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☒ **Mitigation Techniques & Missions**

Optical Navigation and Fuel-Efficient Orbit Control Around an Irregular-Shaped Asteroid

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Since the beginning of space exploration, robotic probes have been invaluable for probing into the secrets of the solar system. As our interest to explore continues to grow, spacecraft are requiring greater and greater autonomy due to the distance from Earth to be able to return the desired data. Long-duration missions close to asteroids are an example of an area which requires this autonomy due to the uncertainty and sensitivity of the surrounding dynamical environment. Figure 1 illustrates graphically how an object's orbit varies drastically for different but similar initial conditions [1]. For the orbits shown, the initial position around the asteroid is varied, and the velocity is assumed to be the local circular velocity. The first orbit starts directly on the X-axis, and remains stable for great lengths of time. The second orbit is shifted 45^o from the X-axis, and after nearly a week escapes the asteroid's gravity. The final orbit begins on the Y-axis, and impacts the asteroid after two orbits. Given how such an irregular gravity field affects the trajectory of a spacecraft, some form of active control is necessary to ensure the spacecraft can safely execute its mission successfully.

One form of active orbit control, as investigated by Winkler et al. [1], is simple feedback control augmented by disturbance-accommodating filtering. It has been shown that this type of control can effectively keep a spacecraft in a stable orbit around a body with very little control effort. The entire control scheme, though, relies on being able to accurately determine the spacecraft's position and velocity vector with respect to the asteroid, which was assumed to be exactly known in the previous work. In reality, such information would have to be estimated using a combination of optical cameras and LIDAR.

Optical navigation already has some basis in spacecraft guidance. One prominent example would be its previous use in the Deep Impact mission to ensure a successful impact with Tempel 1. More recently, is has been announced that the future NASA mission OSIRIS-Rex, which is scheduled to launch in 2016, will use a 3D Flash LIDAR camera for navigation and mapping purposes as it orbits three miles above the asteroid 1999 RQ36 [2].

This paper will improve the disturbance-accommodating filtering control scheme by demonstrating how to robustly select filter/controller gains. The active control scheme also utilizes state vector estimates provided by 3D Flash LIDAR as would be done with actual missions. To enable this study, an in-house program of an asteroid tumbling through space has already been developed and implemented on a GPU (Graphic Processing Unit). With this code, it is possible to realistically simulate a variety of worst-case lighting conditions on an asteroid of any shape, and therefore provide optical measurements similar to that provided by navigation cameras. With this optical data, fuel-efficient and reliable orbit control strategy will be tested and evaluated for close-proximity operations around a reference irregular-shaped asteroid on a GPU.

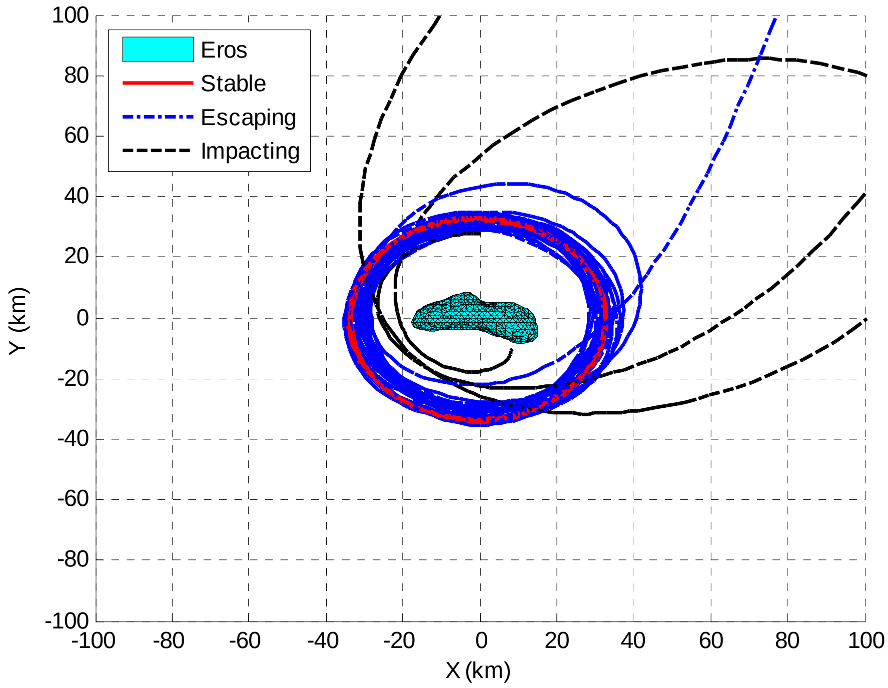

Figure 1. Comparisons of stable, escaping, and impacting orbits around asteroid 433 Eros [1].

References:

[1] Winkler, T., Hawkins, M., Lyzhoft, J., and Wie, B., “Fuel-Efficient Feedback Control of Orbital Motion Around an Irregular-Shaped Asteroid,” AIAA 2012-5044, AIAA Guidance, Navigation, and Control Conference.

[2] Brown, D., “NASA To Launch New Science Mission To Asteroid In 2016,” May 25, 2011. Web, November 10, 2012. <http://www.nasa.gov/home/hqnews/2011/may/HQ_11-163_New_Frontier.html>