A Note on the DMIN Strategy

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In [1], we describe five strategies for resolving threats between actions in a plan. Two of these strategies dominate the others, both theoretically and empirically:

1. DSEP: wait to resolve a threat until it is no longer separable (i.e. the variable bindings guarantee that the threat will occur).

2. DUNF: wait to resolve a threat until there is only a single way of resolving it,

In some cases DSEP is superior, in other cases DUNF is superior. The purpose of this brief note is to describe a new strategy, DMIN, that combines the best characteristics of both strategies. In fact, it provably generates a smaller search space of possible plans than either DSEP or DUNF. We first describe a simple version of the strategy Basic-DMIN, and then describe the more complex cached version Cache-DMIN.

1 Basic-DMIN

Basic-DMIN involves three steps. When a new partial plan is generated, the planner must:

1. Resolve all outstanding threats that have only a single possible resolution (as in DUNF).

2. Of the remaining threats, filter out those threats that are still separable (i.e. the threat will go away under suitable variable bindings).

3. Search for a resolution of the remaining set of threats (each of which can be resolved by both promotion and demotion). If a resolution is not found, the plan fails. If a resolution is found, these threats are left outstanding, and the ordering constraints that resolve them are not enforced.

When a new causal link or threat is added to the plan, steps 1 through 3 must be performed again on the outstanding threats.

Unlike other strategies that delay resolution of threats, this strategy checks to make sure that the set of threats in a partial plan can be resolved, but doesn't prematurely commit to any particular resolution. To the extent possible, this strategy separates backtracking over the space of possible threat resolutions from backtracking over possible step choices in the plan.

This strategy will always generate a space of partial plans that is at least as small as that for DSEP and DUNF. The drawback is that step 3 of the strategy solves a problem that is NP-complete (exponential in the number of unseparable, unforced threats). This means that a planner using this strategy could perform worse on some problems, even though it was generating fewer plans. In practice, we have found that the set of unseparable, unforced threats for a problem is usually extremely small and is often empty. As a result, this simple strategy seems quite effective.

2 Cached-DMIN

To minimize the amount of work in step 3 of Basic-DMIN, we could cache the resolution found to the set of unseparable, unforced threats. When new steps, causal links, or threats are added to the partial plan, the cached resolution must be checked to see if it is still compatible with the new constraints. If not, the cached resolution is abandoned, and the planner must search for a new resolution.

To do this, step three in Basic-DMIN gets expanded as follows:

1. Resolve all outstanding threats that have only a single possible resolution (as in DUNF).
2. Of the remaining threats, filter out those threats that are still separable (i.e. the threat will go away under suitable variable bindings).
3. Check to see if the cached ordering constraints (initially empty) are consistent with the new partial plan. If not, discard the cache.
4. Starting with the cached ordering constraints (possibly empty) search for a resolution of the remaining set of threats.
5. Cache the new set of ordering constraints, but leave the threats outstanding, and do not enforce the ordering constraints.

What makes this strategy efficient are the facts that 1) the set of threats that make it to step 3 is usually small, 2) resolution of these threats is usually easy, and 3) this resolution often remains compatible for several planning steps. When a cached resolution becomes invalid, it is frequently the case that only one resolution remains for one or more of the threats in the set.

References

1. Peot, M, and Smith, D., Threat-Removal Strategies for Partial Order Planning, *Proc AAAI-93*.