Estimation Algorithm of Relative Position and Attitude during Proximity Rendezvous and Docking Using Multiple Ultra-Wide-Band Devices

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Rendezvous and docking systems need to measure relative distance and relative attitude between space vehicles before docking. In case of deep space vehicles, spacecraft has to cope with proximity rendezvous automatically because of the limitation of signal transmission time from and to ground station. The topic of this research is a proposal of relative distance and attitude estimation algorithm for automatic rendezvous and docking system by using UWB (Ultra-Wide-Band) devices. The UWB devices are small, high precision, and low power radar transceivers. They can measure distance between the UWB devices and communicate with each other simultaneously.
This rendezvous and docking system is the case study of the space probe "PROCYON-mini" carried by the "DESTINY" spacecraft. The mission objectives of PROCYON-mini are close observation of asteroids and automatic rendezvous and docking to the DESTINY in deep space. The rendezvous and docking mission of PROCYON-mini is divided in three phases, and PROCYON-mini uses different navigation sensors in each phase. This research aims to validate the feasibility of rendezvous and docking mission in deep space and evaluate the navigation accuracy of proximity phase in which the distance between the space vehicles is from 30cm to 300m.
In this paper, ranging accuracy and noise characteristics of UWB devices are evaluated by measurement experiments with actual devices. In the experiments, distance and angle between moving UWB devices are measured and the noise characteristics (e.g., bias noise and random noise) of the UWB devices are evaluated.
Considering the modeled noise characteristics, a filtering algorithm is proposed in order to estimate relative position and velocity. Attitude information of chaser and target spacecraft is estimated with Star Tracker (STT) in each spacecraft. The attitude information can be shared by using the communication function of the UWB devices. In addition, multiple UWB devices can also be used to estimate the relative attitude by using distance information. When the STTs cannot estimate attitude because of some limitations such as sun keep out angle, shadows of chaser or target and update frequency, the UWB devices are used to estimate attitude and angular velocity. This research introduces and compares estimation algorithms for relative position, velocity, attitude and angular velocity into three patterns. These patterns are different in what components are used to estimate attitude information: STT only, UWB devices only, and UWB devices and STT complementary.

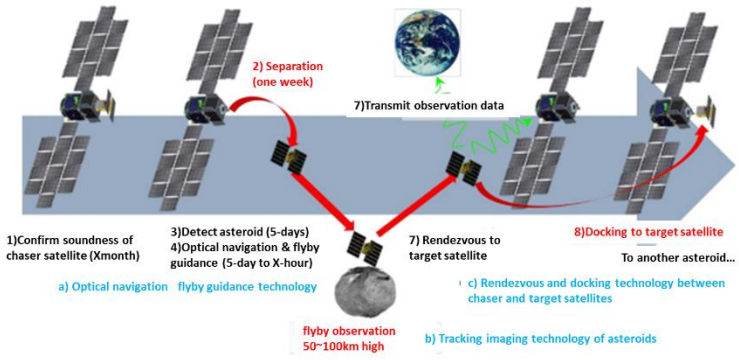

Fig. 1. Mission phase of PROCYON-mini and DESTINY

References

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