Paper ID: 58999
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (3) (3)

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MODEL PREDICTIVE STATIC PROGRAMMING FOR STATION KEEPING IN LIBRATION POINT ORBITS

Abstract

Lagrange point orbits (LPOs) in multibody dynamical systems offer a variety of scientific advantages for space exploration. This has led to an exponential increase in the number of missions planned to various LPOs both in the Sun − Earth and Earth − Moon systems. The instability of many LPOs cause a spacecraft to drift away from the reference trajectory in the presence of unmodeled disturbances which include Solar Radiation pressure, gravitational perturbations, orbit insertion and tracking errors, manoeuvre execution errors and so on. If the deviation of the spacecraft is left unchecked, it will escape the Lagrange point region and will result in mission failure. To avoid this situation, station keeping manoeuvres are performed on a periodic basis to maintain the spacecraft in the vicinity of the reference trajectory. They are computed on the ground and involve large operational costs. Therefore, a robust, autonomous and computationally efficient station keeping strategies are the need of the hour. In this paper, a fuel optimal and computationally efficient station keeping strategy based on the philosophy of Model Predictive Static Programming (MPSP) will be demonstrated for both high and low thrust missions. The current station keeping strategies, are primarily based on linearized dynamics about the LPOs, which involve calculating State Transition Matrices and solving Algebraic Riccati Equations. Techniques based on above strategies henceforth require heavy computational effort and are completely avoided in MPSP based formulation. The linearization of system dynamics make the current methodologies ineffective to be applied in the case of large deviations from a reference trajectory. The MPSP technique iteratively solves a non-linear, finite horizon, terminal constraint problem without making any such approximations in a closed form manner. The computational efficiency of the technique is a result of converting the dynamic optimal control problem into a static optimization framework with a static co-state variable. Further, this technique involves calculation of sensitivity matrices which are obtained in a 'recursive' manner for fast computations. Finally, the technique will we effectively applied on a quasi-halo orbit in the Sun − Earth − Moon four body problem using a prediction and correction type sliding window to address robustness issues against unknown disturbances and mission uncertainties.