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OPTIMAL TRAJECTORY DESIGN FOR SAFETY RENDEZVOUS BASED ON SPARSE MODELING

Abstract

This paper proposes a new method for rendezvous problems applicable under various constraints. Rendezvous problem is one of the essential topics for space development. There exist many situations where the rendezvous problem is applied: supplying goods to International Space Station, repairing or inspecting satellites, and removing debris. In the rendezvous problem, numerical and analytical approaches to obtain the optimal trajectory have already studied. However, most of conventional approaches cannot solve the fuel optimal problem directly. In addition, considering safety constraints for collision avoidance makes the conventional analytical approaches complicated and intractable.

In order to overcome these problems, this paper focuses on optimal control based on "sparse" structure presented by Nagahara, 2016. For example, Homan transfer trajectory can be considered as an optimal fuel sparse trajectory operated by only two thrust burns. By using sparse modeling, the minimum fuel trajectory can be obtained directly, which cannot be achieved in the conventional methods. The final state of the rendezvous problem is set as the linear constraint condition by using the state transition matrix of the Hill-Clohessy-Wiltshire equation. The solution for a fuel minimum trajectory is exploited by Alternation Direction Method of Multipliers (ADMM) algorithm. This algorithm performs iterative calculation using a proximity operator representing a gradient of a non-differentiable function. The proximity operator of L^1 the norm of an objective function represents the fuel consumption of the trajectory design problem for rendezvous. Therefore, since the ADMM algorithm can be performed without differential calculations, it is executed at high speed.

This paper examines how the design parameters in the ADMM algorithm work in the optimal fuel rendezvous problem. Moreover, this paper considers the rendezvous problem under several safety constraints: camera angle constraint, obstacle avoidance from target satellite's antenna, and plume impingement. Some of those constraints cannot be solved by the standard ADMM algorithm, because constraint conditions must be represented as a convex set in the standard one. Therefore, this paper proposes a new method to solve the problem based on ADMM algorithm including constraints represented as non-convex sets.