UQOP 2019
Uncertainty Quantification & Optimization Conference
18-20 March, Paris, France

Structured-Chromosome GA Optimisation for satellite tracking

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Keywords: Genetic Algorithms, variable-size optimisation, satellite Observation Scheduling, aerospace engineering.

ABSTRACT

This research addresses the problem of autonomous scheduling of space objects' observations from a network of tracking ground stations to enhance the knowledge of their orbit while respecting allocated resources. The presented approach aims at supporting the space sector by tracking both operational satellites and non-collaborative space debris. As for the former, it is crucial to accurately know the satellite state to precisely calibrate the instruments, interpret scientific data, and communicate with ground stations. For the latter, the debris position and velocity is mainly employed to predict and avoid impacts with other objects, as well as monitor the decay and predict the possible re-entry. However, in the last years, the number of space objects to be tracked has been increasing strongly and now most of them are tracked infrequently and with low accuracy.

An optimisation routine has been used for minimising the uncertainty on the final state of an orbiting object scheduling the observations from a network of ground stations. The performance index and objective function is a measure of the uncertainty that is evaluated by means a sequential filtering approach based on unscented Kalman Filter [1] that estimates the satellite state distribution conditional on received indirect measurements.

The free variables describing the observation schedules are 1) the number of times a specific ground station is used, 2) in which satellite pass over the station this has to measure and 3) the number of observation to perform. Consequently, without simplifying assumptions, the number of design variables is not constant among different solutions, and the observation scheduling optimisation falls under the area of the variable-size mixed-discrete global optimisation. To deal with dynamically varying search spaces, a number of additional challenges, harden dramatically the complexity of the search algorithm. Among the different algorithms, genetic algorithms

*This work was funded by the European Commission's H2020 programme, through the H2020-MSCA-ITN-2016 UTOPIAE Marie Curie Innovative Training Network, grant agreement 722734.

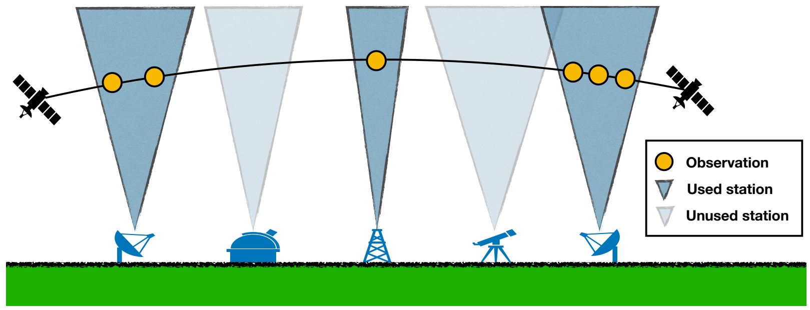

Figure 1: *Graphical 2D representation of satellite single passage over network of ground stations. The dark shaded blue field-of-view indicates that a station is used to take measurement, whereas the light shaded blue indicates that the station is not operated.*

(GAs) are recognise as the most suited to face this kind of problem [2]. For handling the optimisation of satellite tracking observation campaigns we propose the Structured-Chromosome Genetic Algorithm (SCGA) [3]. This bases its strategy on revised genetic operators that have been reformulated for handling hierarchical search spaces. Furthermore, the performances of presented tool are compared to an implementation of the "hidden-genes" Genetic Algorithm [4], standard Genetic Algorithm and Random Search.

The potential of the presented methodology is shown by solving the optimisation of a tracking window schedule for a very low Earth satellite operating in a highly perturbed dynamical environment.

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