



A Closer Look at Causal Links: Complexity Results for Delete-Relaxation in Partial Order Causal Link (POCL) Planning

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Where are POCL Plans or Causal Links relevant?

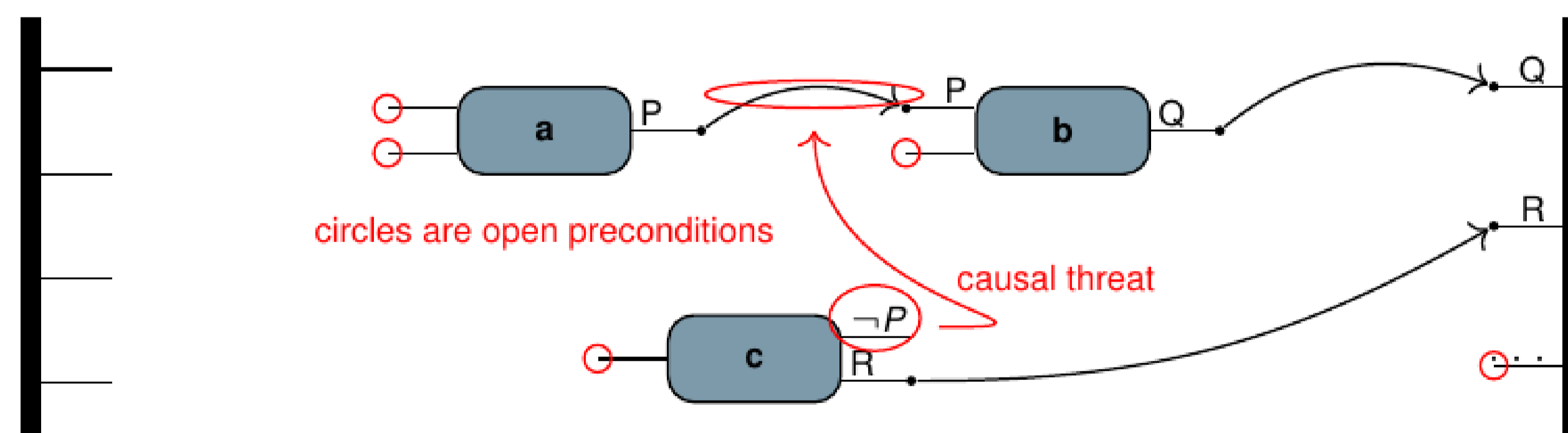
- In planning algorithms based on POCL plans:
 - Temporal planning due to parallelism
 - Some hierarchical approaches (some including time!)
 - For solving classical problems (not state of the art anymore)
- Some plan *encodings* (e.g., via SAT) rely on causal links.
 - To solve planning problems
 - For plan optimization

POCL Plans in more Detail

When is a POCL plan a solution?

- When all preconditions are supported by a causal link, and
- there are no causal threats.

Given a POCL solution, each linearization is a classical solution.



Causal threats can be resolved by adding ordering constraints. Here:

- Promotion: move c before a
- Demotion: move c behind b

Decision Problem

Input: A POCL plan P .

