Lecture *Hierarchical Planning*

Chapter:
Further Hierarchical Planning Formalisms

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Overview:

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  - Others focus on the idea to refine/decompose *state features* rather than compound tasks.

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  → Consequently, the solution criteria also involve causal links.

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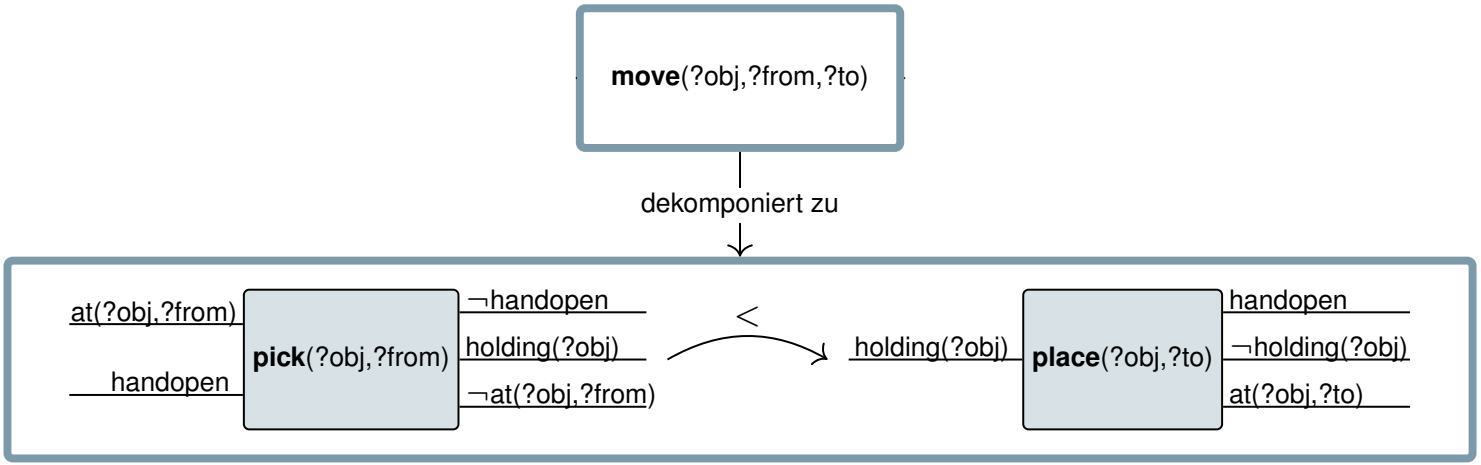

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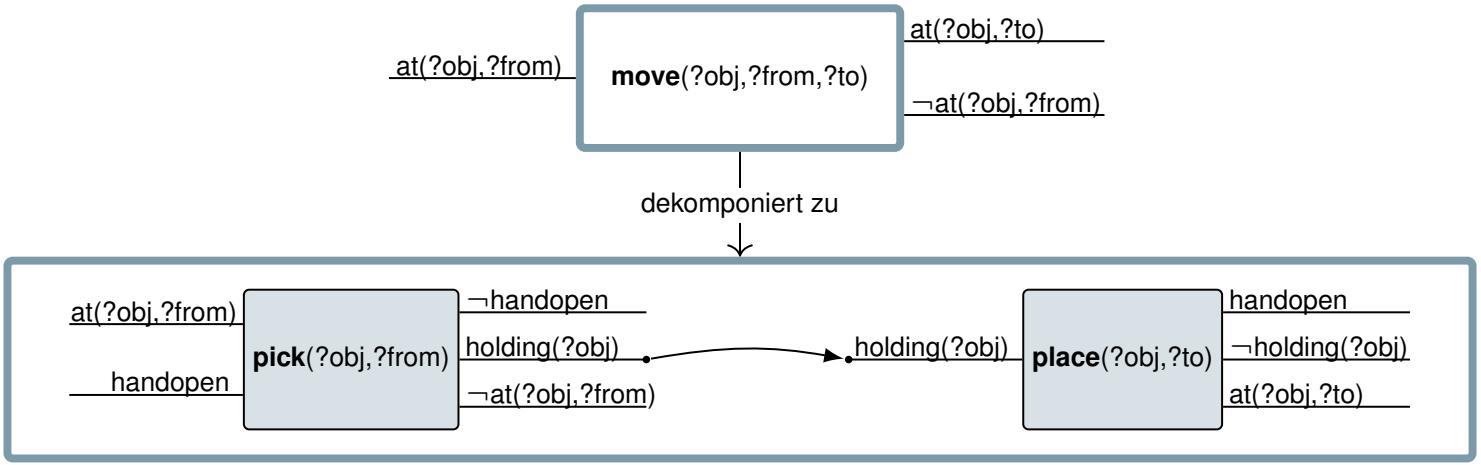

