Comments on "SOFIA's Choice: Automating the Scheduling of Airborne Observations"

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Abstract

The author comments on the above-mentioned paper, also included in these proceedings. The author of these comments is not an authority either on planning or on the SOFIA observatory airplane, so these comments do not address the feasibility of the suggested approaches. Comparison is made to similar problems in the planetary-spacecraft domain. Concerns are raised about the level of overlap required between technical domain experts and planning domain experts, but no recommendations are made. These concerns are a focus of ongoing research in the planning community, and some tools exist to address them.

Commentator's Background, or "What gives you the right...?"

The commentator is not an authority on the planning and scheduling domain, and is not an authority on observatories, so he does not have any comments directly on the feasibility of the planning strategies proposed. The commentator has extensive experience in the development of flight software for planetary missions, and has related experience with the mission designs, mission activities, mission planning and operations. These missions pose analogous planning problems to the SOFIA mission.

Analogies to Planetary Mission Planning Problems

Planetary missions pose planning problems analogous to the SOFIA mission, although the specific constraints and models are different. For instance, on the New Millennium Deep Space 1 (DS1) mission, the science team had to schedule an asteroid encounter sequence. An asteroid encounter is a short time period (usually, hours) during which the mission will try to pack in as many observations as possible. Some constraints on the mission plan:

- Some observations can only be taken at certain distances from the target, or under certain lighting (phase-angle) constraints.
- Since not all instruments share the same boresight, shifting from one instrument to another, or from one target on the asteroid to another requires time, during which other observations cannot be taken.
- Some types of observations (imaging spectrometers, particles and field experiments) require slewing relative to the target, while others (imaging) require staring at a single target.
- There are points during the closest encounter when the spacecraft cannot slew fast enough to track the target.
- Onboard data storage is limited. Storage space can be reclaimed by downlinking data to Earth, but this takes time away from data collection.
- Orbital tours have similar types of constraints, combined with orbital constraints on when particular targets are visible.

Because of these analogous planning problems across different problem domains, it would be desirable to come up with representations and solutions that are not closely coupled to particular domains.

Applicability of MDS Concepts

The commentator is currently working as the Guidance, Navigation, and Control lead for the Mission Data System (MDS) project at the Jet Propulsion Laboratory. MDS is developing a framework to describe planetary mission system in terms of the states of the system, how they are estimated and how they are controlled. States are controlled by imposing goals on the states, which constrain their acceptable values over certain time periods. A temporal constraint network is used to enforce the precedence & simultaneity dependencies among various goals.

Imposition of goals results in a recursive elaboration process, where additional states and subgoals are imposed to support higher level goals. This elaboration establishes a hierarchical decomposition of the mission system, and allows designers to decouple the knowledge of different components of the system. Elaboration allows the software system to "fill in" a high-level mission plan by adding detailed configuration requirements and preparatory

activities. Elaboration also provides a framework for implementing the flight rules that are typically found in a spacecraft design. (Flight rules include requirements on preparations for certain activities, such as turning on and warming up equipment. They also define mutually exclusive activities, such as the inability to point an instrument in two directions at once.) This elaboration, coupled with models of the behavior and constraints on each state, allows an MDS-based software system to capture domain knowledge and to evaluate the feasibility of a proposed plan and its elaboration. If no conflicts (violation of flight rules) are discovered in the elaborated goals on any state, the plan is legal.

Analysis of the system into its constituent states also simplifies the job of extending the system models. New types of activities can be added as new goals on existing states, making use of existing models. Unfortunately, this process does not give any hints on how conflicts can be resolved.

Overlap between Domain Experts and Planner Experts

Apparently, the typical process of designing a planner requires the implements to gather heuristics from the domain experts. The implementers then represent these heuristics, using tools supplied by a planner engine, such as HSTS. Unfortunately, this requires extensive interactions between domain experts and planning experts, and requires the planning experts to become domain experts (or vice versa). I understand that more automated heuristic gathering is an open research area. It would also be desirable not to rework the planner when new observations are added. With current planner designs, addition of new observations requires addition of new heuristics, and redesign of some portion of the planner.

Planner-Imposed Restrictions on Domain Modeling

The available search methods apparently place severe constraints on the types of constraints that can be represented in a planner. In the SOFIA problem, the plane can only fly in cardinal directions (North, South, East, and West) in order to discretize the possible directions. This is an artificial constraint on the system modelled, and requires domain experts to understand the limits on representation imposed by the planning system.

No Surprises, No Silver Bullets

According to the author of this paper, these are not novel observations, and they are active areas of research. I look forward to learning more about the HSTS system and planning, in general, in the interactions at the Planning & Scheduling Workshop.