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Computation of Quasi-Periodic Tori and Heteroclinic Connections in Astrodynamics Using Collocation Techniques

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Many astrodynamical systems exhibit both ordered and chaotic motion. The invariant manifold structure organizes these behaviors and is a valuable tool for the design of spacecraft trajectories. The study of a system's dynamics often begins with the computation of its invariant tori (equilibrium points, periodic orbits, quasi-periodic orbits) and associated stable and unstable manifolds. Periodic orbits, in particular, have been used effectively for the design of low-energy transfers in the circular restricted 3-body problem (CR3BP). Quasi-periodic orbits offer similar benefits and are often more prevalent in the phase space, but additional complexities are involved in their computation. The foundation of this work is the development of a numerical method for computing two-dimensional quasi-periodic tori. The approach is applicable to a general class of Hamiltonian systems. Using a Fourier discretization and Gauss–Legendre collocation, a continuous representation of the torus is obtained. Included in the scheme is the computation of the torus's stable and unstable manifolds. These manifolds can then be used for the design of natural transfers. Two methods are presented for locating and continuing families of heteroclinic connections between quasi-periodic orbits in the CR3BP. A collocation-based approach for transitioning trajectories to a higher-fidelity ephemeris model is also included.