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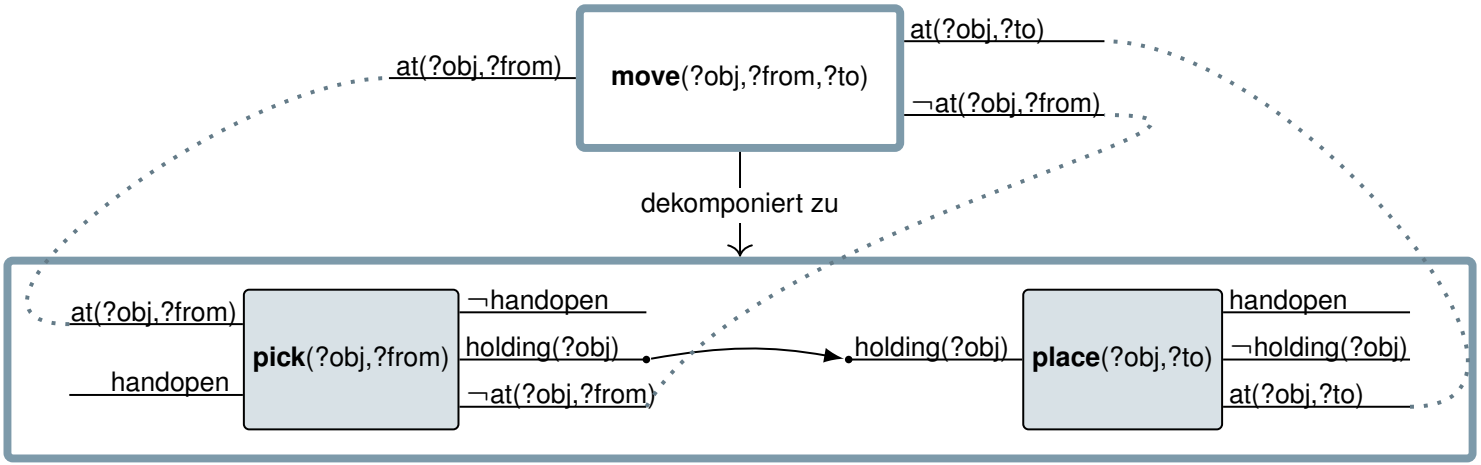

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- To exploit it during search.
- To provide *modeling support* by restriction to legal models (test all decomposition methods).

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  - Consequently, causal links are allowed to point to or from compound tasks as well.
  - Thus, we need to alter how causal links induce ordering constraints: In contrast to the previous definition (cf. first lecture) only those causal links induce an ordering that are defined between two primitive tasks.

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  - Solutions are defined as primitive plans without flaws. (Similar to the decomposition-based algorithm.)
- Similar to HTN vs. TIHTN problems, task insertion is an optional property of the the hybrid planning problem class.

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- They all try to express “what it means that a compound task has preconditions or effects”.
- There are differently strong restrictions, though their theoretical impact is very limited.

Downward Compatible

Definition (Downward Compatible, Bercher et al. 2016)

Let $m = (n_c, P)$ be a method, $n_c = (pre, eff)$ an abstract task and P a partial plan.

- If $\varphi \in pre$, then there exists φ as precondition of a task in P without causal link, which points towards it.
- If $\varphi \in eff$, then exists φ as effect of a task in P.

