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Last-Minute Semi-Analytical Asteroid Deflection by Nuclear Explosion

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In this paper, a semi-analytical method to optimize the miss distance for impulsive asteroid deflection is presented. It can be applied to the design of any impulsive asteroid deflection mission. It is particularly useful when optimizing last-minute deflection by nuclear explosion, where the optimum impulse direction can be far from tangential. The method hinges on minimizing the impulse size under a constraint on the b-plane coordinates. The optimization is based on a fast, semi-analytical algorithm developed for Low Earth Orbit optimal collision maneuvers design. Several deflection strategies can be selected following this algorithm. Additionally, impulsive deflections leading to resonant returns are avoided by analysing the resonant circles in the b-plane.

To test the performance of the method, it is applied to the fictitious asteroid 2017PDC. As a first strategy, the b-plane cross point is constrained to be at a distance from the Earth center greater than a given amount. The minimum-impulse maneuvers with varying anticipation show non-trivial properties. For integer multiples of the asteroid period, the optimal maneuver is purely prograde or retrograde. An increasing tendency, superimposed to periodic variations, can be observed on the required impulse size as the deflection is performed closer to the conjunction. The impulse size abruptly grows shortly before the conjunction. The optimal maneuver orientation may present discontinuities as the maneuver anticipation changes. This will happen when different local optima exchange global optimality. Finally, we compute the resonant circles corresponding to returns of the asteroid in up to 20 years after the 2027 encounter. The optimal maneuver timing can be chosen as to avoid short-term resonant returns, thereby eliminating the risk of an impact in a subsequent encounter.

The strategy presented above strongly modifies the timing of the conjunction and could potentially lead to a collision if the along-track orbit uncertainty is large. For this reason, as a second strategy we propose minimum-impulse deflection maneuvers that increase the Minimum Orbit Intersection Distance (MOID) above a threshold. The optimal MOID-increasing maneuvers show completely different properties. The required impulse size is about an order of magnitude larger than for the previous strategy,

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but it shows a purely periodic behavior. This suggests that this method is especially interesting for last minute deflection maneuvers.

Comments:

Oral presentation preferred