Paper ID: 64187
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (2) (7)

Author: Dr. Hodei Urrutxua
Universidad Rey Juan Carlos, Spain

Mr. Pablo Solano-López
Universidad Rey Juan Carlos, Spain
Mr. Roger Gutierrez-Ramon
The Graduate University for Advanced Studies, Japan
Mr. Adrian Barea
Universidad Rey Juan Carlos, Spain

ASSESSMENT OF HYBRID MACHINE LEARNING APPLICATIONS ON TRAJECTORIES IN THE CR3BP

Abstract

Classical dynamical systems theory has been the basis for the study of dynamical systems since its development. However, in recent years many scientific and engineering areas, including the study of astrodynamics, have turned their attention to the application of new methodologies. In the analysis of the Circular Restricted 3 Body Problem (CR3BP), traditionally the study of periodic orbits, stability regions and invariant manifolds has been used to design trajectories and study their characteristics. These dynamical structures are obtained using numeral algorithms relying on iterative techniques and differential correction methods.

In this paper, we investigate the applicability of novel methodologies based on Machine Learning to solve equivalent problems. More specifically, we focus on state-of-the-art hybrid techniques of classical mathematical models and Machine Learning, evaluating their performance and applicability to the astrodynamics domain. We design, train and benchmark different Neural Network (NN) schemes to predict the behaviour of CR3BP trajectories. Amongst the NN that we study are a reservoir-like NN, namely an Echo State Network (ESN), and a Recurrent Neural Network (RNN), in particular the Long Short-Term Memory (LSTM) scheme, with different configurations of nodes and inner layers. These NN are suitable candidates for solving astrodynamical problems, as they are designed precisely to deal with time series and time-dependent functions. They also exhibit good robustness properties and predictive capability when learning complex data or modeling problems with complex dynamics, thus being used in applications with a high number of variables and data. For the NN's training procedure, we feed the NN with a subset of numerically computed synthetic, fully non-linear trajectories with predetermined initial and boundary conditions. Different sample trajectories with different energy levels and characteristics are used to avoid overfitting of the NN and help them capture the full behaviour of the CR3BP, while a different subset of the sample trajectories is used for validation purposes. Results obtained from the NN are used to compare the feasibility of their use as a standalone tool for astrodynamical studies. The accurateness of the results in the past, as well as the Lyapunov times are used for evaluation.

The studies include the tailoring of different hybrid schemes that combine the NN with numerical propagators, alternative training methods and possible pitfalls with respect to classical techniques, including numerical burden and accuracy. Benchmark trajectories include typical case scenarios in the Earth-Moon vicinity as well as other dynamical systems seen in the Solar System.