- Prevents/detects the most obvious modeling flaws.
- abstract tasks can always be decomposed – as it is the case in standard HTN planning

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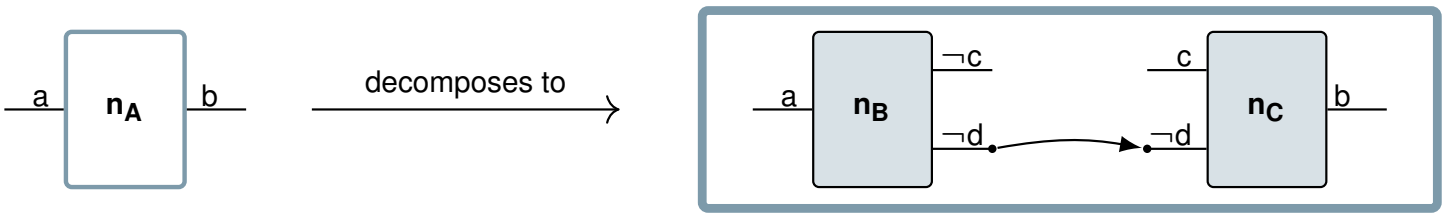

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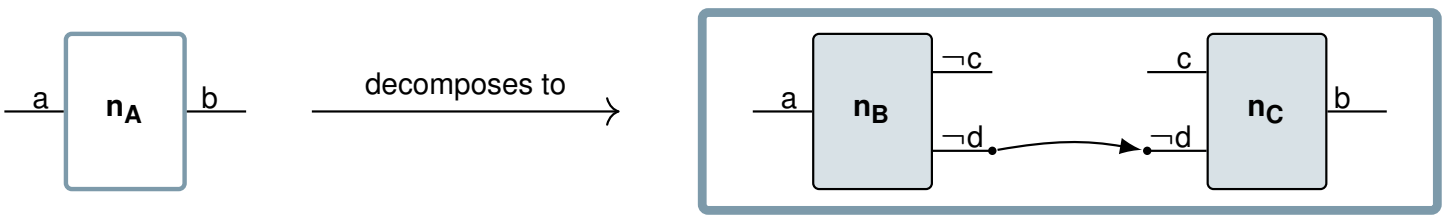

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State-transition Semantics

Definition (Biundo and Schattenberg, 2001)

Let $m = (n_c, P)$ be a method, $n_c = (pre, eff)$ an abstract task, and P a totally ordered plan.

- There needs to be a state s satisfying pre, $s \models pre$, such that P's task sequence $\bar{t}$ is executable in s.
- For all states satisfying the first criterion, $\bar{t}$ generates a state satisfying eff, $s \models eff$.

- State-transition semantics adopted to abstract tasks.
- Strong assumption: open preconditions need to be supported by one single state.

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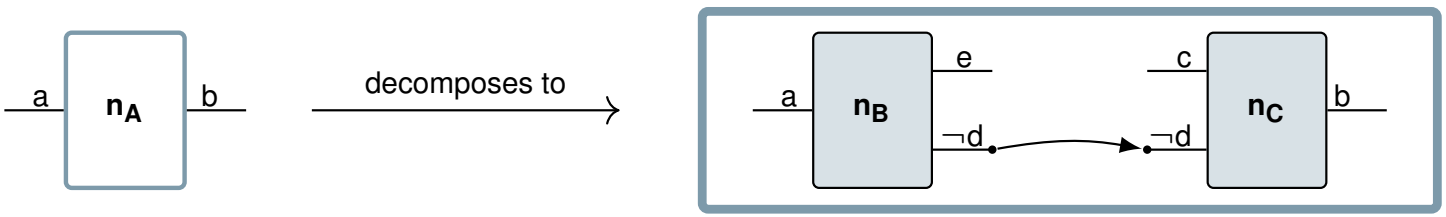

