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Author: Ms. Dr. Parvathi S P
Indian Institute of Space Science and Technology (IIST), India, parvathisp.12@iist.ac.in

Dr. R V Ramanan
Indian Institute of Space Science and Technology (IIST), India, rvramanan@iist.ac.in

EVALUATION OF ITERATIVE ANALYTICAL TECHNIQUES FOR THE TRAJECTORY DESIGN OF A DIRECT JUPITER ORBITER MISSION

Abstract

During an interplanetary travel, a spacecraft experiences the gravitational pull of numerous celestial bodies. The motion of the spacecraft is studied by solving the n-body equations of motion using numerical techniques. As the interplanetary transfer is a two-point boundary value problem, we do not have complete information on the initial states. So, the main task is to arrive at a good guess of the initial states. Usually analytic techniques that are based on simple force models are used to generate a quick initial guess. For a direct orbiter mission to Jupiter, it is understood that the velocity impulse required will be huge. To surpass this expenditure, usually gravity assist missions are attempted for a Jupiter mission. However, in this research, an evaluation is carried out for the trajectory design of a direct Jupiter orbiter mission. The iterative analytical techniques based on the patched conic and the pseudostate concepts are used to obtain the trajectory design for the minimum energy opportunity of 2022. A comparison is made on the initial states of the departure trajectory and the achieved target parameters. Also, the velocity impulses required at the departure and the arrival are also tabulated. The trajectories obtained from the iterative pseudostate technique and the biased iterative patched conic technique are compared. The results are propagated under a full force model and the accuracies in terms of the achieved target parameters viz. the closest approach altitude and the time of periapsis, are tabulated. Also, the trajectory correction maneuvers required for the analytical designs to achieve the expected/desired target parameters are computed. The results are analyzed to understand the trends and tradeoffs of the different analytical techniques for a Jupiter obiter mission. Methodology The analytical design techniques generate the transfer trajectory for a given transfer opportunity viz. Departure epoch and flight duration. The minimum energy opportunity is computed using grid search optimization technique under the patched conic force model. For all the analytical trajectory design techniques, the Lambert problem is the lifeline. The Lambert problem states that given two position vectors and the flight duration, the orbit of a body passing through these position vectors is determined uniquely. Here, the Lambert problem is solved using the universal variables method proposed by Vallado. The current research explores both the patched conic and pseudostate concepts for the analytical trajectory design. An iterative method based on the one-step pseudostate concept, named as iterative pseudostate technique (ITR-PS), is used. The iterative nature of this technique helps identify the four distinct design options for an opportunity. The analytical tuning strategy is used to tune the departure/arrival hyperbolic orbit characteristics to achieve the departure/arrival V-infinity vectors at the pseudosphere. The ITR-PS technique provides improved design in terms of the achieved target parameters as compared to the conventional techniques. The biased iterative patched conic (B-ITRPC) technique considers the aspherical gravity perturbations of the Earth and the third body perturbations of the Moon and the Sun in the departure phase of the trajectory. Upon computation, surprisingly, the ITR-PS and BITRPC designs are of the same merit for Jupiter mission and so, we need not go for the complicated B-ITRPC technique. The ITR-PS technique itself proves sufficient for the mission design and analysis purposes. Further details are to be included in the full length paper.