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FINDING REAL-WORLD ORBITAL MOTION LAWS FROM DATA

Abstract

Purpose - Careful planning of propellant used for satellites ensures they follow a set trajectory. Drag is a major force acting on a satellite; if not considered, it can cause position errors of up to hundreds of kilometers. Finding orbital motion laws from data is a critical step in improving predictions of a satellite's position.

Mehodology - We use Sparse Identification of Nonlinear Dynamics (SINDy) to discover equations that describe laws of physics in space that are not deterministic and can be influenced by multiple factors such as drag or the reference area (related to the attitude of the satellite). This aims to find partial differential equations (PDEs) of a physical system using only the system's state over time. Unlike previous works, we maintain the physically interpretable coordinate system and do not perform any dimensionality reduction technique on the data. Finding the interpretable stochastic PDEs from data will unlock many space surveillance and tracking applications.

Results - We have successfully trained SINDy to discover equations that describe an orbit with high-fidelity ephemerides. Training the model with multiple representative trajectories of Low Earth Orbit – with various inclinations, eccentricities, and altitudes – and testing it with unseen orbital motion patterns, we attained a mean error of around 140 km for the positions and 0.12 km/s for the velocities.

Conclusion - Uncovering orbital motion PDEs with SINDy from highly informative, high-entropy datasets provides advantages that traditional models cannot, such as delivering interpretable, accurate, and complex models of orbital motion that can be used for propagation or as inputs to predictive models for other variables of interest, like atmospheric drag or the probability of collision in an encounter of a spacecraft with space objects.