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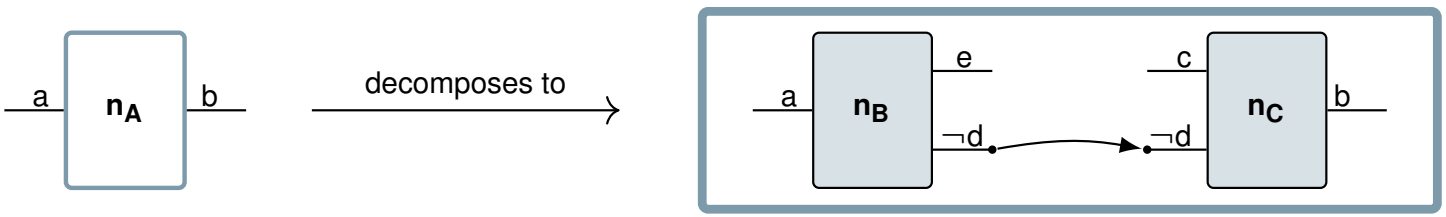

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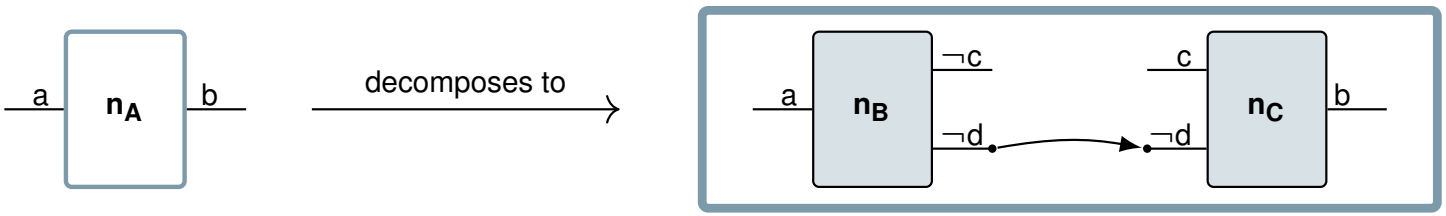

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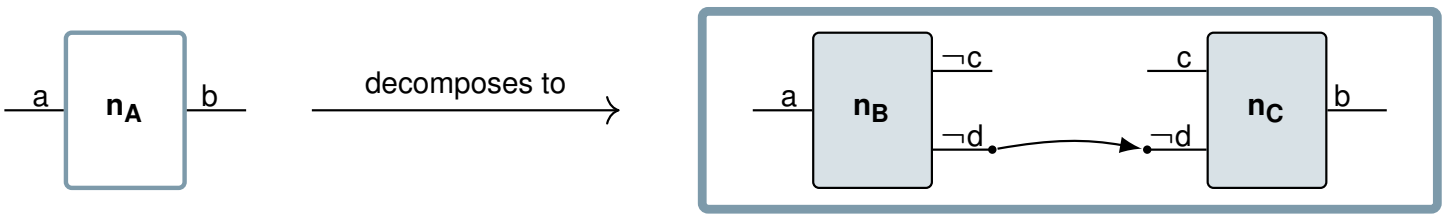

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Causal Threat Criterion

Definition (Yang, 1990)

Let $m = (n_c, P)$ be a method, $n_c = (pre, eff)$ an abstract task, and P a plan.

- *pre* and *eff* are actual preconditions and effects in P.
- There are no causal threats.

- Slightly weaker than the last criterion: open preconditions do not need to be achieved by one single state.

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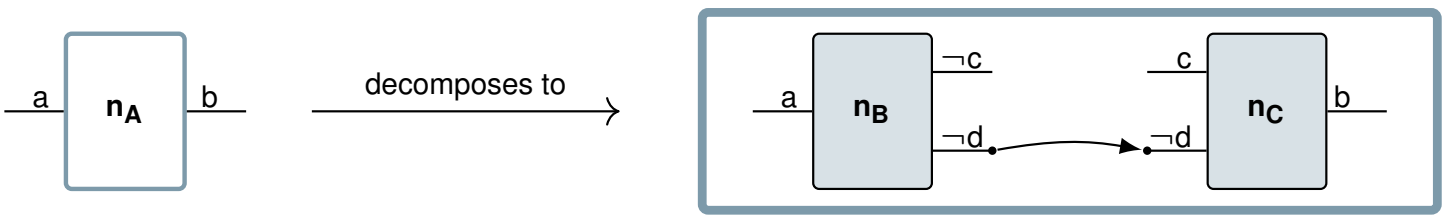

