Trajectory Design for Lagrange Point Missions using Dynamical Systems Theory

Yoshihide Sugimoto

Abstract on Ph.D. Thesis

This thesis investigates orbit maintenance of periodic orbits around a collinear Lagrange point in Elliptic Restricted Three-Body Problem (ER3BP) that includes the eccentricity of co-orbiting dominant two bodies. Since the ER3BP is higher fidelity dynamic model than commonly used Circular Restricted Three-Body Problem (CR3BP), the designed orbit in the ER3BP gives a realistic initial condition. The application of the Dynamical Systems Theory (DST) impulsive velocity correction is performed to cancel out the stretching displacement, which is obtained using the eigenvalue problem of the State Transition Matrix, from the reference orbit. The maneuver stabilizes the determined state displacement. Also the periodic orbits have been designed numerically by differential correction and Recursive Multi-Step Linearization (RMSL) method. The RMSL method can avoid the difficulty of the long ballistic trajectory design by means of the trajectory separation into multiple segments. Those results are verified in actual dynamic model using real ephemerides.

In the ER3BP, the period of particle's motion has to be synchronized with the primaries orbital period because of the time dependency of model. On the other hand, the orbits around collinear Lagrange points are highly unstable and the periodic orbit design problem is not so straightforward when the orbit period becomes very long. The RMSL method is an alter- native method to multiple shooting method to eliminate the velocity gap to design a ballistic trajectory. The whole period is divided into multiple segments and enables linear analysis along the trajectory for each divided segment and the velocity disagreements generated by the separation are then minimized within a sufficient tolerance. The RMSL method gives any length of the periodic orbit once the dynamics are briefly provided.

The feasible maintenance maneuver design comes out from the loosing the control constraints. The diverging subspace is only error stretching direction in the state displacement. Therefore, when the diverging component is nullified, the deviation will not increase and stay around the reference trajectory. The idea is that only the diverging displacement in the orbit deviation is canceled out by the impulsive velocity correction to stabilize the motion nearby the reference trajectory. However, the periodic orbits in the ER3BP are closed in the phase space with the multi-revolution and the maximum error stretching direction may change in every revolution. Therefore, the correction methods are described as Local and Global corrections depending on the correction target of the error stretching direction. The Local correction method define the correction target based on the STM propagated in a specific correction time interval and the Global correction method is taking account the diverging direction obtained from the Monodromy matrix.