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# MANOEUVRING CONSIDERATIONS FOR QUASI-PERIODIC TRAJECTORIES

**Abstract**

The libration point regions in the Sun-Earth and Earth-Moon systems are considered for ambitious space concepts involving long-duration crewed operations by space industry and agencies. It is required for such projects to cope with regular in-space operations, rendezvous, docking activities. For this application some kind of traffic management is required as is proven by the example of the International Space Station. The centre manifold existing within the vicinity of the libration points provides a variety of natural periodic and quasi-periodic orbits suitable for such proximity operations. This includes, but is not limited to halo, Lyapunov and quasi-halo orbits. In general, quasi-periodic trajectories can be described as two-dimensional invariant tori, and it is preferable to regard them directly as invariant object, covering any trajectory on its surface. A parametric representation reveals the structure of a torus and enables a discretisation of the torus which is used to implement and derive manoeuvre strategies and phasing considerations. In this paper manoeuvres are introduced to change the phasing of a spacecraft on a torus. Furthermore, amplitude changes, therefore transfers from one torus to the other, are studied. Analytic solutions to those problems are known from the linear Lissajous motion, where optimal manoeuvres are introduced. Manoeuvring the spacecraft for amplitude or phase changes can be performed in multiple ways, either by defining two-impulse and optimal transfer arcs between two locations, or by velocity changes (single manoeuvres). This is possible if the initial trajectory either cross the final trajectory or its stable manifold. In the later case, applying a manoeuvre sends the spacecraft onto a stable manifold and will asymptotically reach the final trajectory. Quasi-periodic trajectories at the Earth/Moon libration point EML2 are computed, and optimal manoeuvre strategies are proposed and compared with the known linearised solution. This analysis details and expands the understanding of the natural dynamics and points out the knowledge and advantages gained from the structure of the torus and their parametric representation useful for manoeuvre implementations. For the case of a vehicle visiting an exploration gateway station on a halo orbit around EML2 feasible transfers and the associated fuel expenses from an arbitrary initial orbit to the invariant torus are studied. Furthermore, the motion of the vehicle on the torus relative to the station is characterised.