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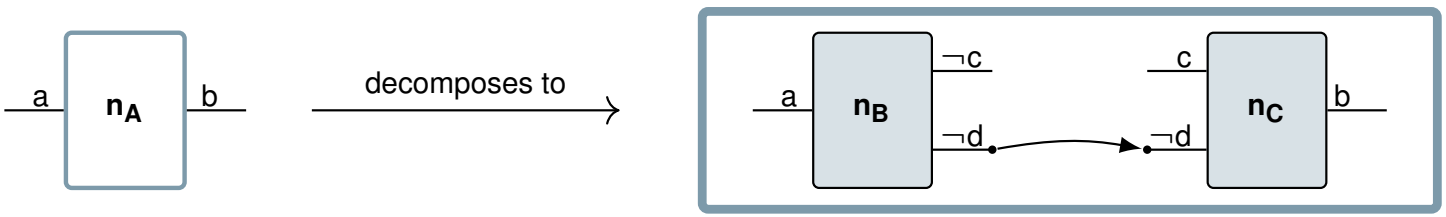

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Definition (Young et al., 1994)

Let $m = (n_c, P)$ be a method, $n_c = (pre, eff)$ an abstract task, and P a plan.

- Any of n_c's preconditions *pre* contributes to at least one of its effects *eff* via a chain of causal links
- ... and vice versa.

- Neither stronger, nor weaker than the previous criterion.

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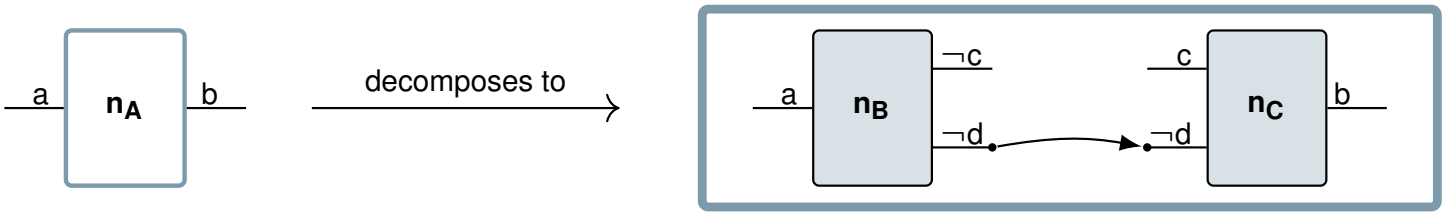

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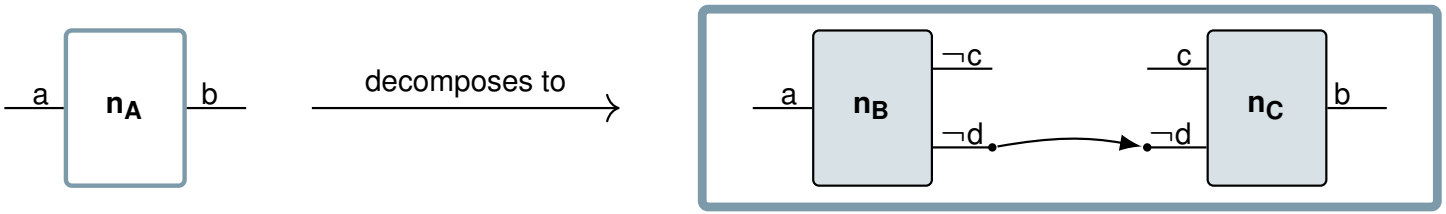

