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GENERATION AND CLASSIFICATION OF CRITICAL POINTS IN UNCERTAIN N-BODY PROBLEMS VIA MACHINE LEARNING

Abstract

The study of dynamical systems is relevant for a wide variety of problems in astrodynamics. These are systems defined by differential equations that may have no known analytical solution. Despite this, the study of such systems gives rise to a rich variety of phenomena that are interesting in both a theoretical sense and for practical applications.

One such example is the location of critical points. In astrodynamics, these are commonly studied in the context of equilibrium points in the N-body problem. Equilibrium solutions can be found numerically for some restricted cases of the full system. Machine learning techniques are frequently used to find patterns from data and are therefore a promising technique for studying patterns in dynamical systems. In particular, recent advances in generative models have shown remarkable performance in synthesizing new data based on examples.

This work demonstrates the application of physics-informed generative models for learning distributions of critical points in astrodynamics. The class of generative models used are flow-based models, which transform a tractable distribution into a more complex one that allows direct sampling of new points. The architecture proposed in this paper integrates the generative layers with a classification of the critical points according to their stability properties. In many dynamical systems of interest, in fact, equilibrium points may be characterised as stable, unstable, or metastable depending on the system's behaviour in the region of the critical point. In addition to generating new points, the proposed method classifies the critical points by learning in a semi-supervised manner from the classes of known critical points. This allows further analysis of how certain types of solution are distributed in the system. The methodology is applied to equilibrium solutions in the N-body problem with uncertain parameters.