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SAFETY TRAJECTORY OPTIMIZATION IN ULTRA-CLOSE PROXIMITY TO LARGE DEBRIS

Abstract

Safety considerations are critical in the success of the rendezvous and docking mission, especially in ultra-close proximity to large debris, where collisions could occur. However, when the thrusters fail to work or the control system has a failure, the collision-avoidance manoeuvre of the chaser spacecraft is not applicable. The anomalies in flight suggest that it is essential to take passive trajectory protection into account, which aims to ensure to the safety of the free-drift trajectory after the thrusters are turned off. This paper focuses on a trajectory-optimization method for a chaser spacecraft operating in ultra-close proximity to large debris. The strategy of passive trajectory protection is combined with active trajectory protection to provide constraints for optimization in case of any failure. Apart from the constraints with respect to the configuration of the target complex and collision probability to ensure the safety of the manoeuvre trajectory, ensuring the safety of the related free-drift trajectory generated by orbital extrapolation imposes additional constraints to optimize the position and velocity at the potential failure point along the manoeuvre trajectory, namely, the starting point of the free-drift trajectory. With the defined constraints, the safe rendezvous trajectory-planning problem is therefore reduced to a constrained nonlinear optimization problem. The optimal solution is obtained by using an adaptive Gauss pseudospectral method. The objective of the method is to use the dynamic residuals as the metric to determine if the number of global collocation points should be increased or if the domain should be divided into more segments and, if so, the number and locations of the newly created segments where collocation points need to be added. Obviously, with this method, a more accurate approximation to the solution of the original continuous optimization problem can be obtained with fewer optimization variables compared to a purely global pseudospectral method. Simulation examples show that the optimized trajectory and its related free-drift trajectories from the failure points are guaranteed to avoid collisions, while the proposed optimization method is capable of developing an accurate approximation to the original continuous problem within an acceptable error tolerance, namely verifying the effectiveness of the proposed methods.