Paper ID: 18393
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ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (1) (3)

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ATTITUDE CONTROL OF SPACECRAFT USING OPTIMAL NONLINEAR CONTROL SDRE AND THETA-D

Abstract

The purpose of this paper is to present an application of the state-dependent Riccati equation and Theta-D techniques to spacecraft attitude control where spacecraft kinematic is modeled by quaternion parameters. The SDRE and Theta-D methodology are applicable special forms of nonlinear systems where satellite model is one of the candidates. However, the nonlinearity of the spacecraft model makes the process difficult. One the solution is the linearization where the nonlinear spacecraft model is linearized around the origin and resultant linear models are used in the controller design. This method is acceptable by assumption of the smallorder of nonlinearity and small angle. So the design satellite attitude control systems that involves plant uncertainties and large angles maneuverers flowed by stringent pointing control may require new nonlinear attitude control techniques in order to have adequate stability, good performance and robustness.Recently emerging technique which systematically solves the nonlinear regulator problem is the state dependent Riccati equation method that proposed by cluotier at 1996. In the SDRE method the nonlinear dynamics are brought to time-invariant linear-like structure containing state-dependent coefficient. In the process the coefficient matrices being evaluated at the current operational point in the state-space. The process is repeated in the next sampling periods.The major problem with SDRE is the time-consuming online computation of the Riccati equation. According to theta-d technique by expanding the solution of SDRE as power series, a new method proposed for solving the state dependent Riccati equation. By introducing an intermediate variable , the co-state can be expanded It does not need time-consuming online computations like the state dependent Riccati equation technique.The theta-d nonlinear optimal control technique is employed to design a closed-form feedback controller for this problem by finding an approximate solution to the Hamilton-Jacobi-Bellman equation approximately by adding perturbation to the cost function. By manipulating the perturbation terms both semi-globally asymptotic stability and suboptimal properties can be obtained. This method overcomes the large control for large initial states problem that occurs in some other Taylor expansion based methods.as a result, the resulting nonlinear feedback law can be expressed in a close form.All these solutions are suboptimal since the optimality conditions derived by Cloutier at 1996 are difficult to be validated for high order nonlinear models where the spacecraft is one of them.To good understanding,the results of proposed nonlinear techniques would be comparison by linear quadratic regulator technique.Numerical results show that the theta-D controllers achieve excellent tracking performance and exhibit insensitivity to parameter variations over a wide flight envelope. Notice that the results of SDRE and theta-d techniques are the same of together. The control effort of LQR technique is more expensive in comparison by the nonlinear technique.