Manifold Dynamics and their Applications to Low-Energy Transfers

Project Plan Presentation

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Mani-what?

- A particular case of spacecraft motion – the Circular-Restricted Three-body Problem (CR3BP) – studies the motion of a third body under the influence of two other much more massive bodies
- The CR3BP exhibits some *funky* behaviour as a dynamical system

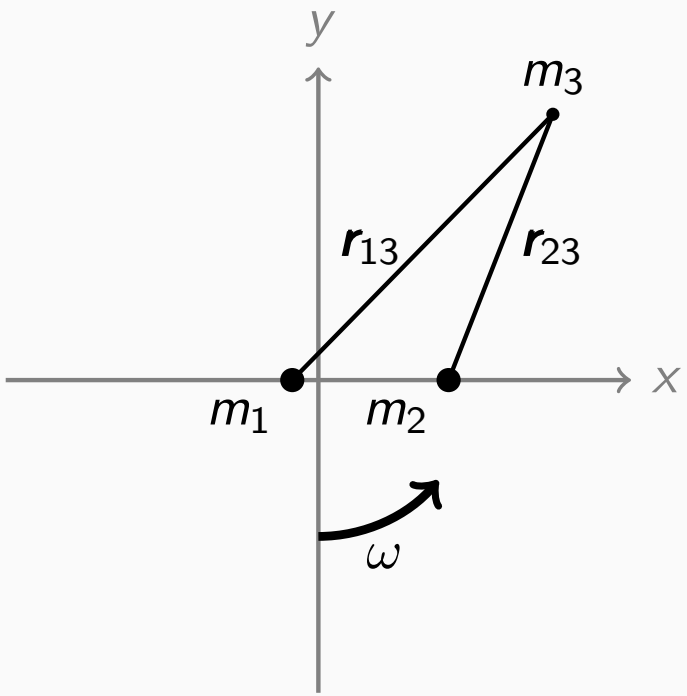


Figure 1: Normalised co-ordinate system for the CR3BP – ω and primary separation normalised to unity.

Introduction to Manifolds

One dynamical phenomenon, manifold tubes – orbits that approach and depart a periodic orbit in the CR3BP – can be exploited to give new ways of transferring matter in phase space

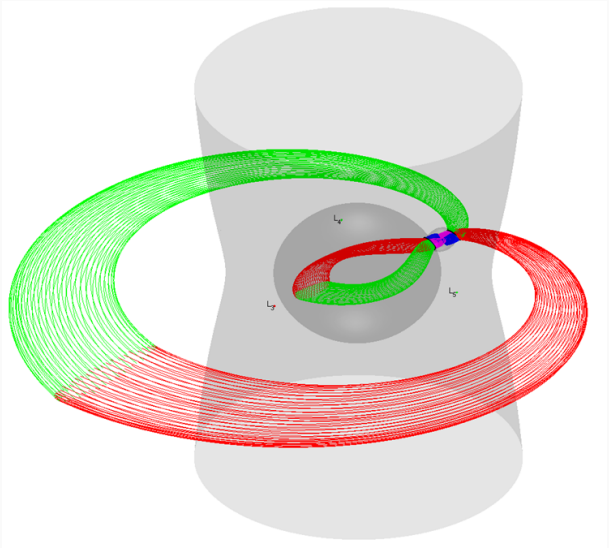


Figure 2: Stable (green) and unstable (red) invariant manifolds associated to Earth-Moon L1. Source: Renkli Seyler, `https://renklisheyler.wordpress.com/research/motions-in-cr3bp/invariant-manifold-tubes/`

Potential Applications

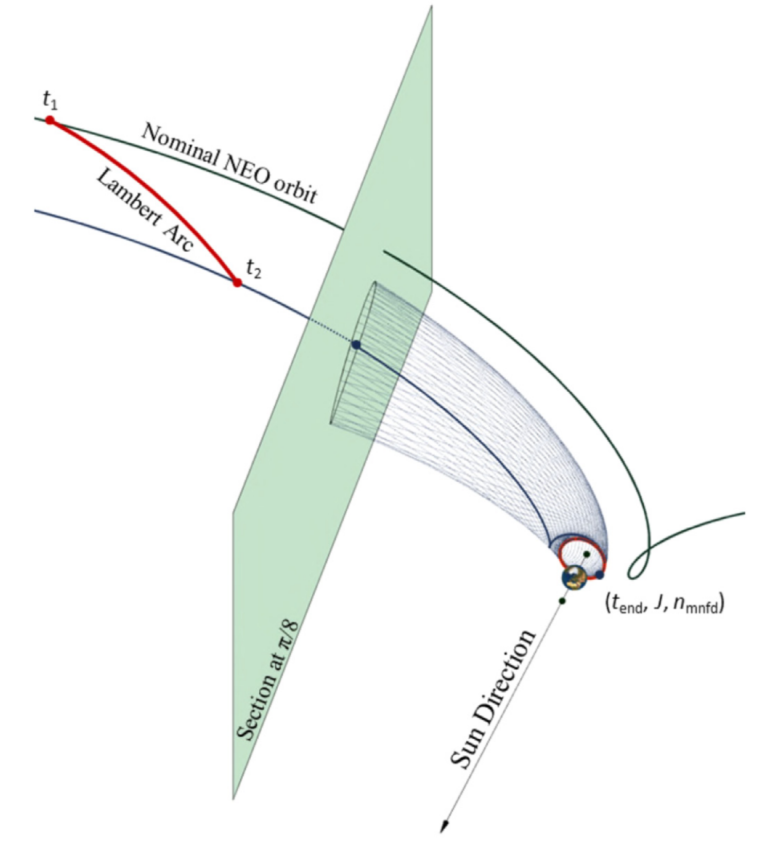


Figure 3: The use of stable invariant manifolds to perform an asteroid retrieval mission to Earth-Moon L2. [Sánchez and García Yárnoz, 2016]

