Modeling and Simulation of Contact Dynamic Behavior in Space Missions

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Abstract

Understanding of contact dynamics or collision behavior is important in the design and operation of space systems. In this presentation, two distinct examples are introduced and discussed.
The first example is Japanese "Hayabusa" probe that made physical contact on the surface of the target asteroid "Itokawa" for the soil/dust sample acquisition (see Fig.1). The sample acquisition strategy is called touch-and-go operation, in which a compliant mast mounted on the spacecraft makes the physical contact for a very short time, then bounce and lift off from the surface. Since the environment is almost micro-gravity, the spacecraft naturally bounce on the surface. In order to predict the motion behavior and evaluate the safety of the mission scenario, the first author of this presentation has conducted a wide range of simulations based on mathematical models of the complaint mast and that of the surface contact. The simulations were based on linealized models for simplicity, but practically useful to predict the motion behavior of the Hayabusa spacecraft during the touch-and-go sampling.
The second example is capturing operation of a free-floating target, which will be a dead or malfunctioning spacecraft, by a manipulator arm mounted on a chaser satellite in Earth orbit. This problem has been addressed for many years, but we still need a lot of research effort particularly in case that the target is "non-cooperative." A bad scenario is that the chaser mis-hits the target then makes the situation worse. On the other hand, a good scenario is that the collision between the chaser arm and the target can absorb the kinetic energy of the tumbling target. The authors believe that such operation will be possible by an appropriate impedance control of the chaser arm. In order to discuss this issue, the authors proposed a concept named Virtual Mass for Impedance Systems so as to achieve "impedance-matching." The concept has been verified by mimetically simulations and hardware experiments (see Fig.2).

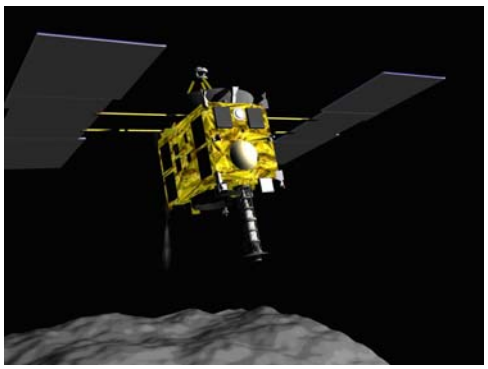

Fig.1: Touch-and-Go sampling by Hayabusa

Fig.2: Target capture experiment using a free-floating test bed