

Mission Operations Planning with Preferences: An Empirical Study

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Abstract

This paper presents an empirical study of some non-exhaustive approaches to optimizing preferences within the context of constraint-based, mixed-initiative planning for mission operations. This work is motivated by the experience of deploying and operating the MAPGEN (Mixed-initiative Activity Plan GENerator) system for the Mars Exploration Rover Mission. Responsiveness to the user is one of the important requirements for MAPGEN; hence, the additional computation time needed to optimize preferences must be kept within reasonable bounds. This was the primary motivation for studying non-exhaustive optimization approaches.

The specific goals of the empirical study are the following: (i) assess the impact on solution quality of two greedy heuristics used in MAPGEN, (ii) assess the improvement gained by applying a local linear programming technique to the final solution, and (iii) compare the resultant solution quality to the optimal solution found via a branch and bound search.

Introduction

This paper presents an empirical study of some non-exhaustive approaches to optimizing preferences within the context of constraint-based, mixed-initiative planning for mission operations. Our motivation derived from the problem of activity planning for the Mars Exploration Rover (MER) mission and the system used to accomplish this task: MAPGEN, Mixed-initiative Activity Plan GENerator (Bresina, et al., 2005a). Responsiveness to the user is one of the important requirements for MAPGEN; hence, the additional computation time needed to optimize preferences must be kept within reasonable bounds. This was the primary motivation for studying non-exhaustive optimization approaches. A secondary concern was to incorporate preference optimization into MAPGEN without major changes to the planner's search algorithm.

The MAPGEN system represents a successful mission infusion of mixed-initiative planning technology. MAPGEN was deployed as a mission-critical component of the ground operations system for the Mars Exploration Rover (MER) mission. Each day, the Tactical Activity Planner (TAP) employs MAPGEN to collaboratively plan the activities of the Spirit and Opportunity rovers, with the objective of achieving as much science as possible while ensuring rover safety and keeping within the limitations of the rover's resources (e.g., power).

The MER mission has been operating with great success for over two years, and MAPGEN continues to be employed for activity plan generation for the Spirit and Opportunity rovers. During the multi-year deployment effort and subsequent mission operations experience, we have learned valuable lessons regarding application of mixed-initiative planning technology to mission operations (Bresina, et al., 2005b). These lessons have stimulated new research in mixed-initiative planning with preferences.

The MER scientists express their intent to the MAPGEN system through the requested activities, the associated priorities, and science constraints. By enforcing the specified science constraints, MAPGEN ensured that the data collected satisfied the science intent. However, in addition to these hard constraints, the scientists often have temporal preferences in mind, which could yield higher quality data. Such temporal preferences cannot be formally encoded in MAPGEN. Some of these preferences are verbally communicated to the TAPs, and if they have time, they try to satisfy them by fine-tuning the plan. In addition, there are other more global preferences related to solution quality that were not formally encoded and were left up to the TAPs to satisfy.

We have extended our research version of MAPGEN by enabling the system to enter temporal preferences and are exploring alternative techniques for optimizing the satisfaction of (possibly competing) preferences. In this paper, we focus on non-exhaustive approaches that are more efficient and easier to integrate into MAPGEN, and we present the results from an empirical study aimed at evaluating these approaches. Specifically, the goals of the empirical study are the following: (i) assess the impact on solution quality of two greedy heuristics used in MAPGEN, (ii) assess the improvement gained by applying a local linear programming technique to the final solution, and (iii) compare the resultant solution quality of the optimal solution found via a branch and bound search. In order to make it easier to perform a controlled empirical study, we employed analogs of MAPGEN and the MER planning problems.

In the next section, we present background material on aspects of MAPGEN that are relevant to the empirical study, the representation and types of temporal preferences, and the local linear programming technique. In the subsequent sections, we describe the design of the empirical study and discuss the results. We close with some concluding remarks.