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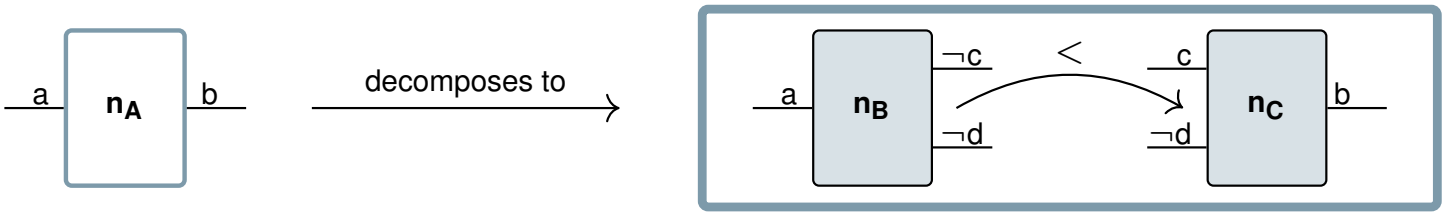

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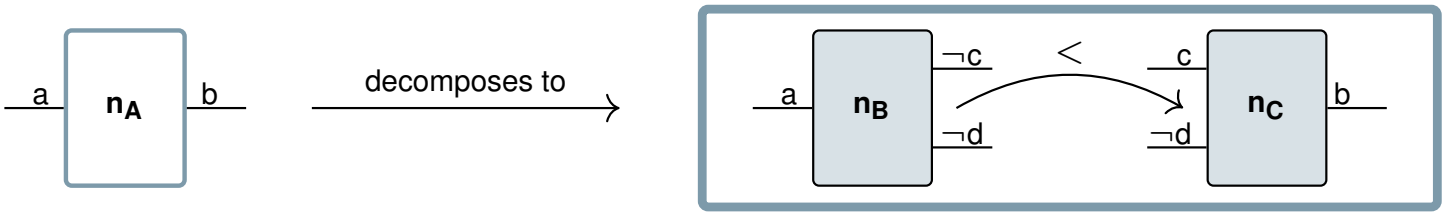

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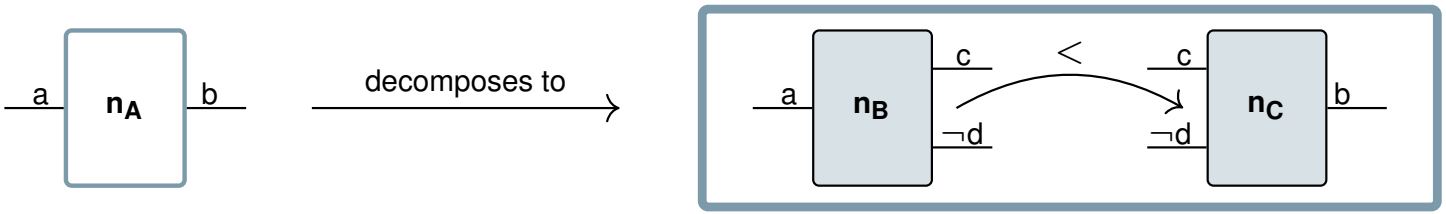

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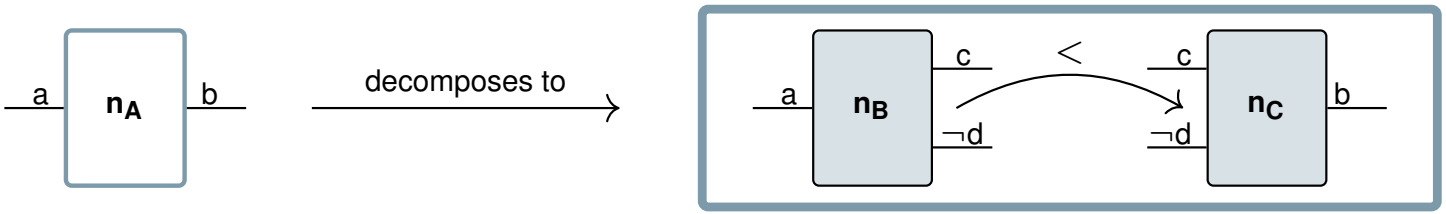

