Commentary on "A Local Search Solution for the INTEGRAL Long Term Planning" Matthew Kitching and Nicola Policella

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This paper presents a work that has been performed at the European Space Agency (ESA) on the long-term planning of observations by the ESA INTEGRAL satellite (INTErnational Gamma-Ray Astrophysics Laboratory). The INTEGRAL mission aims at observing gamma-ray emissions from the universe using several instruments on board an Earth-orbiting satellite. Each year, ESA emits an announcement of opportunity (AO) to which scientists answer by emitting observation requests. The result is an over-constrained planning problem over a one year planning horizon. The problem is over-constrained because the requests cannot be all fully satisfied. Hence, the questions are: which requests to satisfy, at which level, and how? The complexity of the problem does not come from physical constraints (mainly, scheduling constraints: two observations cannot overlap). It comes from user constraints (special requirements on the way some observations are performed: observations with no splitting, periodic observations, observations to be spread) and from a complex criterion to be optimized. From the scheduling point of view, a particularity of this problem is that the planning horizon is split into non overlapping intervals (each one associated with the usable part of a satellite revolution) on which observations can take place.

This problem has been already addressed in the context of the ESA APSI study (Advanced Planning and Scheduling Initiative (Steel et al. 2009)). In (Pralet and Verfaillie 2009), the authors model the problem and propose a local search algorithm in the space of feasible plans. This algorithm considers two kinds of local moves: either the enlargement of an observation activity in a satellite revolution r, or the enlargement of an observation activity after the removal of another observation activity in r. The feasibility of a local move is verified by checking that the current set of observation activities in r is schedulable. Checking is performed via a call to an APSI generic scheduling algorithm.

In this paper, the authors propose also a local search algorithm in the space of feasible plans. However, this algorithm uses another structure for plans: revolutions are arbitrarily split into sub-revolutions and at most one observation activity is associated with each sub-revolution. Such a structure guarantees schedulability, without any check to be performed. On top of this structure, a local move merely consists in changing the observation activity associated with a sub-revolution.

This plan structure arbitrarily constrains the original problem because an observation activity cannot lap over several adjacent sub-revolutions resulting from the splitting of a revolution. As a result, the optimum of the new problem is worse than the one of the original problem. However, local moves are far more easier in this structure: no necessary schedulability checking. As they are faster, far more moves are possible within a given computing time (between 100 and 1000 times more). Regions of the search space that remain unexplored with the first local search algorithm can now be explored. The final result is an increase in the quality of the plans produced within a given computing time (see the experimental results which compare both algorithms). To sum up, the proposed approach limits the search space, but explores it more efficiently, and finally produces better quality solutions.

Such results confirm that several algorithmic options shall be explored to solve as well as possible a given planning problem. They show that some a priori "bad" algorithmic ideas may be actually valuable and that experiments are the only final judge.

A question is: Does this approach work because the planning horizon in the original problem is already split into non overlapping intervals (each one associated with a revolution)? Could this approach be extended to other over-constrained scheduling problems such as, for example, the scheduling of communications between satellites and ground stations?

References

[Pralet and Verfaillie 2009] Pralet, C., and Verfaillie, G. 2009. AIMS: A Tool for Long-term Planning of the ESA INTEGRAL Mission. In *Proc. of the 6th International Workshop on Planning and Scheduling for Space (IWPSS-09)*.

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