PDC2015
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IAA-PDC-15-02-11

The linear method for impact probability estimation using a curvilinear coordinate system

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Keywords: *impact probability; fast numerical method; orbital coordinate system;*

ABSTRACT

We developed a new linear method for estimation of the impact probability of near-Earth objects (NEOs). The important advantage of this method is using the unique curvilinear coordinate system related to the nominal orbit of an asteroid. One of the coordinates of this system is the mean anomaly in the osculating orbit of an asteroid. The other two coordinates of this system are Cartesian ones and their origin lies in the osculating orbit. This system allows one to take into account the distribution of virtual asteroids mainly along the nominal asteroid orbit. The method is based on the assumption that errors in the coordinates and velocities of an asteroid have a normal distribution at all times. The probability is calculated as a six-dimensional integral of the probability density function of coordinates and velocity errors. Also, we proposed a technique that allows us to decrease by several orders of magnitude the time of this integral's computation in the introduced coordinate system.
This method has a limitation on usage due to the assumption. Close approaches to massive bodies can break the normal distribution of virtual asteroids and disturb the impact probability value. However, it works well enough and quickly if close approaches either absent or do not have a noticeable effect on the result. It should be emphasized that newly discovered objects generally have a short observation arc and few observations; hence generally they have large errors in their orbit parameters. In this case, at the time of close approach we can estimate the impact probability using the proposed method, yet after this close approach the orbit parameter errors become much larger and therefore the impact probability becomes much smaller, so it can make no sense to calculate it after close approach.
In the cases where close approaches are not significant a comparison with the Monte Carlo method shows good agreement. The results of our research also show

the advantage of using the proposed curvilinear coordinate system instead of a Cartesian one in cases where the dispersion ellipsoid of virtual asteroids is large enough.

D. E. Vavilov, Yu. D. Medvedev *A fast method for estimation of the impact probability of near-Earth objects* // Monthly Notices of the Royal Astronomical Society, 2015, volume 446, issue 1, 705-709.