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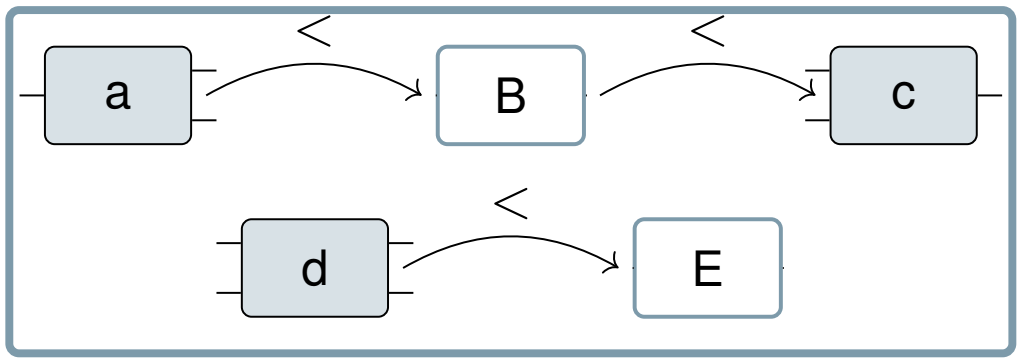
  - $\mathcal{P}'$ satisfies all legality criteria.

Encoding HTN Problems into Hybrid Problems

For each primitive task t, create an abstract copy T without preconditions and effects. Then:

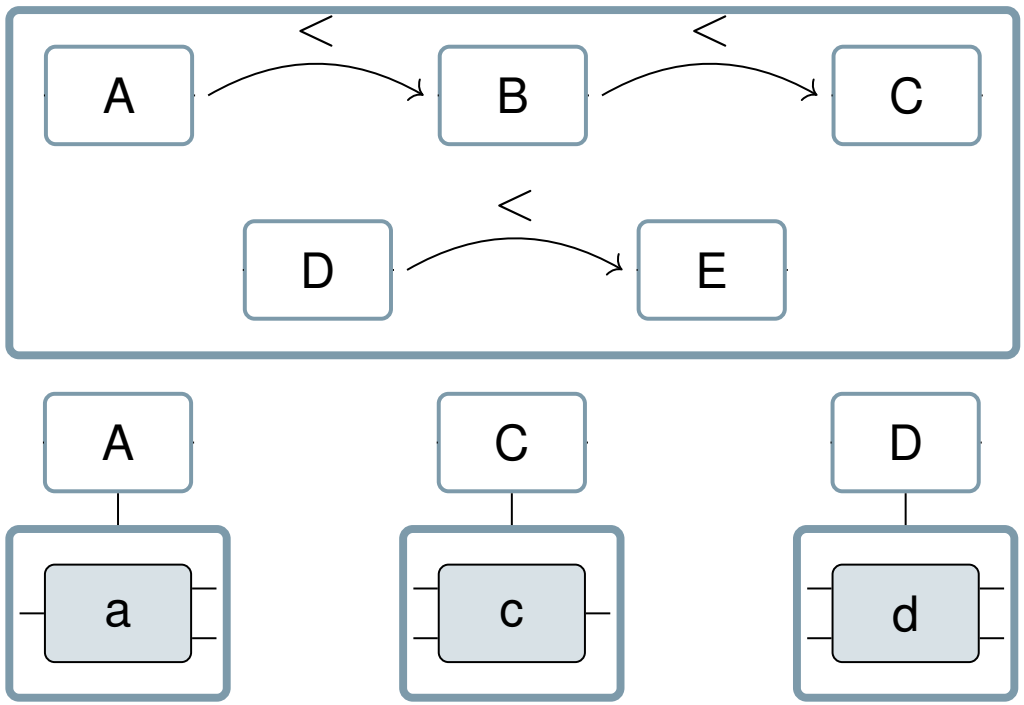
- Add a method $m = (T, P)$ with P containing exactly t.
- In each plan, replace t by T.



Encoding HTN Problems into Hybrid Problems

For each primitive task t, create an abstract copy T without preconditions and effects. Then:

- Add a method $m = (T, P)$ with P containing exactly t.
- In each plan, replace t by T.



