Commentary on:
MrSPOCK: a Long-term Planning Tool for MARS EXPRESS

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by

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The European Space Agency has initiated an Advanced Planning and Scheduling Initiative (APSI) to create a general Timeline Representation Framework (TRF) for automating planning, scheduling, and sequence generation for space mission operations. This paper describes how the framework is realized in MrSPOCK (the MARS EXPRESS Science Plan Opportunities Coordination Kit), a mixed-initiative planning system. The modeling of MARS EXPRESS (MEX) long term plans and their optimization using genetic algorithms are presented along with experiments and planned extensions to the APSI-TRF.

At the time of the writing of the paper, MrSPOCK was being used to generate plans based on a subset of the mission's constraints. Results indicate a significant improvement to the schedule according to a value metric capturing different aspects of mission performance and resource usage. Although the output plans have not been validated by MEX mission planners, the planners said that the plans may be a significant improvement.

The paper also demonstrated flexibility of their system to be able to generate plans that emphasized some criteria more than others by simply changing weights on the objectives. They also showed how the model could be extended to incorporate more detailed constraints.

The user interface includes interesting approaches to exploring alternatives in a planning tool. Optimization criteria are compared in a table and in a graph for alternative plans. In addition, a chosen resource or state variable can be compared for many alternatives plans in a timeline view. Combining this with the ability to modify optimization criteria weighting appears to result in a powerful system for exploring alternatives. This flexibility is especially important since it is typically difficult to extract all of the constraints and preferences of human planners.

Prior work on user interfaces for planning has typically only incorporated one or two of these comparison methods and instead focuses on overall visualization and plan editing. Users often want to make at least small changes to auto-generated results, and it can be very convenient for them to add local constraints on the fly (such as locking an activity to keep it from being rescheduled). It is interesting that the MrSPOCK interface is concerned mainly with presentation and comparison of alternatives, possibly indicating that an interface for more detailed editing could be implemented and used independently.

The use of a genetic algorithm (GA) is also an interesting choice for plan generation. Scheduling problems of this kind are often intractable to solve optimally, and many other systematic search methods are only able to address parts of a problem in isolation. As a kind of local search algorithm, a genetic algorithm is able to work on large and difficult problems resulting in a best-effort plan that tends to slowly improve with more computation time. However, a common pitfall of the local search approach is that easy fixes and improvements can be overlooked. Other planning systems have sought to avoid this problem by adding some systematic search to improve different small parts of the overall plan (e.g., Clement and Johnston, 2005; Hiatt at al. 2009). This may not be a problem in the case of MrSPOCK.

The GA is used just to determine whether a maintenance operation is taken during each apocentre and pericentre of MEX's elliptical orbit. Communication and science operations are then filled in using a simple policy based on temporal constraints of operation. The authors did not directly state that an extension of the model to include new constraints (such as with battery power as suggested by the authors) would not affect the architecture, but my expectation is that the constraints would just constrain the policy of filling in the details of the schedule, in which case the constraints might be used to filter out inconsistent schedules. Thus, the architecture seems maintainable at the specified level of abstraction. However, for other scheduling problems, the use of the GA could be quite different, possibly requiring an algorithm not based on the evolution paradigm.

The paper describes the use of the genetic algorithms at a high level. While the details of exactly how mutation, crossover, and selection are set up may not be important, it would be nice to know how the initial population of schedules was chosen.

While the paper talks about the system more than its infusion, the infusion approach seems to be to integrate MrSPOCK into the existing ground planning and sequencing system. This is similar to the approach of MAPGEN where automation tools were integrated with mars rover operations during the extended mission (Chang et al. 2004). In some ways this integration complicates the planning process, making it more difficult for users to adopt. It will be interesting to find out if the particular

interface and operational use of MrSPOCK is effective in reducing user workload.

Reducing workload is a daunting challenge for mixed-initiative decision making because of the difficulty of capturing the needs of the users. A particular challenge not addressed by APSI-TRF or MrSPOCK is how users change and manage constraints and preferences beyond the weighting of optimization criteria. It is not clear from the paper to what extent this will be a problem for MrSPOCK.

Overall, the MrSPOCK appears to be strategically designed to efficiently discover and present valuable alternative solutions to human planners while retaining flexibility. The user interface seems to be effective and unobtrusive. A simple abstraction of the problem is given to the GA, and the more detailed plan can be constructed from its solution based on other constraints in the system. The scheduling algorithm seems specialized to MEX planning and may not be relevant to planning for other missions. However, the future use of MrSPOCK will be very instructive in how to automate mission planning.

References

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