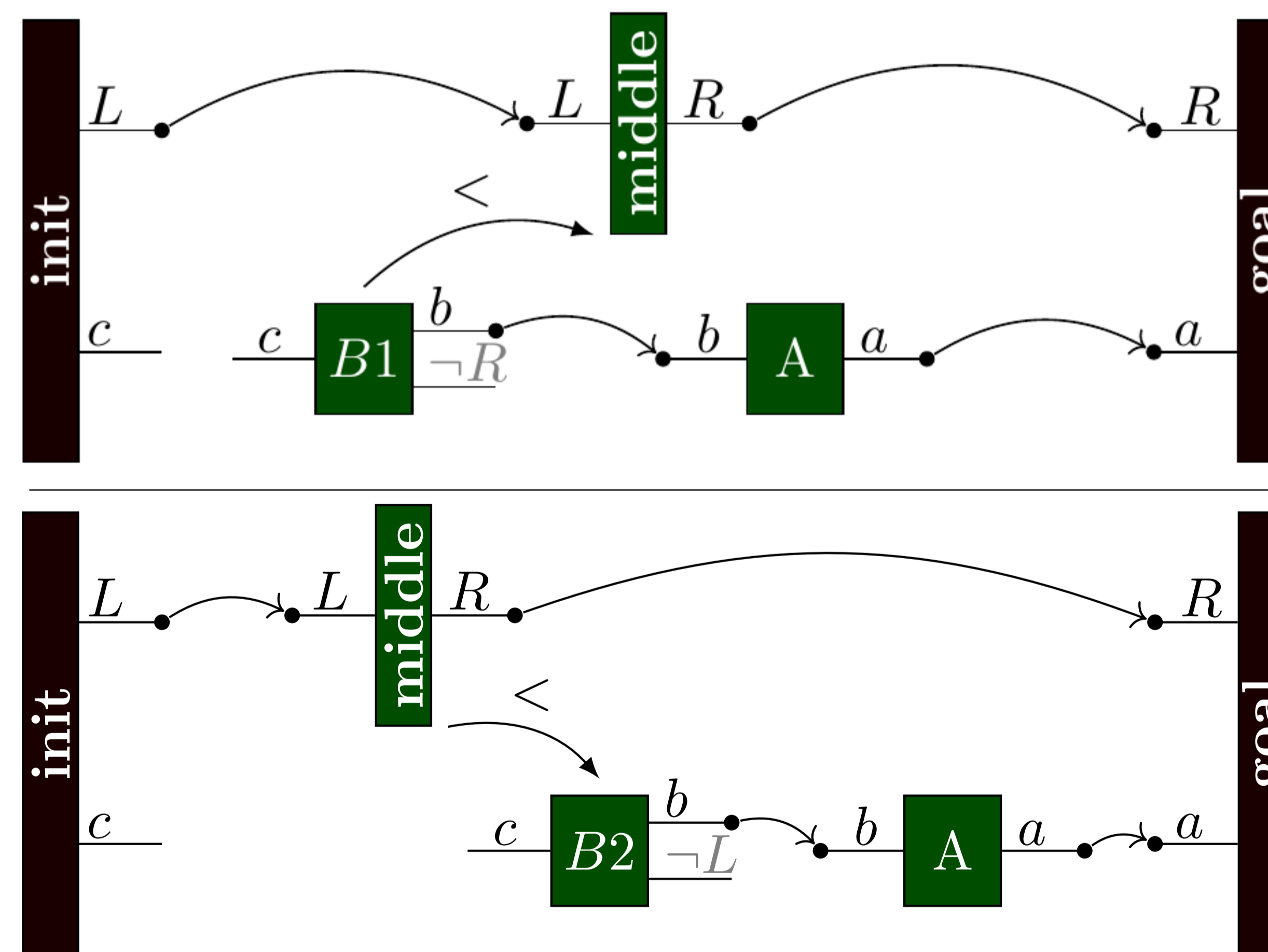
Question: Can P be refined into a solution?
(i.e., via the insertion of actions, links, and orderings)

Relevant Problem Relaxations

Which problem relaxations could we perform?

- (Delete-)relax the domain, i.e., the actions to insert.
 - Decidable in P for classical problems!
- Relax the current plan/search node:
 - Delete-relax its actions
 - Ignore its causal links

Prize question: *How* to ignore existing causal links?



