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AN OPTIMIZATION APPROACH FOR DESIGNING OPTIMAL TRACKING CAMPAIGNS FOR LOW-RESOURCES DEEP-SPACE MISSIONS

Abstract

In the last years, the technology readiness level reached by low-budget small platforms has allowed small organizations, such as universities and research centres, to launch low-budget satellites in the near-Earth orbits. In spite of a constant platform technological development, space missions beyond the near-Earth environment are still out of the reach of these stakeholders. One of the key limiting factor is the maturity of the associated ground segment and, on the specific focus of this paper, its tracking capabilities. While traditional deep-space missions rely on dedicated and extensive networks, near-Earth missions by small organizations often depend on amateur stations or third-party services with reservation slots. As for the scenario of a low-resource deep-space mission, tracking would be even more critical as the number of suitable stations is smaller, the associated efforts more onerous, and the construction of competent amateur stations may be unrealistic.

In the aim of moving deep-space missions for small organizations one step closer to feasibility, this paper presents an approach for the optimal scheduling of observation campaigns for tracking deep-space small spacecraft under limited resources. Indeed, in such scenarios, optimisation becomes an essential tool to handle the increased uncertainty and complexity arising from lower availability of information. Given a network of available ground stations, the developed method autonomously generates optimized tracking observation campaigns, in terms of stations to use and time of measurements, that minimize the uncertainty associated to the state of the satellite. The outcome is a spectrum of optimal solutions characterized by different allocated budgets. The developed approach relies on a Structured-Chromosome Genetic Algorithm that copes with mixed-discrete global optimization problems with variable-size design space. This operates on a hierarchical reformulation of the problem by means revised genetic operators. The optimizer is enhanced by a multi-population strategy that favorites the migration of promising solutions improving the information-gain efficiency. The step of estimation of the spacecraft state, and its uncertainty, given a set of measurements is performed using a novel particle filter approach able to handle imprecise observations likelihood. In a scenario characterized by low-resources, this method has been preferred over traditional filters, e.g. Gaussian ones, because of its ability to properly handle a wider range of uncertainty models, including scarce or vague information.

To show its potentiality, this approach has been applied to the design of observation campaigns for tracking a nanoSat in its interplanetary cruise to an asteroid.