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ANALYSIS OF NATURAL LANDING TRAJECTORIES FOR PASSIVE LANDERS IN BINARY ASTEROIDS: A CASE STUDY FOR (65803) 1996 GT DIDYMOS

Onur Celik[(1)], Joan-Pau Sanchez[(2)], Ozgur Karatekin[(3)] and Birgit Ritter[(4)]
[(1)]*Research Student, The Graduate University for Advanced Studies (SOKENDAI), Sagamihara/JAPAN, +81(0)50-6867-5062, onur.celik@ac.jaxa.jp*
[(2)] *Lecturer, Cranfield University, Bedford/UK, +44 (0) 1234 750111 x5120, jp.sanchez@cranfield.ac.uk*
[(3)]*Senior Researcher, The Royal Observatory of Belgium, Brussels/BELGIUM, +32 23736730, ozgur.karatekin@observatory.be*
[(4)]*Researcher, The Royal Observatory of Belgium, Brussels/BELGIUM, +32 (0) 23736753, birgit.ritter@observatory.be*

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ABSTRACT

Binary asteroids are believed to constitute about 15% percent of the near-Earth asteroid (NEA) population. Their abundance and yet-to-be-resolved formation mechanism make them scientifically interesting, but they can also be exploited as a test bed for kinetic impactors, as the Asteroid Impact and Deflection Assessment (AIDA) joint mission proposal suggested. In addition to impactor spacecraft of AIDA, i.e. DART, the observation spacecraft, called Asteroid Impact Mission (AIM) (whose future is now uncertain) is to characterize the binary asteroid system (65803) Didymos, including pre- and post-impact variations. Due to the highly perturbed dynamical environment around asteroids, large, and generally expensive missions are preferred to be operated in a safe distance to the target asteroid. Even if advanced remote sensing techniques provide the finest details of the target, surface agents can obtain higher resolution and ground truth data even by using rather simple measurement methods.

Lander solutions for small body exploration have already been suggested in various missions/proposals. The most recent example is the AIM proposal, which envisage

to deploy MASCOT lander on the surface of the secondary body of the Didymos system, informally called Didymoon. Additionally, AIM proposed to carry two CubeSats on board. A team led by the Royal Observatory of Belgium (ROB) proposed the Asteroid Geophysical Explorer (AGEX) CubeSat to land on Didymoon. CubeSats can foresee much more daring employments in small body (i.e. low gravity) environments due to their versatile character and low development cost. Nevertheless, they possess only limited AOCS capabilities because of their size, and in many cases they are passive.

This research offers novel and purely ballistic landing trajectories by exploiting the natural dynamics of binary systems. The framework of Circular Restricted Three-Body Problem (CR3BP) is used for this purpose, in which two asteroids orbit each other around their common center of mass, while the third body (CubeSat) moves under the influence of their gravitational field. Starting different latitude-longitude point on the surface given by a densely defined mesh, the trajectories are propagated backwards in time through the low energy gate of the asteroid system, i.e. L2 point. A newly developed bisection algorithm ensures to generate the lowest energy trajectory for landing point under given constraints. The results suggest that landing speeds less than 8 cm/s are possible, while the coefficients of restitution over 0.9 would ideally ensure a successful landing.

Robustness of trajectories is also investigated. Uncertainties in the deployment mechanism and GNC errors of the mothership are considered. Pseudo-random errors are added to trajectories that are successfully obtained in backwards time propagation; these error-containing trajectories are then propagated forward to the surface in a Monte Carlo simulation. The deployment altitude is found to be severely degrading the success rate. The GNC velocity errors are also found to be more effective than their position counterparts. A success rate over 99.7% (3σ) can be achieved, though extra requirements might need to be considered for the mothership design.

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