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MIXED-INTEGER GA OPTIMIZATION FOR THE CONTROL OF A FORMATION OF SMALL SATELLITES EQUIPPED WITH MULTI-CONSTRAINED ELECTRIC THRUSTERS

Abstract

Formation flying missions have been investigated for more than twenty years, and they have now become an appealing reality also for small satellites. The low cost and fast production time of the small satellites allows to project short duration missions in which many redundant agents of the formation are launched together, following a fail-safe approach, since each satellite can be easily replaced.

In the scenario here considered, one or more small satellites (Chasers) must acquire and maintain a reference trajectory with respect to a larger and non-cooperating Target satellite that keeps performing its scheduled tasks, such as periodic maneuvers to keep its repeating ground-track orbital characteristics. This is for example the case of SAR remote sensing formation missions, in which the only emitting antenna is on the large satellite, while small satellites are equipped with passive antennas.

The Chaser must perform its formation guidance and control tasks within the framework of its thruster constraints: the case of a low thrust electrical engine is here considered.

The constraints of such a thruster are relevant to: (a) single-axis orientation of the thrust (since only one engine is present); (b) the thrust level (only two levels are possible: maximum and zero); (c) maximum ON time (due to power consumption and temperature issues); (d) minimum ON time (because of the time required to prepare the motor ignition, it is preferrable not to have very short ignitions); (e) maximum number of ignitions; (f) minimum time between two subsequent ignitions. The algorithm developed to satisfy all these constraints is a model predictive control based on a mixed-Integer genetic algorithm optimization, which provides a fast estimate of the schedule of the necessary actions. The algorithm takes J2 and drag perturbations into account; at the scope a differential orbital parameters linear relative dynamics model has been used, while the real-world dynamics is represented by a high precision orbital propagator.

The results show that even such a multi-constrained control system, typical of a small satellite or even of a CubeSat, can perform a wide range of typical formation operations, such as station keeping in normal mode and during Target's scheduled operations, and acquisition of different relative configurations, like Helix or Train formations. Notice that the proposed method allows to compute the maneuvers' profile almost in real time, not asking for the long horizon for typically required scheduling. Limits in terms of accuracy and mission duration are as well highlighted.