Systematic Nonlinear Planning

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CS660

Context

- December of 1991
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STRIPS

- Based on common sense problems
- Operator: name, prerequisite list, add list, delete list
- STRIPS Planning problem: operators, initial propositions, goal propositions
- Solution: sequence of operations
- Improvements:
  - Lifting
  - Nonlinear Planners
  - Abstraction

Nonlinear Planning

- Causal Link: proposition, destination, source
- These are easy to extract in a linear plan. Nonlinear plans require more ordering information:
  - Threat: a step that might either add or delete the proposition that is needed in the causal link
  - Safety Condition: a strict ordering such that the source step occurs before the destination step
- Nonlinear plan: symbol table, set of causal links, and a set of safety conditions

A “Complete” Nonlinear Plan

- Every step name appearing in the causal links and safety conditions is in the symbol table.
- If w is a step name in the symbol table, and w has prerequisite P, then the plan contains some causal link of the form $s \xrightarrow{P} w$.
- If the plan contains a causal link $s \xrightarrow{P} w$, and the symbol table contains a step name v that is a threat to the causal link, then the plan contains either the safety condition $v < s$ or $v > w$.

Topological Sort

- The first step is START.
- The last step is FINISH.
- For each causal link $s \xrightarrow{P} w$, step s precedes step w.
- For each safety condition u < v (or v > u) in the plan, the step u precedes the step v.
- Lemma: Any topological sort of a complete nonlinear plan is a solution
- A nonlinear plan is “order inconsistent” if it has no topological sort

The Procedure FIND-COMPLETION(β, C)

1. If the nonlinear plan β is order inconsistent, or the total cost of the steps in β is greater than c, then fail.
2. If β is complete, return β.
3. If there is a causal link $s \xrightarrow{P} w$ in β and a threat v to this link in the symbol table such that β does not contain either $v < s$ or $v > w$, then nondeterministically return one of the following:
   a) FIND-COMPLETION(β + ($v < s$), c)
   b) FIND-COMPLETION(β + ($v > w$), c)

4. There must be some step w in the symbol table and some prerequisite P of w such that there is no causal link of the form $s \xrightarrow{P} w$. In this case, nondeterministically do one of the following:

a) Let s be (nondeterministically) some step name in the symbol table that adds P and return the plan FIND-COMPLETION($\beta + s \xrightarrow{P} w$, c).

b) Select (nondeterministically) an operator o_i from the allowed set of operations such that o_i adds P. Create a new entry in the symbol table that maps a new step name s to the operator o_i. Then return the plan FIND-COMPLETION($\beta + s \xrightarrow{P} w$, c).

Lifting

- "For every possible computation involving ground expressions there is a lifted computation involving variables such that the ground computation is a substitution instance of the lifted computation."
- 4b is now "Let o_i be a copy, with fresh variables, of one of the given operator schemas. If P is not a member of the add list of o_i, fail. Otherwise, create a new entry in the symbol table that maps a new step name s to the schema copy o_i. …"

Conclusion

- SNLP is an improvement due to the complex, nonsystematic nature of previous lifted nonlinear planning algorithms.
- SNLP is a simple, sound, complete, and systematic procedure.