well known, the control-moment-gyros exhibit geometric singularity problem. This condition arises when no control torque is produced by CMG configuration for the commanded control torque along a particular direction. A singularity robust inverse steering law has been implemented to overcome the problem of singularity in this work. Fractional calculus has been successfully utilized in system dynamics modelling as well as control law design. The superiority achieved through Fractional calculus compared to its integer order counter-part can be attributed to its additional tuneable parameters, that incorporate more design specifications. A novel pole perturbation method has been introduced here for the design of fractional order proportional derivative (PD) controller. Based on the perturbed pole(s) characteristics, a number of perturbed spacecraft dynamics are summarized. Frequency domain specifications namely phase margin, gain crossover frequency and isodamping condition have been considered for design of fractional PD controller, for each perturbed system. Based on the quantitative performance such as control effort, settling time and maximum overshoot of each fractional control design, an optimal fractional PD controller structure is arrived. The developed fractional control structure has been used to control the nonlinear spacecraft dynamics under various conditions viz. nominal, inertia variation and singularity condition. This design is compared quantitatively with conventional PD controller. The control effort, settling time and maximum overshoot obtained for the fractional order PD controller for nominal case are 240.9409, 93.15 s and 1.67 deg./s respectively. Whereas these values are 4.73e+6, 81.152 s and 2.2 deg./s for the integer order PD controller. The large control effort requirement for PD controller is due to chattering phenomena due to gimbal rate constraint. However, this behavior is not observed in case of fractional order controller. Through high fidelity computer simulations, it is established that the designed fractional PD controller is superior to the integer order PD controller for an agile spacecraft attitude control.