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Title

6-DOF orbit-attitude stabilization around an asteroid by using performance based intermittent event-triggered control

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Abstract

Ever since JAXA's Hayabusa returned to earth miraculously with rocky samples taken from asteroid 25143 Itokawa for the first time in the history of human beings, much more attention has been paid to the field of asteroid exploration. So far, the most reliable strategy for landing on an asteroid has been to send the probe into near-circular stable orbits that center the asteroid with a very low orbital altitude, take accurate photos to generate 3D geographical models to analyze the most suitable areas of landing, use various detection devices to detect and analyze the asteroid's surface and inner situations, and finally land on the asteroid, take some samples, and return.

The stabilization of a circular orbit around an asteroid is much more difficult than orbital stabilization around a planet like the Earth. As a result of the non-spherical structure of an asteroid, the gravitational field of an asteroid is irregular, with quite different gravity at the same orbital altitude. Thus, a stable orbit that centers an asteroid is always very hard to find or even completely impossible, and the only accessible approach is to employ corresponding orbit maintenance control strategies to ensure that the probe is flying around the asteroid on a near circular orbit. Considering the actual circumstance of a non-spherical gravitational field led by an asteroid, it's permitted to deviate the orbital altitude of the probe in a minor range, which means that a performance-based event-triggered strategy is a very good choice in this case. Researchers at Caltech [1] have tested this way, but they didn't consider the influence of attitude in these strong orbit-attitude coupling mission scenarios resulting from a strong non-spherical gravitational field.

Considering the ill-fated lifetime of JAXA's Hayabusa with all kinds of failures in actuator systems and sensor systems, this paper provides a full 6-DOF performance barrier-based event-triggered control system design while considering strong orbit-attitude coupling led by the non-spherical gravitational field of an asteroid. The proposed method can stabilize the orbit and attitude of a probe instantly by carrying out corresponding control orders when they are identified to escape the regulated bounded areas. Both the influence of the asteroid on the orbit and attitude of a probe have been considered so that the mutual influence of attitude and orbit on each other can be calculated in the real-time dynamics of the simulation procedure, which takes asteroid 25143 Itokawa as the centering celestial body. Further work will be done with fault-tolerant strategies in correspondence to the lessons of JAXA's Hayabusa.

References

[1] Ong, Pio, Gilbert Bahati, and Aaron D. Ames. "Stability and safety through event-triggered intermittent control with application to spacecraft orbit stabilization." *2022 IEEE 61st Conference on Decision and Control (CDC)*. IEEE, 2022.