Mixed-initiative Planning in PASSAT

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Introduction

This document describes a mixed-initiative planning system called *PASSAT (Plan-Authoring System based on Sketches, Advice, and Templates)* [Myers et al., 2002]. In contrast to many AI planning systems, PASSAT provides a suite of tools that are intended to augment human planning skills rather than replace them.

At its heart, PASSAT is a plan-authoring system in which users construct and modify plans interactively. Users can draw upon a library of *templates*, to the extent they desire, to assist with plan development. Templates correspond to a form of hierarchical task network (HTN), and may encode both parameterized standard operating procedures and cases corresponding to actual or notional plans developed for related tasks.

To complement these interactive tools, PASSAT includes a range of automated and mixed-initiative planning capabilities. Users can invoke an *automated planning* mode based on standard HTN methods to expand open tasks within a plan. A mixed-initiative *plan sketch* facility helps users refine outlines for plans to complete solutions, by detecting problems and proposing possible fixes. *Advice* enables users to define high-level policies for plan content that the system enforces during interactive and automated plan development. PASSAT also includes *process facilitation* mechanisms to aid the user in managing incomplete tasks during plan development.

Two key principles have guided the design of PASSAT:

(a) Flexible, 'out of the box' planning: Traditional AI planning systems lock users into the set of solutions implied by a domain's predefined action models. Within PASSAT, templates are viewed as guidelines for performing tasks; the human planner is free to expand the set of solutions defined by the templates. In particular, a user can override constraints, drop tasks, or insert additional tasks to match his personal preferences or the demands of the current situation. This flexibility is critical for domains in which correct and comprehensive collections of templates cannot be provided.

(b) Controllable user-centric automation: Automated capabilities should complement human planning skills and be readily directable by a human.

PASSAT is generic, domain-independent technology but is tailored toward applications for which (a) the complexity of the domain precludes full capture of all relevant planning knowledge, and (b) human input is critical, but some amount of automation would improve plan quality and reduce overall planning time.

Many potential application domains for planning technology have these characteristics. Examples include Special Operations Forces (SOF) mission planning (the motivating domain for our work), disaster relief planning, noncombatant evacuation operations, and mission and ground operations planning for space applications.

Mixed-initiative Plan Development

A user directs planning in PASSAT through a browser-based interface. PASSAT provides two main modes of mixed-initiative plan development: *interactive plan refinement,* and *plan sketching*.

Interactive Plan Refinement

Interactive plan refinement in PASSAT involves three types of planning step: *expand task*, *instantiate variable*, *resolve constraint*.

Expand Task For task expansion, the system offers the user the choice of applying a predefined template, specifying a set of subtasks interactively, sketching a solution (see below), or dropping the task.

When the user chooses a template to apply, the system unifies the task and the template's purpose, making appropriate substitutions throughout the template. PASSAT adds the subtasks and constraints of the template to the plan. PASSAT also extends its agenda to include planning steps to expand the new subtasks, to check the new constraints, and to instantiate any unbound variables from the template. The planning step for the parent task is marked as completed and removed from the agenda.

PASSAT checks the status of all constraints created during task expansion. For a valid constraint, the planning step to check it is removed from the agenda. For an invalid constraint, the planning step is flagged.

Other planning steps may be affected by a task expansion. If the expansion results in the assignment of a variable, the planning step for instantiating that variable is removed. Also, the status of constraints that contain that

variable might now be resolvable; the system checks those constraints and updates the planning steps, if necessary.

Instantiate Variable To aid with variable instantiation, PASSAT presents to the user the set of values that satisfy all relevant constraints; the user can select from this set, provide an alternative value (hence, override a relevant constraint), or simply mark certain values as unacceptable. When the variable is instantiated, any impacted constraints are rechecked.

Resolve Constraint As noted above, PASSAT provides automated checking of constraints as part of template application, with the agenda being used to track constraints that the system was unable to validate. *Resolve constraint* steps enable a user to declare that the system can disregard designated unsatisfied constraints in a given situation. A user may wish to do so because (a) he has more recent information that would validate the constraint, (b) he knows that the constraint is overly strong for the current situation, or (c) he wants to explore a *what-if* scenario.

Robust Plan Sketching

Within PASSAT, a user can *sketch* an outline of a plan, with the system providing assistance in expanding the sketch to a full solution [Myers et al., 2003]. A sketch consists of a collection of tasks that (1) may be only partially specified, and (2) may occur at various levels of abstraction in the plan hierarchy.

When given a sketch, PASSAT generates possible *expansions*, which amount to least-commitment plan structures that embed the sketch and all derived consequences. The user may choose any of these expansions to continue planning; the agenda will be updated to reflect the derived set of outstanding tasks.

The sketch processing capability within PASSAT builds substantially on [Myers, 1997] but provides robustness through an ability to recognize and respond to *invalid* sketches. By invalid, we mean a sketch for which there is no legal completion relative to the set of defined templates. PASSAT guides the human planner through the process of modifying a plan sketch to eliminate detected problems. The role of the system is to identify sketch problems and possible repairs, while the human acts as the decision maker in navigating through the space of options.

Advice

PASSAT's advice mechanism enables a user to express high-level requirements on solutions. Examples within the SOF domain include *Don't use more than 3 landing zones* and *All landing zones should be < 1 mile from the hostage site.* Advice is relaxable, capturing conditions that the user would like satisfied but that can be dropped if necessary.

Enforcement of advice involves restricting the set of operations (human or automated) that are allowed in constructing plans. PASSAT monitors evolving plan content to identify operations that would violate user advice. Violations lead to user notification, as well as the posting of appropriate planning task entries on the agenda. PASSAT's advice framework builds on our previous work on giving strategic advice to fully automated planners [Myers, 1996], with adaptations and extensions as required for a mixed-initiative plan authoring environment.

Process Facilitation

PASSAT facilitates the planning process through the maintenance of an *agenda* of 'planning steps' to be completed for the current plan. By planning steps, we mean process-level decisions and actions in support of plan development, rather than the activities within the plan itself. The PASSAT agenda supports the three types of planning step describe earlier: *expand task*, *instantiate variable*, and *resolve constraint.*

The user can filter the planning steps in the agenda display along several dimensions, including step type and completion status. The user can also sort the agenda by step type, step priority, creation time, and alphabetical order. The agenda provides critical assistance to the user for large-scale planning operations, as it enables the user to stay focused without losing track of important details.

Conclusions

With its combination of interactive plan authoring, plan sketching, and advice, PASSAT enables a user to quickly develop plans that draw upon past experience encoded in templates but that are customized to his individual preferences and the current situation. The human remains the key decision-maker within PASSAT, but can invoke automation when appropriate to aid with task expansion, constraint checking, and process management. This style of mixed-initiative planning is essential for many domains, where the generation of high-quality, trusted solutions requires substantial human insight and judgment.

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