The Generation and Inspection of Metric-Temporal Plans within the Sapa Planning Framework

Daniel Bryce, Minh B. Do, & Subbarao Kambhampati
Department of Computer Science and Engineering
Arizona State University, Tempe AZ 85287-5406
{dan.bryce, binhminh, rao}@asu.edu

1 Introduction

Sapa [Do and Kambhampati, 2001], [Do and Kambhampati, 2002], [Do and Kambhampati, 2003a], one of the best performers in the 2002 International Planning Competition, generates fairly complex metric-temporal plans from problem descriptions modeled in pddl 2.1 level 3 [Fox and Long, 2003].. Such scale-up in generating non-trivial plans requires advanced visualization techniques for human understanding of the plans. To help users understand the complex interaction of plan steps, and the reasoning for their ordering, we have developed a GUI for interacting with Sapa. Given the properties of plans using durative actions with discrete resource changes, there are two ways to view the plans, either procedurally or logically, with the respective charts:

- **Gantt charts** exploiting the temporal aspects of plans (Figure 1).
- **Pert charts** concentrating purely on the logical structure of plans (Figure 2).

The properties that can be visualized with these charts are:

- **durative actions** that have a start and end time.
- **makespan** that is represented in time units.
- **causal links** from effects at the beginning and ends of actions to support preconditions of other actions.
- **resource mutual-exclusion** between actions that use the same resource.
- **predicate mutual-exclusion** between actions influencing interacting predicates.

This paper outlines the unique capabilities of the Sapa software in the generation and inspection of metric-temporal plans. Special emphasis is placed on human interaction to better illustrate the more tangible portions of a software demonstration involving Sapa.

2 Software Overview

Sapa uses many state of the art techniques for plan generation, as well as powerful visualization techniques to facilitate user interaction with the planner.

2.1 Plan Generation

Sapa generates parallel position constrained metric temporal plans by doing forward state-space search. The plans can then be greedily or optimally post-processed to produce a more flexible order-constrained plan[1]. The heuristic to guide the search is estimated from building the relaxed temporal planning graph for each search state. The detailed procedures can be found in Do and Kambhampati [2003b].

Sapa's major technical contributions are:

- Allowing various objective functions for multi-objective search,
- Using planning graphs to derive heuristics sensitive to both cost and makespan,
- Easy adjustment of heuristics to account for metric resource limitations, and
- Linear time greedy post-processing to improve execution flexibility and quality with respect to given criteria.

2.2 User Interaction

The human interaction with Sapa, through use of a GUI, improves plan inspection and explanation. The sequence of actions that is output by the planner has many attributes that are not captured visually in the text output. These are action start times, durations, causal link relations, executability constraints, and resource utilization conflicts. The start time and duration of each action is shown in the text output, but these have little intuitive value as compared to actual visualization through a Gantt chart, as in the GUI. Furthermore, the relations between actions are complicated to show in text, so they are depicted by color-coded arcs between the actions in the Gantt and Pert charts. In addition, to emphasize the relations and de-emphasize the start times and durations of actions, there is also a Pert chart view of the plan, where contrary to a Gantt chart, every action's graphic is of unit size and there is no time scale.

Further dissection of plans is available in both the Gantt and Pert chart views. The charts are configurable to show only certain types of relations between actions. Also, individual actions can be selected to show only those relations that involve the action, further diminishing the user's memory load. The inspection of actions is facilitated either through

[1] the later technique is in experimental phase

directly clicking on them, or selecting them from an action list. In addition, a view of the details (e.g. start time, duration, objects involved, and relations with other actions) of the action is made available in text. De-selecting an action will remove the action detail view, un-highlight the action, and reinstate the links for all actions in the plan. Other options for plan inspection, independent of the individual actions, include viewing the plan statistics (such as those mentioned for the text output), and zooming/panning the charts.

3 Extensions

Aside from the enhancements suggested from usability testing of Sapa [Bryce, 2003] to make user interaction more intuitive, there are many ideas within the context of the GUI that may be worth exploring:

1. Interactive user selection of non-dominated plans[2].
2. Interactive user reordering and re-planning of plan segments.
3. Resource usage time line.
4. Viewing the optimal post-processing of a plan [Do and Kambhampati, 2003b].

4 Conclusion

We have shown how Sapa can generate metric-temporal plans and how the interface to the planner allows humans to gain enhanced understanding of the generated plans. The main benefits of the interface include:

1. Supporting domain *authoring* and planner *implementation* through explanation of a generated plan's structure.
2. Enhancing human understanding of how to *execute* the generated metric-temporal plans.
3. Conveying *relations* between actions that would be cumbersome through simple text.

For the latest information on Sapa and a usable on-line java applet of the interface, please visit http://rakaposhi.eas.asu.edu/sapa/.

References

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[2]In lieu of implementing a pareto-optimal search strategy for Sapa's multi-objective optimization of cost and makespan.

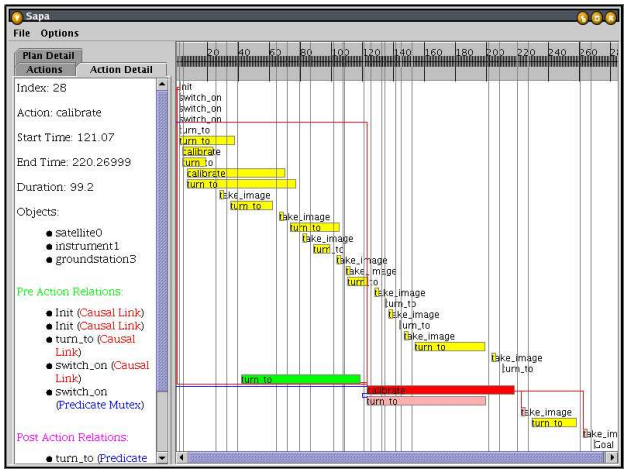

Figure 1: Gantt chart of a plan for the Satellite domain, showing an inspected action.

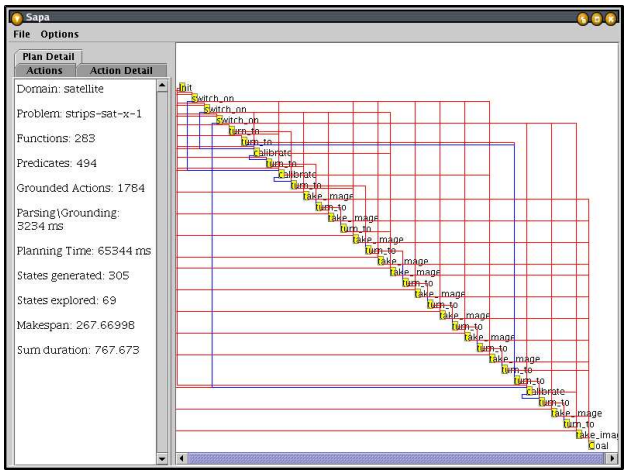

Figure 2: Pert chart of a plan for the Satellite domain, showing plan statistics.