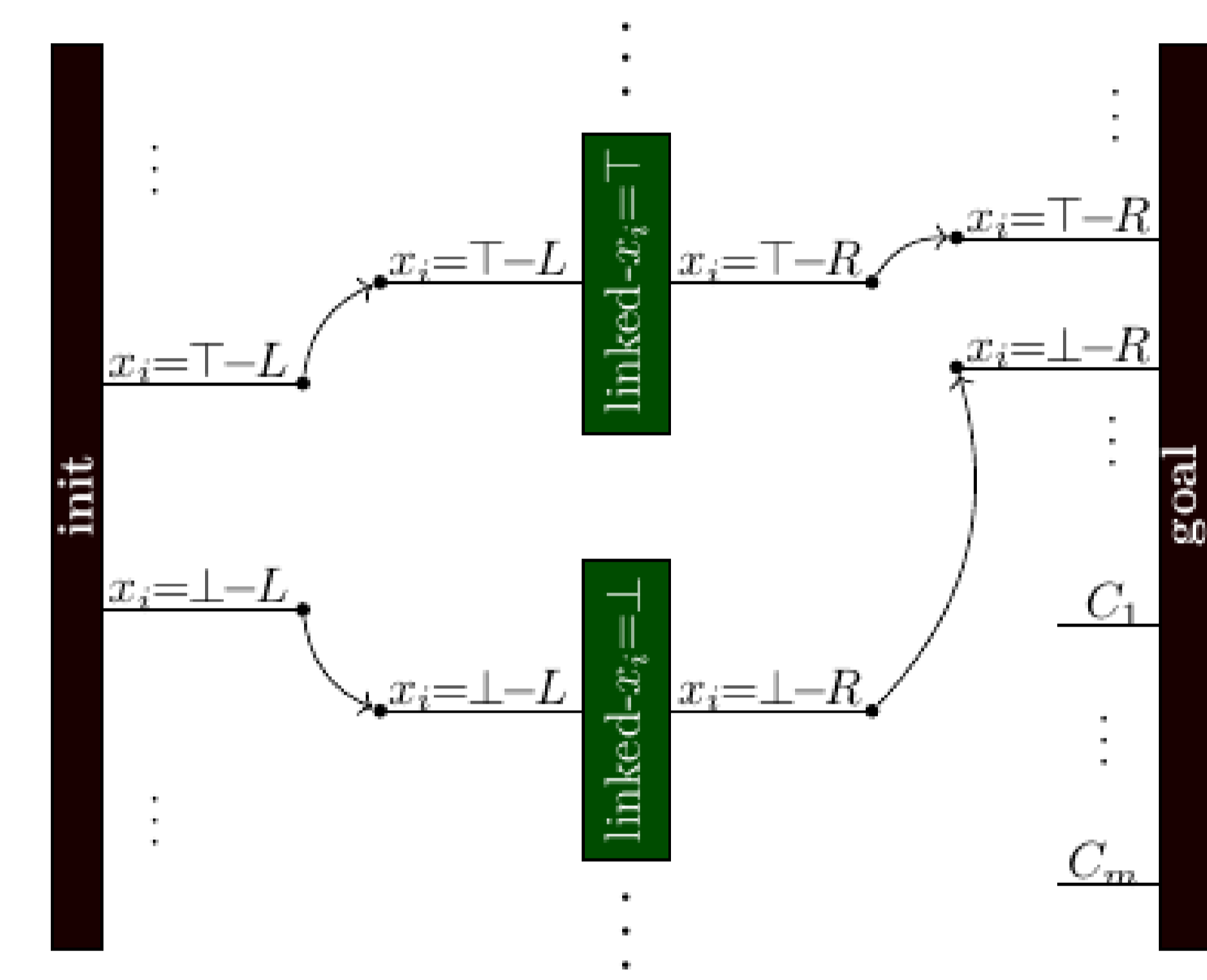
Additional actions: $c \xrightarrow{B1} b \xrightarrow{\neg R} a$ $c \xrightarrow{B2} b \xrightarrow{\neg L} a$

Delete-Relaxation adhering Causal Links

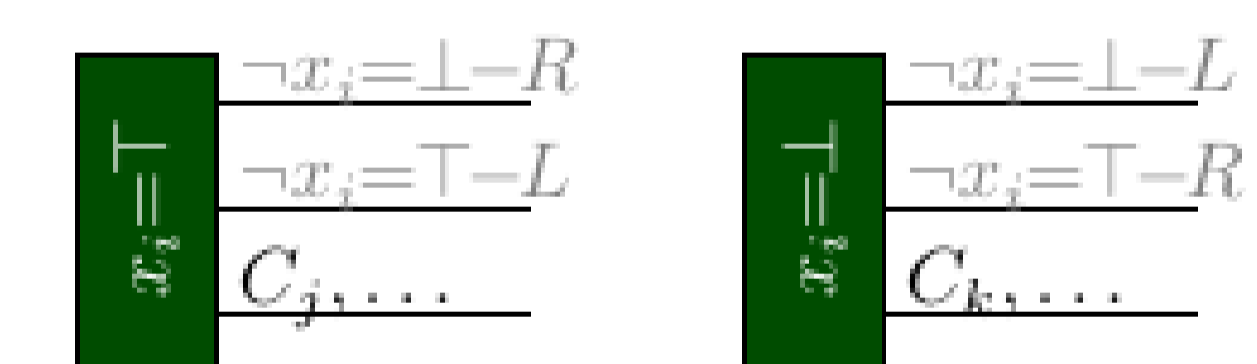
- Existing causal links are respected despite delete-relaxation,
- i.e., even delete-relaxed inserted actions may raise causal threats!

Delete-Relaxation adhering Causal Links is NP-complete

We reduce from SAT, $C = \{C_1, \dots, C_m\}$ is a finite set of clauses, based on the finite set of variables $X = \{x_1, \dots, x_n\}$.



Additional actions:



Results: Summary

actions of initial plan	causal links respected?	ordering constraints	insertable actions	Computational Complexity
*	*	*	original	PSPACE-complete
original	*	partial order	delete-rel.	NP-complete
delete-rel.	no	*	delete-rel.	in P
*	*	total order	delete-rel.	in P
*	yes	partial order	delete-rel.	NP-complete
original	*	partial order	none	NP-complete
delete-rel.	*	*	none	in P

