Internship in ESA's Advanced Concepts Team
On
Applying Machine Learning to trajectory design and system cartography in multi-body dynamics

European Space Research and Technology Centre
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Topic description

Exploiting natural structures of multi-body dynamical systems for trajectory design can lead to substantial savings in propellant and reduced mission complexity. In Circular Restricted Three Body Problems, stable and unstable invariant manifolds give rise to low-energy interplanetary pathways that could transform deep-space mission analysis.[1] Past and current missions like Hiten, Genesis and BepiColombo make use of weak stability boundaries and low-energy interplanetary transport networks to significantly reduce the cost of orbital maneuvers and achieve what would have been impossible under traditional Keplerian assumptions.[2]

As of today, this low-energy trajectory design framework is however unsuitable for real-time optimization and fast transfer cost estimation due to:

1. The computational cost of finding intersections between stable and unstable structures emerging from orbits.

2. The cost and intuition required to perform orbit cartography given a multi-body system of interest, to identify suitable initial, final and transitory orbits for mission analysis purposes.

Candidate's task

The objective of this internship is two-fold:

1. To explore the use of modern machine learning techniques to characterize connections between stable and unstable invariant structures given two multi-body dynamical systems.
2. To perform AI-assisted systematic orbit cartography for such systems to facilitate preliminary mission analysis studies.

First, deterministic simulations will be performed using open-source tools, to create a database of orbits and low-energy pathways in the solar system. A learning strategy will then be defined, and neural networks designed to infer conjunction properties between stable and unstable invariant structures of different systems. This could include a parametrization of the conjunction space and a characterization of the initial and final orbits from which the invariant structures emerge. Secondly, reinforcement learning strategies will be considered and applied for system orbit cartography. The objective being, given a dynamical system of interest, to identify periodic and quasi-periodic solutions as well as bifurcations in the state-space. Results will be compared to those obtained with traditional mapping techniques using bifurcation indicators and pseudo-arclength continuation schemes. Alternatives to reinforcement learning will also be explored.

Ultimately, the candidate will apply the developed tools to propose trajectory design solutions for relevant mission scenarios in the solar system. This includes direct comparisons with current and past missions using low-energy pathways, as well as explicit validation of the trajectories in a high-fidelity simulator.

Joining the ACT

Creativity and out-of-the-box thinking are essential in the ACT. Therefore, the team is constantly striving to be a diverse, inclusive and equitable workplace bringing together people from various backgrounds. We strongly encourage people from under-represented groups to apply to be part of our team as diversity is central to our mission and core values.

In order to make our hiring as fair as possible, we also ask applicants to not include photos in their CVs.

References

[1] Ross, S.D et al. “Dynamical Systems, the Three-Body Problem and Space Mission Design”, (2011)

[2] Koon, W.S. et al. “The Genesis Trajectory and Heteroclinic Connections” (2000)

[3] Belbruno et al. “Weak Stability Boundaries and Invariant Manifolds” (2010)