Paper ID: 42401
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (1) (1)

Author: Mr. Stijn De Smet
University of Colorado Boulder, United States

Prof. Daniel Scheeres
Colorado Center for Astrodynamics Research, University of Colorado, United States

IDENTIFYING HETEROCLINIC TRANSFERS USING ARTIFICIAL NEURAL NETWORKS

Abstract

This paper demonstrates the usage of artificial neural networks (ANN) to automatically identify heteroclinic connections in astrodynamics systems. Transfers between planar Lyapunov orbits and between halo orbits in the CRTBP are considered. The methodology focuses on automation to allow applying it to a variety of different dynamical systems and Jacobi levels.

Heteroclinic connections can be used to freely transfer between different Langrangian point orbits (LPOs). They are found by computing the unstable manifolds of the departure LPO, and the stable manifolds of the arrival LPO and then finding the intersections of these manifolds on a Poincaré map. For this research, we use the periapsis Poincaré map. Because of the non-linearities, usually, a dense sampling of the Poincaré mapping of different starting points on the LPOs is required. This paper demonstrates how ANNs can be employed to reduce the number of integrated manifolds, while allowing accurate predictions of the Poincaré map for a wide variety of Jacobi values for all possible departure and arrival points on the LPOs.

The methodology consists of several steps. First, traditional methods are used to compute periodic orbits and their manifolds. Second, training data is collected for the ANNs. For a few departure and arrival locations along the LPO, the unstable and stable manifolds are integrated to the next periapse. Third, an unsupervised training technique groups the Jacobi values and locations along the orbit in families, resulting in smoothly changing Poincaré responses. This facilitates the subsequent training of the ANNs, since large discontinuities are separated into different families. Fourth, for each family, a separate ANN is trained to predict the mapping of those Jacobi values and locations along the orbit. Fifth, candidate connections are selected from the predicted manifold intersections on the Poincaré map, as opposed to traditional intersections determined by numeric integration. Finally, a predicor-corrector scheme is used to nullify the position and velocity errors on the predicted connections. This last step also allows quantification of the error in the identification of the ANN predicted connections.

This methodology has been applied to find heteroclinic connections, or lack thereof, in the Earth-Moon system from L_1 to L_2 Lyapunov orbits for Jacobi values between 3.07 and 3.17. The predicted heteroclinic connections were within 0.1-1% of the arclength along the periodic orbit from their true locations. The same methodology is currently being applied to halo-to-halo transfers. The results of this analysis will also be presented at the meeting.