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A NOVEL APPROACH FOR DETERMINATION OF INERTIAL CHARACTERISTICS OF TUMBLING SPACECRAFT

Abstract

In recent years, on-orbit servicing missions have gained a growing attention throughout the world. Since a number of the target spacecraft is non-cooperative, an accurate determination of inertial characteristics is necessary prior to the capture. However, the conventional non-contact measurements provide little information about the target except its attitude information. Therefore, estimating the accurate inertial characteristics of a non-cooperative target is usually extremely difficult via non-contact measurements. The Extend Kalman Filter (EKF) plays a key role in the estimation of inertial characteristics of spacecraft. However, the EKF is based on linear dynamics and measurement models, so the estimation of inertial characteristics is coarse and uncertain for a tumbling non-cooperative target.

To conquer these limitations, a novel approach named fitting-analytical-solution smoother (FASS) is developed to obtain high-precision determination of inertial characteristics of a tumbling spacecraft. The essential idea of FASS is to fit the noisy attitude measurements using certain functions with undetermined parameters. Specifically, the fitting functions are made up by the analytical solution of quaternion differential equations in the attitude dynamical model. The differential equations are a system of linear ordinary dierential equations, whose general solution has not been derived yet except for certain special types. To the authors' best knowledge, few attempts have been made on the analytical solution of the equations. The present study aims at deriving the analytical solution, and consequently utilizing this solution in the high precise determination of inertial characteristics.

In this paper, the target object is assumed to be symmetrical, since quite a large number of the on-orbit spacecraft are symmetrical. Based on the symmetry assumption, the quaternion differential equations are solved analytically. It is proved that the solution of quaternion dynamics equation consists of two sinusoidal functions with undetermined parameters. Furthermore, the relationship between the parameters and the inertial characteristics is also revealed. Thus in the FASS the inertial characteristics can be calculated by sinusoidal functions through fitting the measurement data. As for the fitting process, the Fast Fourier Transformation (FFT) is utilized to get a good a priori estimation of the parameters, and the simplex method is utilized to find the optimal fitting parameters. Numerical simulations show that the FASS is more reliable and accurate than the EKF method in terms of inertial characteristics estimation and attitude prediction.