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ATTITUDE CONTROL ALGORITHM FOR SATELLITES WITH PARTIALLY KNOWN INERTIAL PROPERTIES

Abstract

In the past several decades, the utilization of space for human activities has expanded considerably, and both private and government sectors are actively involved in improving the commercial and scientific value of space. However, with the increased number of functional objects populating the orbits around the Earth, the amount of space debris has also accumulated at an alarming rate. Such a state may pose a risk to the safety of both current and future space missions; in particular, spacecraft may need to realize sudden evasive maneuvers, and the space debris must be continuously monitored. Therefore, the mitigation of space debris has become an important theme in space-related research.

A particular challenge in debris mitigation is the ambiguities that arise in inertial properties when capturing objects. To stabilize the attitude of a spacecraft, a typical control algorithm requires accurate inertia measurements. When the spacecraft captures an unknown object, its body configuration and mass change, thereby changing the dynamics and inertial properties. This can lead to the generation of tumbling effects and occurrence of possible deorbiting scenarios owing to the sudden shift in momentum. Therefore, the control algorithm must be robust against these ambiguities and parameter variations. Depending on the known system characteristics, the algorithm can be designed considering model based or adaptive properties to satisfy the control requirements.

Considering these aspects, this paper presents an intelligent attitude control algorithm for a satellite with partially known inertial properties. When the chaser satellite captures an arbitrary object with partially known inertia and velocity, the inertia and velocity of the combined system change instantly. Consequently, an intelligent controller is required, which can adaptably counter these variations to successfully maneuver the system to a stable orientation. To this end, first, the inertia of the combined system is determined using the recursive least squares method. Subsequently, the attitude stabilization problem is addressed using a neural network based controller involving backpropagation and gradient decent techniques to minimize the error function to achieve the control objectives. A high performance can be realized by combining the system identification with controller design. The proposed controller is compared with a classical Proportional-Derivative controller and a fuzzy based controller to analytically understand how the classical control, human intelligence, and machine learning techniques cope with the uncertainties emerging owing to sudden variations in the system. These control architectures are implemented on the MATLAB/Simulink software environment for further validation.