Autonomous Orbit Determination of Multiple Spacecraft
Using Active Sensing of Satellite-to-Satellite Tracking

Kota Kakihara[1*]
[1]*The University of Tokyo, Japan*
kakihara@space.t.u-tokyo.ac.jp

Keywords : Active Sensing, Autonomous Orbit Determination, Satellite-to-Satellite Tracking.

Orbit determination is essential for space missions, especially for the interplanetary missions. Interplanetary spacecraft orbits are conventionally estimated by processing the observations from the Earth. This ground-based navigation is well-developed but expensive, and it is excessive for reasonable missions, such as interplanetary micro-spacecraft. Therefore, autonomous orbit determination without ground stations will be significant for future interplanetary missions.
Satellite-to-satellite tracking (SST) is a measurement to observe the relative range and range-rate between two or more spacecraft, and it is applicable for autonomous orbit determination. Previous studies show that inertial orbits are observable by using only range measurement data if spacecraft are strongly perturbed by the third body (Fig.1), and this method cannot be applied for general problems, such as two body problems[1]. This research proposes new orbit navigation method using SST and active sensing technology (Fig. 2).

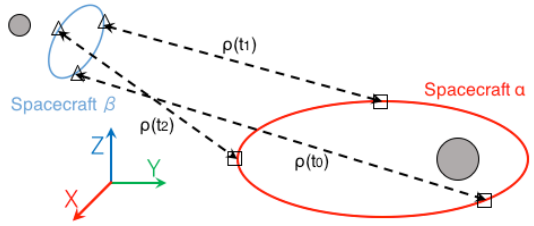

Fig. 1 SST with third body

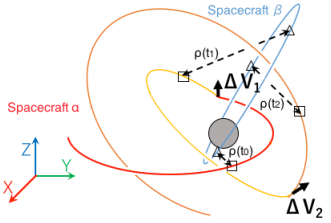

Fig. 2 SST with maneuvers

The key problem of SST is the uncertainty of orbit orientations. There is rotational symmetry about the central body for orbit determination with only range measurement, and the information of orientation parameters is needed for absolute orbit determination (Fig. 3). The proposed method uses more than two active sensing ΔV maneuvers and these maneuvers give oriental information. This paper proves that one maneuver is not sufficient because the range data are symmetric about the orientation axis of the ΔV (Fig. 4).

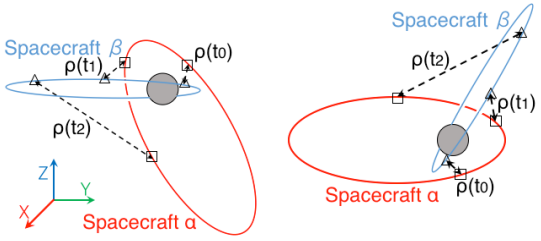

Fig. 3 Rotational symmetry about central body when there is no maneuver.

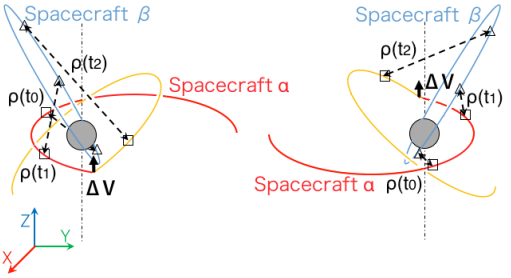

Fig. 4 Rotational symmetry about orientation axis of the ΔV when there is one maneuver.

Theoretical analyses prove that the positions and velocities of two spacecraft and the magnitudes of two ΔVs can be detected if the information of times and orientations of ΔVs are given. Finally, numerical simulations confirm that the orbits and the magnitudes of ΔVs are observable in general two body problem cases but the orbits are not observable if the number of ΔV is one or the orientations of two ΔVs are the same. This result shows that this method would be applicable to interplanetary missions.

Reference

[1] Hill, K., and Born, G.H., Autonomous Interplanetary Orbit Determination Using Satellite-to-Satellite Tracking, *Journal of Guidance, Control, and Dynamics*, Volume 30, No.3, 2007, pp.679-686.