Celestium: Optimized and Accurate Planetary and Interplanetary Satellite Modeling via Utilization of Novel Algorithms and Advanced Differential Equations

Kumar, Nikhil (School: The Carol Martin Gatton Academy of Mathematics and Science in Kentucky)

In 2022, the Satellite Industry Association reported a staggering 45% increase in the number of operational satellites, resulting in an orbital population exceeding 7,000 around Earth. With the growing reliance on satellite technology, the demand for precise and dependable orbit modeling has increased. This project aims to help aid this problem through the creation of Celestium, a sophisticated software solution engineered to compute satellite orbits while accommodating a spectrum of perturbations, including J2 effects, atmospheric drag, etc. Celestium enables users to define satellite orbits through two methods: the basic position (r and velocity (vectors or the Keplerian Orbital Elements (KOEs) set comprising semi-major axis (a), eccentricity (e), inclination (i), true anomaly (θ), argument of periapsis (ω), and the right ascension of the ascending node (Ω). The transformation between the perifocal frame of reference (PQ) and the Earth-Centered Inertial frame (ECI) is accomplished using a translation matrix (R_(PQ→ECI)), allowing for an r and v to be generated from the KOEs (which then is numerically integrated via the Runge-Kutta method). Celestium incorporates perturbations by adjusting a derived acceleration equation. The accuracy of Celestium's simulations aligns closely with empirical data collected by NASA for satellite trajectories. Additionally, Celestium accommodates various attitude maneuvers, including Hohmann transfers, further enhancing its versatility.