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ATTITUDE CONTROL FOR SMALL SATELLITES USING GRADIENT-MODIFIED METHODS

Abstract

The paper presents some aspects for the synthesis of small satellites attitude control system. The nonlinear model of the satellite has six degrees of freedom and it includes rotation angles in order to describe the kinematic of its motion. Unlike regular papers, which cover the regular aircraft case, where the kinematic equations use Euler angles, in our case, when the satellite has a complex evolution, some papers recommend the quaternion or the rotation angles for the attitude parameterization. Using kinematic equations written in terms of Euler angles, beyond the benefits related to the significance of physical measurable sizes, the following drawback occurs: the use of trigonometric functions in the developed algorithms and the singularity in the matrix for some specific angles. To avoid complications related to solve the kinematic equations, the rotation angles can be used for attitude control, as it is shown in the paper. After linearization of the movement equations, the stability and command matrices are determined and then, a gradient-modified method is proposed for the controller synthesis. In order to improve the convergence properties of this gradient method, the adjoint theory was used. Two attitude control cases are analyzed in the paper: the first one is the situation when reaction wheels are used for the satellite attitude control. In the second case it is assumed that micro thrusters are used for the attitude control. For this latest case, a configuration including a Trigger Schmidt element is used. A linear approximation of the Trigger Schmidt element allows deriving linear control laws which are presented and discussed in the final part of the paper. To conclude, the paper brings the following contributions: - The use of the rotation angles for describing the kinematic motion of the satellite; - The linearization based on Fourier transform of the Trigger Schmidt element used for applying the command moment; - The use of adjoint analysis methods for the design of an optimal controller based on decoupled state type PID (Proportional Integrative Derivative) after each of the three axes of the satellite. Their tuning is made via the proposed optimization method; - The improvement of gradient method by combining with shooting algorithm;

The results are developed and used in the framework of the project European Space Moon Orbit - ESMO founded by European Space Agency in which University POLITEHNICA of Bucharest is involved.