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EXPLOITING COHERENT PATTERNS FOR THE ANALYSIS OF QUALITATIVE MOTION AND THE DESIGN OF BOUNDED ORBITS AROUND SMALL BODIES

Abstract

In recent years, the scientific interest towards small bodies significantly raised thanks to their key role in the investigation of the formation of the Solar System, the potential hazard that near-Earth objects represent in the context of Earth planetary defense, and the possible exploitation of these bodies for their materials through asteroid mining. Missions around small bodies present many challenges from their design to the operations due to the highly nonlinear and uncertain dynamics, the limited Δv budget, and constraints coming from orbit determination and mission design. Definition of operational orbits robust to uncertain parameters and unmodeled dynamics, and requiring low Δv for their maintenance and transfers while meeting the mission requirements is a key aspect of these missions. Within this context, mathematical tools to enhance the understanding of the dynamics behavior can prove useful to support the mission design process. In this research activity, a more general approach for the characterization of the chaotic dynamical system is investigated to generate bounded orbits in non-autonomous nonlinear systems. Based on the experience from the fluid dynamics field, it is possible to exploit the intrinsic information embedded within coherent patterns of dynamical systems to better understand the underlying structure that is responsible for the creation of such features. Chaos indicators, like the finite-time Lyapunov exponent, the nonlinearity index, and the Lagrangian descriptors are adopted to reveal patterns of time-dependent dynamical systems. Indeed, these indicators enable the identification of coherent structures in the phase space which separate different dynamical behaviors of the flow in space and time. The proposed qualitative analysis of the dynamics enables the identification of practical stability regions, which are then exploited to design bounded orbits in the proximity of small bodies. The methodology is applied to study

MMX and Hera missions. In the MMX context, the final goal is to obtain bounded orbits useful for the global surface mapping and gravity potential determination of Phobos. On the other hand, concerning the Hera mission, a qualitative analysis of the natural motion about the Didymos binary asteroid system is carried out to compute bounded orbits convenient for the global characterization of the two asteroids and to investigate potential landing trajectories. Sensitivity analyses via Monte Carlo simulations are performed to prove the robustness of the different bounded orbits. This work has received funding from the French space agency, CNES, under the Research and Technology (R&T) programme.