Notes on Partial-Order Causal-Link Planning

A partial-order plan consists of the following:

1. A set of steps. Each step maps to an operator, except for the start step and the finish step. The start step has no preconditions and has the initial state as its postconditions. The finish step has the goals as its preconditions and has no postconditions.

2. A set of orderings. Each ordering specifies a pair of steps, the first step before the second step. The start step is always ordered before all other steps. The finish step is always ordered after all other steps.

3. A set of causal links. Each causal link specifies a pair of steps and a proposition, where the proposition is a postcondition of the first step and a precondition of the second step. The first step is ordered before the second step.

A flaw in a partial-order plan is:

1. a precondition of a step that is not supported by a causal link, or

2. a causal link that is threatened by another step (the threat). That is, another step in the plan negates the proposition of the causal link and can be ordered between the two steps of the causal link.

The first kind of flaw can be fixed by inserting a causal link into the plan. The unsupported precondition becomes the proposition of the causal link, and the flawed step becomes the second step of the causal link. The first step of the causal link can be filled in by:

1. another step in the plan that has the proposition as a postcondition and that can be ordered before the flawed step, or

2. a new step created by finding an operator that has the proposition as a postcondition. The new step must be ordered before the flawed step and ordered after the start step.

The second kind of flaw can be fixed by inserting an ordering into the plan. The threat must be ordered either before the first step of the causal link (called demotion) or after the second step of the causal link (called promotion). However, you can't do any demotion or promotion that violates existing orderings.

In one type of search, the children of a flawed partial-order plan are determined by: (1) selecting a flaw, and (2) creating a child plan for each possible way that the flaw can be fixed. Variations of the Graphplan algorithm [A. Blum and M. L. Furst (1997). Fast Planning Through Planning Graph Analysis. *Artificial Intelligence* 90:281–200.] are the most efficient to date for solving planning problems. More recent results can be found in [D. S. Weld (1999). Recent Advances in AI Planning. *AI Magazine* 20(2):93-123].