Rendezvous control of spacecrafts via constrained optimal control using generating functions

Dijian Chen,[1] and Kenji Fujimoto[2*]
[1]*Nagoya University, Japan;* [2]*Kyoto University, Japan*
k.fujimoto@ieee.org

Keyword : optimal control, generating function method, rendezvous control

Optimal control deals with the problem of finding a control law and the corresponding state trajectory for a given system such that a certain optimality criterion is achieved. For control of spacecrafts, optimal control plays an important role and is often used in designing their trajectories. There is a method called a generating function approach to solve optimal control problems which derives a family of optimal trajectories as a function of the boundary values of the states [1]. The authors have contributed to its extensions such as coping with nonlinear systems [2], discrete-time systems, and proposing a new method called a double generating functions method using a pair of generating functions to obtain accurate solutions with low computational cost.

Many practical optimal control problems require solutions to satisfy prescribed state/input constraints. For instance, the maneuvering devices of spaccrafts such as thrusters and reaction wheels have input and state constraints. So far no results took the constraints into account in the generating function approach. This paper proposes to use a class of penalty functions to obtain optimal solutions satisfying given state/input constraints. A sufficient condition for the penalty function is clarified by which the existence of the corresponding generating function and optimal trajectory are ensured. Then applying the authors' former result on nonlinear single/double generating function method [2] to control the spacecraft, the objective task is achieved.

We apply the constrained optimal control method explained above to a spacecraft rendezvous problem as depicted in Fig.1. Constraints are added to the velocity of the spacecraft so that we can let it stay in a prescribed safe region. Since we need to approximate the penalty function through Taylor series expansion for calculation, the effect of the approximation error is evaluated in this paper. Numerical simulations will demonstrate how the proposed method works with this control task. Fig.2 shows the trajectory of the velocity of the aircraft which indicates that the proposed method let the velocity stay in the desired constrained region successfully.

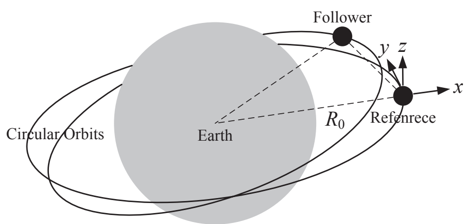

Fig.1. Himegin Hall.

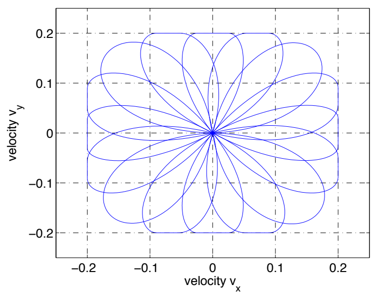

Fig.2. Trajectory of the velocity

References

[1] V. M. Guibout and D. J. Scheeres, Solving relative two-point boundary value problems: spacecraft formation flight transfers application, *Journal of Guidance, Control, and Dynamics*, **27** (2004), pp.693-704.
[2] Z. Hao, K. Fujimoto and Y. Hayakawa, Approximate solutions to the Hamilton-Jacobi equations for generating functions: the general cost function case, *Proceedings of the 9th Asian Control Conference*, Istanbul (2013).