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AGENT-BASED MODELING TECHNIQUES FOR CONTROL OF SATELLITE FORMATIONS IN MULTI-BODY REGIMES

Abstract

Satellite formations are promising alternatives to large, monolithic telescopes in the search for exosolar planets, characterization of distant stars, identification of black holes, and many other potential NASA missions. It may be ideal to place these imaging arrays near one of the collinear libration points in the Sun-Earth system. Thus, when modeling the motion of deep-space formations, it is important to employ a multi-body gravitational model.

Employment of a nonlinear multi-body model, especially when describing the motion of several spacecraft with complicated objectives, may cause traditional optimal control problem formulations to become intractable. For example, the problem of determining the optimal motion of spacecraft in an interferometric imaging formation (while minimizing fuel) has been examined, yet it has only been solved for specific and simplified cases.

The substantial complexity inherent in the analysis of spacecraft imaging formations in multi-body regimes motivates a change in either the analytical formulation of the problem or a transition to more robust computational algorithms and utilities, such as FORTRAN, UNIX, and parallel processing. This paper explores the former possibility by employing decentralized control and agent-based modeling techniques to solve for the optimal motion of spacecraft formations with highly complex objectives, defined in multi-body regimes. Cooperative satellite "agents" share a common objective (high resolution interferometric imaging) and simultaneously pursue private goals (minimal fuel usage). An algorithm is developed based on dual decomposition techniques. The dual problem of an artificially decomposed version of the primal problem is solved, replacing one large computationally intractable problem with many smaller tractable problems. Thus, this method may be most useful when traditional analytical and computational tools are reduced in efficacy due to problem complexity. Simple rules are defined that govern the motion of individual satellites, while complex emergent behavior is observed in formation motion, as a whole. The outcome of the agent-based model is compared to a more traditional nonlinear optimal control solution for a relatively simple two-satellite array example. It is shown that the decentralized control law converges to the traditional nonlinear solution as time progresses. Then, taking advantage of the reduced computational requirement, the agent-based model is employed to simulate more complex arrays with increasing number of satellites and constraints.