An investigation on frame transformations for numerical orbit propagation

Danhe Chen, Nanjing University of Science and Technology, China, Juliachen@njust.edu.cn;
Gen Xu, Nanjing University of Science and Technology, China, stuxugen@gmail.com;
Xiaolong Zhang, Tampere University of Technology, Finland, xiaolong.zhang@tut.fi.

Abstract

Numerical orbit propagation is a key issue related to GNSS application. For example, autonomous constellation maintenance for GNSS satellite can significantly reduce working load on ground segment, and it requires orbit determination and prediction onboard. Our recently CubeSat “Huaian-Enlai”, which lunched into orbit this Jan with a de-orbit sail. The sail use the drag of atmosphere to control the satellite leave its orbit and re-entry earth atmosphere when missions are completed. Currently, we also develop onboard algorithm for its orbit determination, evaluation of orbit control, and selection of optimal trajectory. Another massive market for orbit propagation is GNSS ephemeris extension, which can shorten the First Time to Fix (FTF) on the mobile devices.

Normally, propagator integrate orbit trajectory in Geocentric Celestial Reference Frame (GCRF), while GNSS Ephemeris are given in International Terrestrial Reference Frame (ITRF). Additionally, numerical propagator evaluate the force of the Earth gravity in ITRF each time-step. So coordinate transformation between GCRF and ITRF is a frequently called function. The focus of this paper is investigating on several approaches about the coordinates (frames) transformation between GCRF and ITRF, and find out suitable algorithms based on different mission requirements.

Concerning of the resource limitation, propagator running onboard require specific design for saving computational time, energy, and memory. The time consumption and precision of the transformation between ITRF and GCRF is a trade-off. According to the IERS conventions, matrixes of coordinate transformation between GCRS and ITRS consist of procession, nutation, Earth rotation and polar motion, and as well as IERS Publish Earth Orientation Parameters (EOP) every day. For polar motion and Earth rotation, we would like to investigate the effects of deferent interpolation algorithms of EOP for high precision orbit propagation. Based on IAU76/80, and the latest IAU2000 precession-nutation model, we try to compare the deference for variety orbit propagations. Especially, for IAU2000 procession-nutation model, there are more parameters, meaning it need more computation time, but it also provide a method based on the Celestial Intermediate Pole (CIP), which allow using interpolation algorithm to get the coordinate of CIP simultaneously through pre-stored coordinates. Analysis of the effects of several interpolation algorithms for the CIP, precision, computational efficient, storage requirements, etc is presented.

Different realizations of frames transformation between ITRF and GCRF mainly effect the Earth gravity evaluation for orbit propagator; and the orbit initial state determination if the propagator performs orbit prediction. The algorithm for frames transformation through practice data got from our CubeSat for Low-Earth-orbit (LEO) is validated. In addition, for GNSS orbit, we try to use Galileo and Beidou's Broadcast Ephemeris (BE) or Precision Ephemeris (PE) test the algorithms developed in this paper.