Controllability and Makespan Issues with Robot Action Planning and Execution Commentary

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The increased use of planetary exploration rovers and probes in recent years has posed a big issue for the development of on board planning capability. This is indeed one of the most powerful means to increase the scientific outcome of the next solar system exploration missions. Autonomous planning capability will allow the achievement of goals such like navigation out of visual range and the autonomous reaction without the need of a new plan to be uploaded from Earth.

In this paper the problem of on-board planning and plans execution in the real world is addressed for a planetary exploration rover. The planner used is the IxTeT that was developed to handle robotic planning problems, complex resources, constraints between atemporal and temporal variables and continuous constraints. This planner has also a temporal executive. The IxTeT, as it searches in the plan space, allows to execute plans that are not correct but remain executable during a plan repair attempt. Basically the planner looks for a subset of all defaults (i.e. defaults in the plan that make it not correct) and then it computes a way to solve each of them (resolver). At each default is associated a number of resolvers with their costs. For each default an opportunity factor is computed in function of the costs of all its resolvers and the planner chooses the default with the better opportunity factor. The least expensive resolver is applied unless a plan without defaults is found.

Two main issues are considered: the implementation of a planner which complies with non controllable temporal constraints and the minimization of the plan makespan at the execution time.

The 3DC+ algorithm has been implemented in the IxTeT planner with an existing temporal formalism with explicit uncertainties (STNU), in order to provide dynamic controllability i.e. to plan tasks with uncertain durations. In this way plans are produced which do not fail because of a variation on an uncertain duration and the robustness of the planner results increased. Another advantage deriving from the implementation of the 3DC+ algorithm is to permit more complex synchronisation between activities, potentially making shorter plans especially if an activity intermediate point has to be synchronised with the end of another one with an uncertain duration.

A new heuristic has been implemented in the IxTeT planner in order to minimize the plan makespan: the idea is to choose the resolver that makes the shorter plan between all resolvers of a default. This allows to keep the least commitment strategy yet minimizing the makespan of the plan.

The new implementations of the IxTeT planner have been tested with a simulator and the mobile robot DALA in an indoor environment (the simulator is not able to provide a realistic outdoor environment). This is an ATRV robot with 4 wheels equipped with a laser range finder for indoor obstacle avoidance and a pair of cameras for stereo vision building numerical elevation map and tracking the position of the robot. The on-board computer is a Pentium 4 at 3GHz with 1GB ram. A typical exploration rover mission is defined as part of the evaluation scenario and then instantiated with different parameters to test the stability of the results. Basically the rover must acquire scientific data from several places and communicate with an orbiter during visibility windows.

The new heuristic seems to work well in producing shorter initial plans with algorithm 3DC+ or without it, but it seems to work bad without the 3DC+ from the point of view of the robustness. The robustness is effectively improved by the use of STNU and dynamic controllability.

The development of on-board planning and plan repair capability is a must for future interplanetary exploration missions. In this paper some promising steps in this direction are presented but it seems to be only the starting point of a long process. Though a method to solve the problem of the autonomous management of tasks with uncertain duration has been developed, some issues remain worth of future investigations.

As also indicated by the author, the lack of capability to change order between tasks is a gap to be covered in order to make the repair process complete. In fact the planner has to be able to move communications around navigation as, in a typical planetary exploration scenario, communications are made during fixed temporal windows while navigation is free.

The lack of any geometric reasoning capability seems to be a real chink as the plans produced do not account the planned path for the rover. This feature can be critical for the management of the on-board resources and their constraints and can impair the final scientific outcome.

Another suggested development is to make the simulator able to provide a realistic outdoor environment: this is fundamental for the evaluation of the planner behaviour in a real planetary exploration scenario. It would be interesting to make some simulations using as testbeds some scenario really encountered by last Mars exploration rover missions of NASA. The comparison between the sequence of events obtained in simulations using the autonomous planner and that actually obtained during the real mission by means of successive plan uploads to the NASA rover, could be very helpful.