Comments on "Interleaving Temporal Planning and Execution for an Autonomous Rover"

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Abstract. The subject paper shows promise in leading to a useful system for integrating deliberative planning, plan repair, and execution control in a dynamic environment with real-time constraints. The conditions in which the system described would enable such integration seem to be ones that would apply to significant practical problems for an autonomous rover.

1 My Background

The comments that I will make reflect very much my own background and experience. I've worked on space missions at the Jet Propulsion Laboratory (JPL) for more than 25 years. During almost all of that time, I have been involved with the development of software for use in the uplink process of space missions operations. For example, I led the team that developed the multi-mission version of the computer program called SEQGEN ("sequence generation"), which has been used by more than 20 flight projects. So I'm familiar with the kinds of problems that need to be solved during uplink operations, and the attempts at JPL to have software aid the process.

Much more recently, during the past year, I had the role of a Tactical Activity Planner (TAP) for the surface operations of the Mars Exploration Rover (MER) project. In this role, I was not principally a developer of software, but a user.

The TAP takes a list of requested activities from the scientists, and schedules them into a plan. The chief resources that the plan must conform to are energy, volume of data generated, and time. The principal kinds of rules that the TAP's plan must obey are rules stating that overlapping of certain activities is forbidden.

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The program MAPGEN (Ai-Chang *et al*, 2003) is the main program that the TAP uses. MAPGEN was built specifically for use by MER. MAPGEN's models embody the rules about overlapping activities as well as useful support activities of the CPU on and required heating activities. A separate program, the Constraint Editor, is used each sol by the TAP to express the temporal and ordering constraints among activities. These constraints are understood by MAPGEN.

The TAP's work takes place in a very time-constrained environment. Each sol the operations team does a full cycle from receipt of downlink to uplinking a new, full plan:

receive downlinked data
analyze downlink data
prepare requests
prioritize requests
schedule the requests (the TAP's role)
turn requests into sequences of commands
validate the combined sequences
radiate the sequences to the rover

All of these steps are accomplished between the downlink of data during the sol's afternoon and the uplink the next sol's morning. The scheduling step done by the TAP occupies about 4 hours. (Note: For the extended mission, the times have been shortened.) The need for speedy support by planning/scheduling software is apparent.

I relate all this here because in some ways the planning done by the human TAP using MAPGEN is similar to planning that a more autonomous rover needs to do on-board. So my MER experience greatly informs the remarks that follow.

2 Comments on the Paper

The introduction in the subject paper enunciates the objectives of the work presented. One summary statement is “combine deliberative planning, plan repair and execution control that takes into account resource level updates and temporal constraints”. This appears to be a very worthwhile objective to enable a more autonomous rover.

I will not comment on details of the formalism, except to say that its existence is a good sign that a system built around it would be consistent.

The level of detail envisioned to be handled at the planning level in this system seems to be reasonable; I’m basing this mostly on the example scenario sketched near the end of the paper.

The types of events and reports that the system is designed to handle appear of use in realistic situations. For example, inserting a new goal is one type of event considered, and that is definitely something that must be handled in a realistic system. How about deleting a future goal? And “sudden alterations of a resource capacity” is another feature that adds realism to the system.

It appears that a good attempt has been made to address aspects of systems that can be very helpful and practical, even if not every foreseeable situation is handled without a complete replan. In other words, I like the acknowledgment of the idea that solving some common problems can be an effective step forward, rather than insisting on a system that solves every problem.

Of course, for a system to be usable in a real situation it must perform fast enough and require little enough memory. I’m glad to see that trials of the system on a rover have been done, and encourage future trials, to be able to measure performance and to see how the performance scales to larger systems.

One desirable feature of a planning system is for it to be able to be useful even if it is not in control of “the whole system” being planned. Would this system be able to be a player in a larger system, perhaps with some very “traditional” parts?

I don’t have insight on how difficult it is to prescribe the actions, events, rules, etc. Among the challenges to getting acceptance by a space mission of a planning technology is the need for the models and logic of the planning system to be reviewable by people who are spacecraft and operations experts, but who are not familiar with the planning technology.

Another challenge to infusion is for the demonstrations of the planning system to cover scenarios that are familiar to spacecraft and operations personnel. The scenario sketched in the paper is a good one. It would also be good to take an actual MER sol scenario and see how the planning/execution system does with it.

2 Summary

The subject paper addresses a class of problems whose solution is of practical interest in the direction of making rovers more autonomous. The system described in the paper shows promise and insight toward a solution.

2 Acknowledgment

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Reference

Ai-Chang, M.; Bresina, J.; Charest, L.; J´onsson, A.; Hsu, J.; Kanefsky, B.; Maldague, P.; Morris, P.; Rajan, K.; and Yglesias, J. 2003. Mapgen: Mixed initiative planning and scheduling for the mars 03 mer mission. In *International Symposium on Artificial Intelligence Robotics and Automation in Space (iSAIRAS).*