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REACHABLE DOMAIN OF A PERTURBED SPACECRAFT WITH A SINGLE IMPULSE USING POLYNOMIAL ALGEBRA

Abstract

The reachable domain (RD) geometrically describes all attainable positions of a spacecraft under control with free time of flight. It intuitively shows whether a spacecraft enables to reach the specified position under a single impulse with a fuel constraint. Due to the complicated spacecraft orbit motion, most of the existing RD analysis methods only focus on the study of Keplerian orbit case, which clearly could not represent practical engineering problems. To investigate the RD in the perturbed orbit case, this paper proposes a polynomial approximation method to explore the influence of an initial single velocity impulse on the feasible RD. A new cylindrical coordinate model with the azimuth angle as its independent variable is proposed, therefore it is convenient to map the influence of an initial velocity impulse onto the Poincaré cross-section with a constant azimuth angle. Furthermore, a Matlab built-in convex hull algorithm is applied to analyze the plane RD on the selected Poincaré cross-section. Note that all plane RDs could be combined and incorporated to form the spatial RD.

In contrast to the classical RD analysis method based on the solution of a two-point boundary value problem, the proposed method adopts the semi-analytical Taylor polynomial approximation technique to accurately deliver the influence of an initial velocity impulse along the flow of a high-fidelity orbit model. Therefore, it can be employed to analyze the feasible RD in both Keplerian and perturbed orbit cases. In the Keplerian orbit case, the numerical simulation shows that a sixth order method is accurate enough to obtain the same result with the classical RD analysis method, whose difference is less than 1 m. In an illustrative perturbed orbit case, J_2 influence is considered. The simulation result reveals that the J_2 perturbation not only rotates the RD clockwise, but also reduces the RD. After 50 periods, the projection area of the spatial RD on the x-y plane reduces by 0.4% (about 4×10^5 km^2).

Finally, it is worth to mention that the proposed analysis method not only can be applied to analyze the RD of an active spacecraft under a single control impulse, but also can be employed to explore the influence of the state uncertainties or orbit propagation of space debris generated by a space collision.