18th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Orbit Determination and Propagation (9)

Author: Mr. Yan Nevmerzhitskiy
Moscow Institute of Physics and Technology (MIPT), Russian Federation, nevmerzhitski_y@mail.ru

Mr. Vladimir Panov
Moscow Institute of Physics and Technology (MIPT), Russian Federation, vladimir.panov@phystech.edu
Mr. Vadim Semaka
Moscow Institute of Physics and Technology (MIPT), Russian Federation, semaka.viu@mipt.ru
Mrs. Natalia Zavialova
Russian Federation, zavialova.na@mipt.ru
Dr. Sergei Negodiaev
Moscow Institute of Physics and Technology (MIPT), Russian Federation, snegod@mail.ru

NEW APPROACHES TO ACCELERATE CALCULATIONS OF ORBITAL DYNAMICS

Abstract

Today accurate prediction of space object position is of primary importance in many tasks, such as remote sensing, organizing satellite communications, as well as observing space objects from the Earth. To predict the movement of objects, effective numerical methods are required; moreover, calculation should be carried out for large groups of spacecraft. The need for accurate calculations, as well as high performance algorithms, imposes serious requirements on numerical methods for integrating equations of motion. Numerical methods applied in practice (Everhart, Gauss-Jackson methods) make it possible to carry out reasonably accurate calculations of spacecraft dynamics, but at the same time take a large number of arithmetic operations. In particular, the performance of methods for integrating the equations of celestial mechanics directly depends on the number of calls to calculate the resultant force on the spacecraft, which is a computationally expensive task. Therefore, the main goal of the present work is to develop approaches that can significantly accelerate existing algorithms for the numerical integration of celestial mechanics equations.

Among the calculations of the main forces acting on the spacecraft, the most difficult one from a computational point of view is the calculation of the force of gravitational attraction to the Earth. The last one is represented by a weakly converging series of Legendre polynomials, which requires summation over a large number of harmonics. Therefore, an algorithm of three-dimensional spline interpolation of the gravitational potential with the subsequent calculation of the gravitational force is applied in this work. It is worth noting that error estimation methods based on the Runge rule take several calculations to evaluate the value of error. That is why an algorithm for estimating numerical error without additional calls from the integrator is proposed.

Proposed algorithms were implemented in a software package that was verified by comparison with analytical solutions (movement in circular and elliptical orbits in the field of point mass potential), as well as with the results of calculations in the GMAT package (calculations for real gravitational potential). The results of integration are compared with Everhart, Gauss-Jackson and Dorman-Prince methods using the developed methods for calculating the gravitational force and error estimation. As a result, the computational speed has increased by more than 10 times, which allows real-time calculations of dynamics of a large number of space objects.