Domain Splitting for Cislunar Orbit Uncertainty Propagation

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Abstract: The objective of this work is to develop physics-informed methods of splitting the domain of random inputs for propagation of orbit-state uncertainty in cislunar space. As near-rivals race to establish a permanent presence on the Moon, the United States must act quickly to develop and implement new surveillance capabilities for Space Domain Awareness (SDA). The multi-body dynamics in the region between the Earth and Moon can induce a sensitive dependence on initial conditions, i.e., chaos, and even small perturbations in phase space yield vastly different trajectories. This allows satellites to perform efficient trajectory changes and move more freely through cislunar space. This also makes propagated trajectories sensitive to initial uncertainties, poorly characterized perturbations, and unknown maneuvers. Accurate prediction of a satellite's translation state and associated uncertainty is essential to tracking anthropogenic space objects for SDA. While particle methods will work, their runtime can be expensive and their use in orbit determination and object tracking can be problematic. Instead, this project will consider physics-informed approaches to splitting the input domain, thereby breaking the larger problem into more tractable sub-problems. We will carefully determine the appropriate measure(s) of nonlinearity to identify the possibly multiple directions of splitting and how to best divide along each. Existing methods of non-Gaussian uncertainty propagation will then be used with each sub-domain with the intention of producing a tractable approach to uncertainty propagation in cislunar space.