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Title
Optimized multi-satellite manoeuvring strategy for responsive Earth observation

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Abstract

Traditional space operations are characterized by satellite systems that fly on ad-hoc designed orbits for their entire lifetime, provided that adequate station keeping manoeuvres are carried out when necessary to compensate the effects of orbital perturbations. However, within an increasingly fast-paced and complex world, the ability to respond to unpredicted situations is becoming paramount. An example is given by remote sensing satellites when they are requested to provide combined high resolution observations and very low revisit time over areas of interest in case of local emergencies, e.g., earthquakes, forest fires, or other natural disasters. The related concept of responsive space can be achieved in two ways. On the one side, a solution fostered by miniaturization and standardization of space systems is to develop responsive launch capabilities. On the other side, an alternative solution is to use orbital and/or attitude manoeuvres to adjust the ground tracks of in-orbit satellites in order to optimize coverage on given areas of interest, leading to the concept of agile satellite manoeuvring.

The latter approach becomes appealing for multi-satellite systems, where the number of available space platforms helps in the trade-off between propellant expense and responsive observation requirements. Therefore, it has been addressed in current literature from different perspectives: type of manoeuvre (i.e., impulsive or continuous thrust), type of target to overfly (i.e., punctual target or an extended area of interest), number of targets to overfly (i.e., single or multiple targets), adopted method (i.e., analytical or numerical), and assumed on-board sensor (i.e., information on the type of payload might be available or not). Most of these approaches focus on developing optimal manoeuvres that a single satellite has to perform. Nevertheless, current space actors (i.e., space agencies, industries and private stakeholders) can rely on more than one satellite to manoeuvre.

In this framework, this paper proposes a decision making architecture to overfly a single target, assumed that multiple satellites are available. Satellites can be equipped with radar or optical sensors. Both punctual and extended area of interests are considered. A set of the initial constellation is selected, according to ad-hoc criteria, to estimate the manoeuvres that guarantee the overflight. A J2-perturbed analytical model is implemented to design dual coplanar impulsive manoeuvres. A multi-objective Pareto frontier-based optimization is then adopted to find the subset of satellites that can actually manoeuvre according to different objective functions (e.g., minimum fuel consumption, minimum time to overflight and maximum propellant budget).

A sensitivity analysis with respect to the time to overflight, payload characteristics, target geodetic coordinates is carried out using a synthetic dataset of satellites. The architecture is then applied to a real Earth observation constellation and it is tested using the General Mission Analysis Tool (GMAT).