Attitude Control of Satellites Considering Communication Delays

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Background

Satellite formation flying has become one of the most active research topics of space science due to the ever-increasing interest in 'small' satellites, such as micro- and nano-satellites. However, the successful deployment of a satellite formation requires the design of control systems to overcome the many challenges. One of such critical challenges is existence of time-delays. Due to distance between the satellites and the finite speed of light, signal propagation time from one satellite to another cannot be neglected. It is common knowledge that time-delays can cause undesired responses. Then, it can take a long time and more than desired energy for satellites to settle at desired positions. Thus, time-delays in satellite control cannot be ignored and they form the fundamental barrier to success.

Purpose

Effects of time-delay are studied using analytical tools for delay equations. And the results are confirmed via simulations using MATLAB/Simulink. Then, this project develops a new control method for time-delay problems in satellite formation flying by using an analytical tool, and the method is validated using simulation and experiments. Among many issues for satellite control, attitude control of a satellite is focused in this project.

Design/Method

The new analysis and control strategy accommodates time-delays, which is one of the critical obstacles for satellite control. When the chief satellite is in circular orbit, the motion of deputy satellites relative to the chief and spacecraft attitude dynamics can be represented as delay differential equations. Based on the solution to the delay differential equations, a systematic approach is used to control satellite formation flying. The proposed method is verified and compared via simulations in MATLAB. Then, responses of models without delays are compared to ones of delayed models to show effects of time-delays on the satellite control. Momentum Exchange devices (MEX) are devices that are used in attitude control of satellites. They consist of stepper motor and Brushless DC motor, which is set up, modeled and simulated for control of satellites. A control algorithm for the complete system and its real time digital simulation is developed.

Results

Using the analytical tool for delay differential equations, stability analysis and design of control for satellite attitude have been studied. Stability is predicted from positions of eigenvalues, and applying the feedback control, linear feedback systems have been developed via assignment of eigenvalues. The eigenvalues of the closed-loop are assigned to the desired locations in the complex plane. The analytical results are validated vial simulation using MATLAB/Simulink. Also, experimental results show agreement with analytical analysis and simulations.

Conclusions

The solution methods for delay differential equations give one to analyze time-delay effects and enable one to find feedback gains. The stability analysis results show clearly how the system is. And the control method is used to improve system performance as well as stabilization. In future, safe implementation of the method should be considered.