O-BIPPS Demonstrator - Towards On-board Autonomy

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Abstract. The development of the O-BIPPS demonstrator is discussed. This work seeks to prepare a framework for an on-board deployment of planning and scheduling based on, a previously defined technology roadmap, Beagle 2 experience and a survey of user views. The current demonstrator allows users to construct plans and automatically check validity. Where errors are detected the system will suggest or carry out appropriate repairs.

1 Introduction

As part of the recent Aurora technology evaluation programme, SciSys in conjunction with the Universities of Salford and Durham[1] carried out a detailed study (Woods et al 2002) called On-Board Intelligent Planner and Scheduler (O-BIPPS), which investigated the use of planning and scheduling for remote planetary exploration applications. The work is based in part on the experience gained developing the Beagle 2 Lander software. This first phase of O-BIPPS produced a long term roadmap for the technology detailing how AI planning and scheduling should be developed over the course of Aurora.

Among the many conclusions of the study was the recommendation that planning and scheduling deployed, on-board, robotic exploration missions and in-situ units in particular would be advantageous and necessary if the various Aurora goals are to be met. One of the recommendations of the report is that a prototype demonstrator should be developed to examine the issues surrounding this type of application and supported by a survey of stakeholder views. The O-BIPPS study has been extended to help achieve this objective. The extension has produced a demonstrator for a ground based mission planning support tool which can be used by planning teams to automatically resolve schedule constraint violations. To develop such a tool, appropriate constraint, resource and actions models were constructed along with the actual planning and scheduling algorithms. This modelling exercise was an important first step in developing an eventual on-board planning and scheduling capability. It is envisaged that interaction with potential users of the system both during and after development will provide a useful means of defining the interface between users and this advanced technology. Furthermore, the actual scheduling and planning algorithms were selected on the basis of on-board suitability, so although more resources are available in the form of typical workstation processing power, the development will assume that significantly less capability is available.

It is important to stress that the O-BIPPS activity is aimed at the eventual provision of an on-board planning and scheduling capability as a means of providing greater surface mission autonomy. However the actual development process clearly overlaps with the wider area of ground based mission planning. For an on-board capability to be of practical use it must be carefully integrated with ground segment. Operators must be aware of its capability and limitations. Should the autonomy fail or degrade then it is essential that the ground segment can interface transparently with the on-board system at a number of levels. This has been borne out in a survey carried out as part of the O-BIPPS extension.

1.1 User Survey

Interviews were conducted with six experts in operational aspects of missions run by ESA. These experts covered a number of domains: from collecting and scheduling mission tasks from science teams, to support of action-sequence uploads to platforms, and design of recovery procedures for operational failures. It is known that operational staff are risk-averse (for good reasons) but all of the experts interviewed agreed that the approach to operations would have to change for deep-space platforms and that some degree of increased autonomy was inevitable. The focus then was on how to mitigate the increased risk of more complex systems, provide transparency (so that it was always clear why actions were being planned or executed) and provide mechanisms allowing traditional tele-operation to be reinstated at once if required.

It was also clear that a graduated approach to autonomy was required, so that fears of losing control of a highly autonomous platform could be met. A hierarchy of autonomy has been developed as follows, with the demonstration system operating at levels 1 and 2 (see Table below). Here *executed actions* correspond to the executable actions currently sent by teleoperation; *tasks* could be, for example, particular measurements requested by scientists, and *mission goals* represent the overall objectives of a particular mission.

Clearly it is vital that the development of on-board and ground segment planning systems be closely coupled to ensure maximum efficiency, reliability and robustness.

[1] The Durham AI Planning and Scheduling Group have moved in entirety to the University of Strathclyde

It is hoped therefore that this extended O-BIPPS program to will play a role in helping to ensure reliable migration from ground to on-board autonomy.

Level	Problem description	Action
1	Effects of executed action fail	Retry the action – an immediate reschedule
2	Pre-condition check for executable action fails; resource availability changes	Reschedule existing executable actions
3	Pre-condition for executable action fails	Plan repaired via insertion of extra action(s)
4	New task presented; scheduled executed actions now infeasible	Plan/replan executable actions (lowest level)
5	Existing task sequence infeasible – resource changes or other threats; new opportunities	Reschedule at task level
6	Mission goals faced by threat or opportunity	Generate new tasks and plan for these

2 Demonstrator Description

The demonstration will consist of a software planning support tool which itself comprises a front-end MMI and back end scheduling component. The tool represents an enhanced version of the scheduler developed for the Beagle 2 mission (itself based on the Rosetta mission scheduler).

Users will be able to create and merge operational plans which will then be checked automatically for consistency and constraint violations using an appropriate domain model. On checking temporal constraints the system will indicate where constraints must be tightened to preserve executability. If a plan is found to be invalid, the system will suggest repair options or carry out repair automatically. In addition to demonstrating planning support capability, the tool will also allow discussion of modelling and algorithmic issues for on-board use also allow discussion of modelling and algorithmic issues for on-board use.

3 References

Woods, Aylett, Long and Fox, *Aurora O-BIPPS Final Report*, SSSL-S7718-DOC-005, Dec 2002