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A NOVEL NONLINEAR GUIDANCE SCHEME FOR POWER-LIMITED AUTONOMOUS RENDEZVOUS WITH FIXED DOCKING DIRECTION AND COLLISION AVOIDANCE CONSTRAINTS

Abstract

The optimal-fuel rendezvous has been investigated extensively in recent years, and many algorithms have been proposed. To date, only the optimal rendezvous problems with impulsive propulsion systems have been fully solved. Even though many approaches based on optimal control theories have been presented to solve the problem of optimal-fuel rendezvous with power-limited propulsion system, most of them deal only with optimal rendezvous in circular orbits. In addition, in practical rendezvous missions, various constraints need to be satisfied, such as the final docking direction, limitation of thruster activation, and collision avoidance. This paper proposes a novel optimal trajectory planning algorithm, called the state dependent model predictive control (SDMPC), to solve the optimal-fuel rendezvous problem with power-limited propulsion systems, fixed docking direction, and collision avoidance.

In this paper, the analytical closed-form solution of the Tschauner-Hempel equations for rendezvous in elliptic orbits are studied and exploited. The solution is based on a state transfer matrix that is completely explicit in time, which is effective for rendezvous in both circular and elliptical orbits. To guarantee the final docking direction, the chaser is required to move to an intermediate point first that is on the docking direction, say the –V-bar direction for example. Then, the chaser approaches the target along the opposite direction of the docking axis. Collisions are prevented by setting a safety sphere centered at the mass of center of the target, the radius of the sphere is assumed to be the length of the docking axis on the target. The chaser is not allowed to enter into this safety sphere during the approaching process.

To the best of the authors' knowledge, there has been no report on treating the optimal rendezvous by applying the state dependent model predictive control (SDMPC). This method is firstly proposed to transform the trajectory optimization problem into a quadratic programming problem (QPP), which is more appropriate to be calculated by onboard computers and the solutions can be easily obtained in a fast manner.

Finally, numerical simulations were carried out and the state dependent model predictive control algorithm was applied to a specific ground simulator to conduct the autonomous rendezvous. Both the numerical and realistic simulations demonstrate that this novel algorithm 1) can deal with both circular and elliptical cases, 2) can guarantee the docking direction without collisions under magnitude constraint of orbital thrusters, and 3) could be used to generate the fuel-optimal trajectory on-line rapidly.