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AUTONOMOUS GNC FOR ASTEROID DEFLECTION AND ATTITUDE CONTROL VIA LASER ABLATION

Abstract

This paper presents an autonomous GNC system for a spacecraft conducting a laser ablation mission in close proximity of an asteroid. The laser ablation consists of irradiating asteroid's surface with a laser beam. The laser induces the sublimation of a portion of the surface on the asteroid. The jet of gas and debris thrusts the asteroid off its natural course. The laser will first be employed to de-spin the asteroid. This is used to slow the asteroid's rotational period, making the laser ablation process far more effective. The combination of the thrust on the asteroid, plume impingement, laser recoil and solar radiation pressure will deviate the spacecraft such that autonomous control based on-board estimate is needed. The spacecraft employs and processes the measurements coming from its own on board measurements, given by a laser range finder, high resolution cameras, and an impact sensor. The latter is combined with the attitude information and, thus, used to estimate the plume impingement force, which acts in the same direction of the exerted thrust due the laser ablation. In this way the spacecraft is able to estimate on-board the imparted acceleration and the effectiveness of the laser ablation procedure. An unscented Kalman filter is used to estimate spacecraft position and velocity together with the perturbative accelerations. A second filter is implemented to estimate the asteroid's rotation by extracting and tracking the motion of asteroid's features, using either optical flow or spectral methods. These variables are used to implement spacecraft trajectory control in order to permit the laser to work at his optimal focussing distance. Two trajectory control strategies are considered: in the first one impulse bits maintain the spacecraft within a 1 m box from the reference trajectory; the second strategy is based on continuous control based on low thrust. It is shown that both the techniques are viable and accurate. Discrete control does not downgrade the laser performance given the small oscillations with respect to the nominal conditions. Nonetheless low thrust allows the spacecraft to impart a higher momentum onto the asteroid. Spacecraft dynamics takes into consideration the effects of gravitational forces from the Sun and the asteroid, solar radiation pressure and perturbations due to the ablation process. Other effects due the rotation of the inhomogeneous gravity field of the asteroid and the spacecraft tugging on the asteroid are modelled and included in the description of the overall motion of asteroid-spacecraft system.