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DYNAMIC CHARACTERISTICS OF TETHERED ASTEROID PROBE CONSIDERING TETHER'S FLEXIBILITY

Abstract

A tethered asteroid probe is a probe attached to an asteroid with a connecting rope and the rope is anchored to the surface of the asteroid at one end. The tethered asteroid probes have broad application prospects in asteroid approach detection, sampling, assisted landing, gravity assist, planetary defense, etc. The small size, irregular shape, and uneven density of asteroids lead to weak and uncertain gravitational fields, so the probe needs to consume a lot of fuel to achieve long-term companion flight or hovering. The tethered probe can hover for a long time without consuming fuel by anchoring on the surface of the asteroid with a connecting tether, which is of great value for high-precision mapping, sampling, and other exploration missions. Physical properties such as tether material density, modulus of elasticity, and internal tension affect the possible domain and stability of the hovering. In this paper, the gravitational field in the vicinity of an irregular asteroid and the dynamics of the tether probe are investigated. First, to efficiently obtain the gravitational field on and near the asteroid's surface, a deep neural network was trained to model the gravitational field near the asteroid using the gravitational acceleration data generated by the polyhedral method as the standard data, so that the gravitational acceleration and gravitational potential at the observation point can be quickly obtained. Then, the dynamics equations of the tethered probe under the asteroid's gravitational field are established by taking a probe hovering in the vicinity of the asteroid and taking into account the mass and elasticity of the connecting tether. The equations include the rotation of the asteroid, the elastic vibration of the tether, and the orbital motion of the probe. Finally, the change in the position of the artificial gravitational equilibrium point caused by the tether and its stability are analyzed. The results show that the probe is connected to the asteroid by a tether, which increases the feasible domain of the gravitational equilibrium point. The length of the tether and the amplitude of the tension in the tether have significant effects on the dynamics of the probe, the position of the equilibrium point, and the mass of the tether as well as the influence of the flexibility cannot be neglected. The research in this paper has practical implications for asteroid approach detection and sampling missions using tethers.