Project aim and outcomes

- The project will deliver a full case study for a mission in, and exploiting, the CR3BP
- To achieve this, the project sets the following aims:
  - A comprehensive literature review on CR3BP theory, potential applications and numerical techniques for the contruction of orbits in the CR3BP
  - A suitable mission selection that will exploit a range of features of the CR3BP
  - A software bundle to allow for the computation of the mission analyses and orbit construction

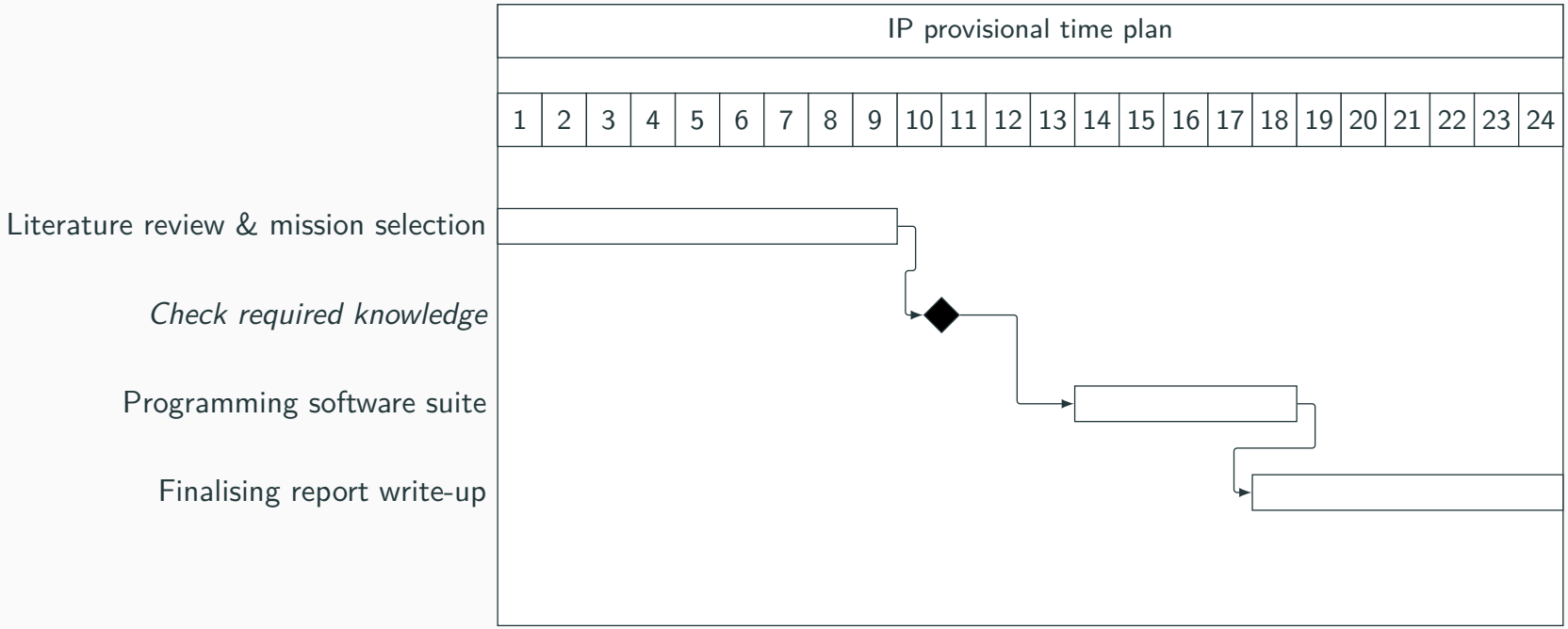
Project scope

- The mathematics behind the CR3BP and its' dynamical phenomena
- The theory behind, and implementation of, numerical techniques for orbit construction including numerical integration, differential correction and optimisation
- Mission trade-offs and requirements
- Software analytics: code coverage, MC/DC coverage, static/dynamic program analysis and parallel processing techniques

Current Project Progress

- Self-proposal made it easy to do the literature review before Semester 1 started
- Mendeley library contains ~80 journal papers and books
- Already worked on (basic) underlying mathematics & written this up into a reference document (16k words)
- Written code (MATLAB, Fortran03) to single-shoot some closed orbits

(Very) provisional time plan



Any questions?

Figure 4: Single-shooting differential correction to construct a family of Lyapunov orbits around L_1; $\mu = 0.0121$

References

Sánchez, J. P. and García Yárnoz, D. (2016).
Asteroid retrieval missions enabled by invariant manifold dynamics.
Acta Astronautica, 127:667–677.

Shuai, W., Haibin, S., and Weiren, W. U. (2013).
Interplanetary transfers employing invariant manifolds and gravity assist between periodic orbits.
56(3):786–794.

Supplementary slides – zero velocity curves in the CR3BP