OPTIMAL MISSION DESIGN TO LAGRANGIAN POINTS

A thesis submitted

in partial fulfilment for the award of the degree of

Doctor of Philosophy

by

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March 2024

ABSTRACT

The problem of generating optimal mission design to Lagrangian points is attempted to be solved in this research. Scientific missions to Lagrangian points have the potential to enhance the understanding of the universe and to accelerate the exploration of space. The generation of orbits around the Lagrangian points and constructing optimal transfers to them from the Earth are complicated tasks due to the intricate multi-body dynamics involved. To overcome these complexities, this research employs a two-step approach, first utilizing a basic force model to generate preliminary designs, and then refining them using the full force Ephemeris model. The conventional approach employs the Circular Restricted Three Body Problem (CRTBP) framework and differential correction (DC) techniques for the design of halo orbit and transfer trajectory design. In contrast, this research explores the use of the Elliptic Restricted Three Body Problem (ERTBP) framework and employs the Differential Evolution (DE) optimization technique. Preliminary mission design to Sun-Earth Lagrangian points and Earth-Moon Lagrangian points are constructed under the ERTBP framework. In the Sun-Earth system, multi-revolution (MR) orbits are designed in a single level, single segment approach and the proposed technique identifies multiple options of MR orbits for the same period and generates both Lyapunov and halo orbit MR solutions for the same period. However, the amplitudes of the MR orbits are found to be unacceptably large for scientific missions like the NASA's ISEE-3 mission. For feasible amplitudes, it is found that only quasi-halo orbits are viable and are designed using a DE-based technique in the ERTBP framework and a realistic ephemeris model. The designed quasi-halo orbits do not require any theoretical velocity corrections for about five years (state-of-the-art in literature is about two and half years). Optimal two impulse transfers to the quasi-halo orbit from an Earth parking orbit are generated under the ERTBP framework and the ephemeris model. It is inferred that both the CRTBP and ERTBP reference designs generate the ephemeris design and there is no noticeable advantage of considering ERTBP reference design. This can be attributed to the small eccentricity of the orbit of Earth around the Sun ($e \sim 0.0167$). Then, the Lagrangian point mission design in the Earth-Moon system is attempted. The dynamics of motion near the Earth is significantly different for Earth-Moon Lagrangian point missions compared to the Sun-Earth Lagrangian point missions because in former, the Earth is the larger primary. The proposed design methodology using differential evolution designs the transfer trajectory in a single segment and involving only two velocity impulses. Because of the robustness of the developed technique, there is no need to

tweak the methodology used for generating the orbit or the transfer trajectory in different dynamical systems. The optimal solutions indicate that there exist trajectories with lower cost significantly shorter flight durations than those reported in the literature. In summary, complete Lagrangian point preliminary design in the ERTBP framework is generated. For the mission design in the Sun-Earth system, it is substantively concluded that preliminary design using the ERTBP framework does not provide significant advantages over the CRTBP framework. The differential evolution technique is found to be very versatile in solving Lagrangian point mission design problems and avoids many complexities associated with the differential correction based technique. However, the DE based schemes are found to be computationally more intensive. The proposed methodology based on differential evolution constructs transfer trajectory independent of the characteristics of the target orbit and hence, preserves the fundamental nature as such (not changing the type of orbit from halo to quasi-halo etc.).