World Academy of Science, Engineering and Technology
International Journal of Mathematical and Computational Sciences
Vol:18, No:01, 2024

Orbit Determination from Two Position Vectors Using Finite Difference Method

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Abstract : An unusual approach is developed to determine the orbit of satellites/space objects. The determination of orbits is considered a boundary value problem and has been solved using the finite difference method (FDM). Only positions of the satellites/space objects are known at two end times taken as boundary conditions. The technique of finite difference has been used to calculate the orbit between end times. In this approach, the governing equation is defined as the satellite's equation of motion with a perturbed acceleration. Using the finite difference method, the governing equations and boundary conditions are discretized. The resulting system of algebraic equations is solved using Tri Diagonal Matrix Algorithm (TDMA) until convergence is achieved. This methodology test and evaluation has been done using all GPS satellite orbits from National Geospatial-Intelligence Agency (NGA) precise product for Doy 125, 2023. Towards this, two hours of twelve sets have been taken into consideration. Only positions at the end times of each twelve sets are considered boundary conditions. This algorithm is applied to all GPS satellites. Results achieved using FDM compared with the results of NGA precise orbits. The maximum RSS error for the position is 0.48 [m] and the velocity is 0.43 [mm/sec]. Also, the present algorithm is applied on the IRNSS satellites for Doy 220, 2023. The maximum RSS error for the position is 0.49 [m], and for velocity is 0.28 [mm/sec]. Next, a simulation has been done for a Highly Elliptical orbit for DOY 63, 2023, for the duration of 6 hours. The RSS of difference in position is 0.92 [m] and velocity is 1.58 [mm/sec] for the orbital speed of more than 5km/sec. Whereas the RSS of difference in position is 0.13 [m] and velocity is 0.12 [mm/sec] for the orbital speed less than 5km/sec. Results show that the newly created method is reliable and accurate. Further applications of the developed methodology include missile and spacecraft targeting, orbit design (mission planning), space rendezvous and interception, space debris correlation, and navigation solutions.

Keywords : finite difference method, grid generation, NavIC system, orbit perturbation
Conference Title : ICMSSC 2024 : International Conference on Mathematics, Statistics and Scientific Computing
Conference Location : Bengaluru, India
Conference Dates : January 29-30, 2024

Open Science Index, Mathematical and Computational Sciences Vol:18, No:01, 2024 publications.waset.org/abstracts/168715.pdf