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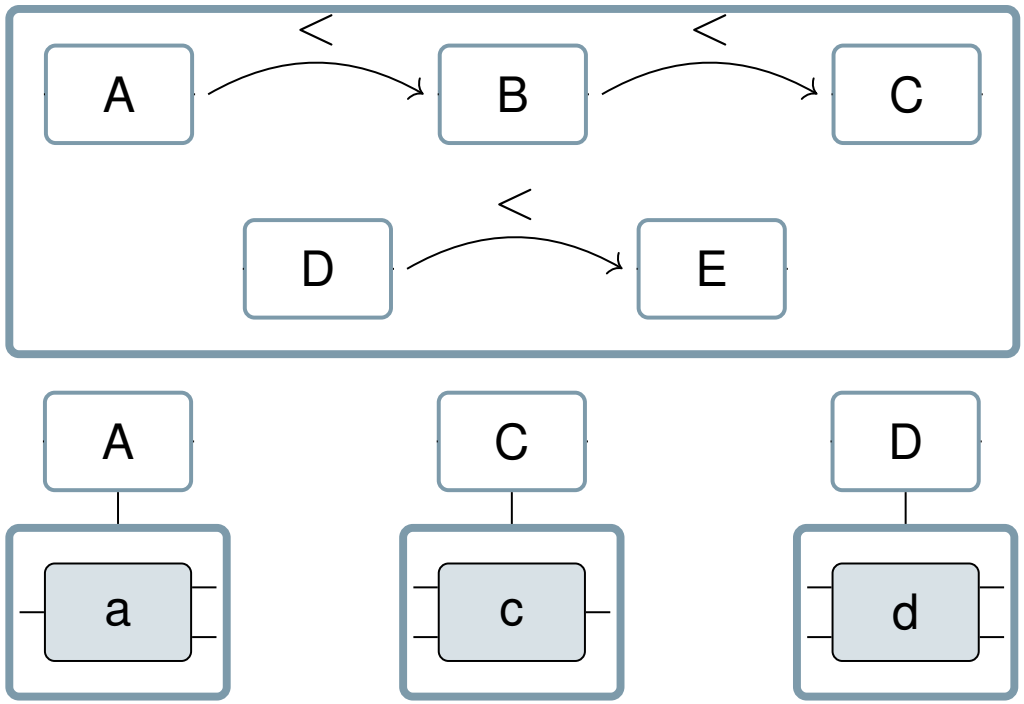

Properties:

- All abstract tasks do not have preconditions or effects
- For all plans holds:
  - either there are only abstract tasks
  - or at most one.
- Thus, all methods in $\mathcal{P}'$ satisfy all legality criteria.

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- So, how hard (or easy) is this problem?
- As we will see: we can express every HTN problem as a hybrid problem without violating any criterion.
- Thus, it's as hard as HTN planning.
- Membership results (lower bounds) are open, but probably identical to those from HTN planning as well.

Complexity Results (Plan Existence)

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Hybrid planning is strictly semi-decidable.

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undecidable:

- Reduce the undecidable HTN plan existence problem to hybrid planning
- For this, we use the property shown before, i.e., that every HTN problem can be encoded by a hybrid problem that satisfies *all* legality criteria.

Hybrid Planning Algorithm

- To solve hybrid problems, we have to use the hybrid planning *algorithm* (i.e., decomposition-based search), because it's the only one being able to deal with causal links by now.

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  - In some cases, we get fewer successors when decomposing, because we can use the effects of compound tasks as producer (see example from blackboard).
  - When decomposing an abstract task that's involved in causal links, we get, in general, much more successors than it's number of methods (see example from blackboard).

Motivation and Problem Definition

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  - Now, also compound tasks can be inserted, which (hopefully) lead to solutions quicker than compared to relying on primitive task insertion completely.
  - Theory-wise, the problem is as expressive as classical planning, because we are not forced to insert compound tasks (and if there is a solution with compound task insertion then there is also one without).

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Summary

- There are many hierarchical planning formalisms – more than just the HTN or TIHTN formalisms discussed so far.
- One of them is hybrid planning, which extends (TI)HTN planning with concepts known from POCL planning.
- Closely related is decompositional planning, which is essentially hybrid planning with task insertion, but without initial partial plan.
- Another formalism is HGN planning, Hierarchical Goal-Task Network planning (we only discussed this briefly).