More than a Name?

On Implications of Preconditions and Effects of Compound HTN Planning Tasks

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September, 2016

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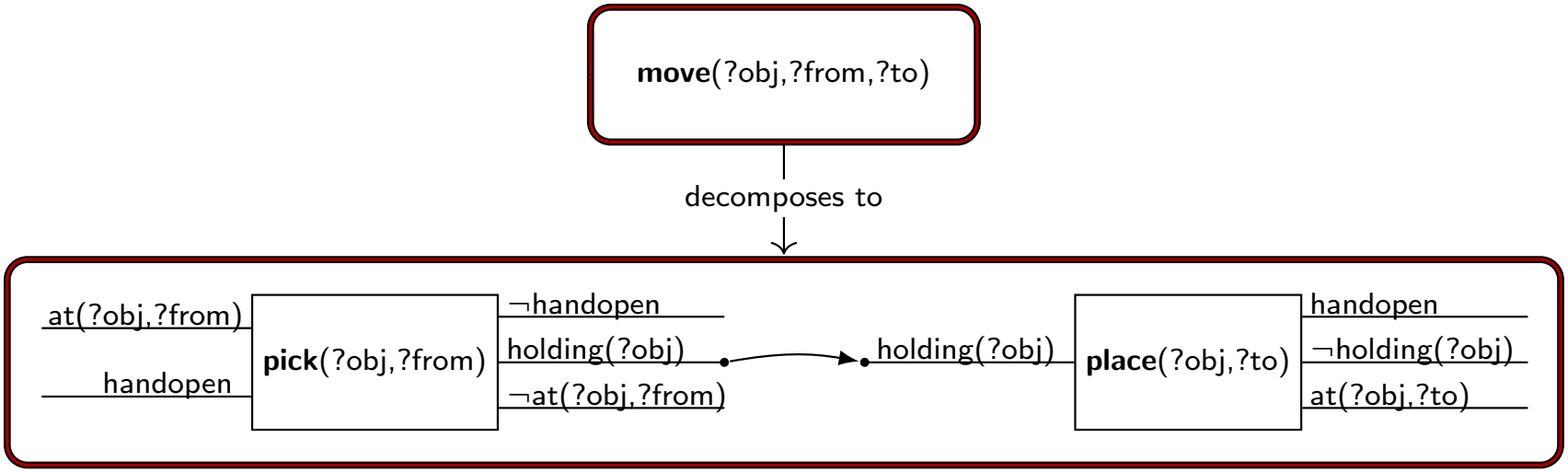
Motivation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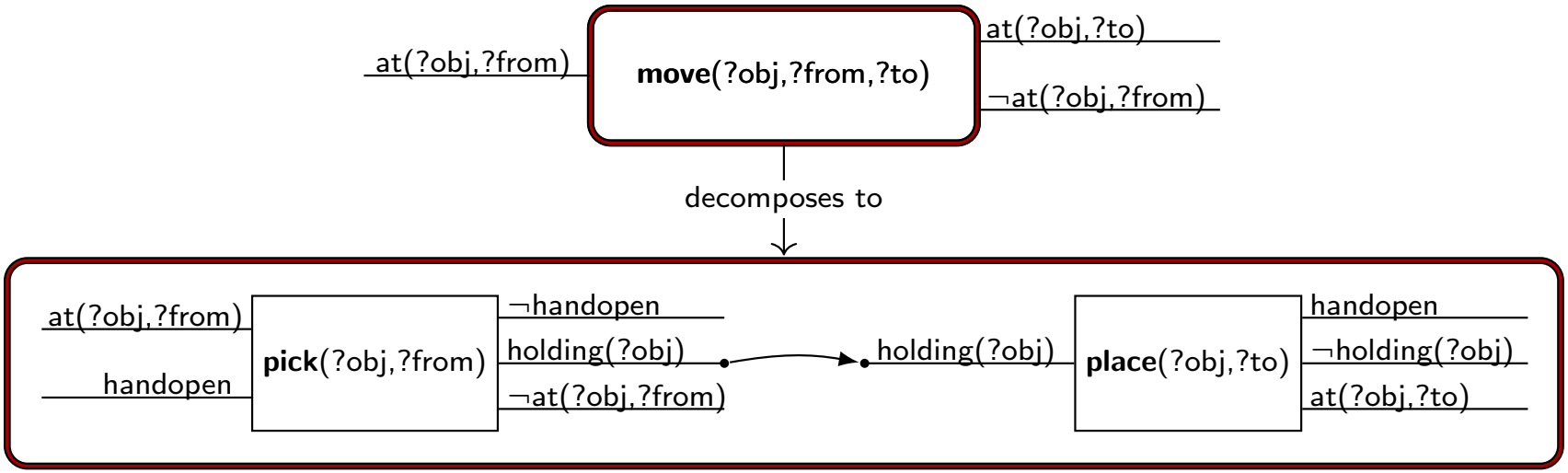

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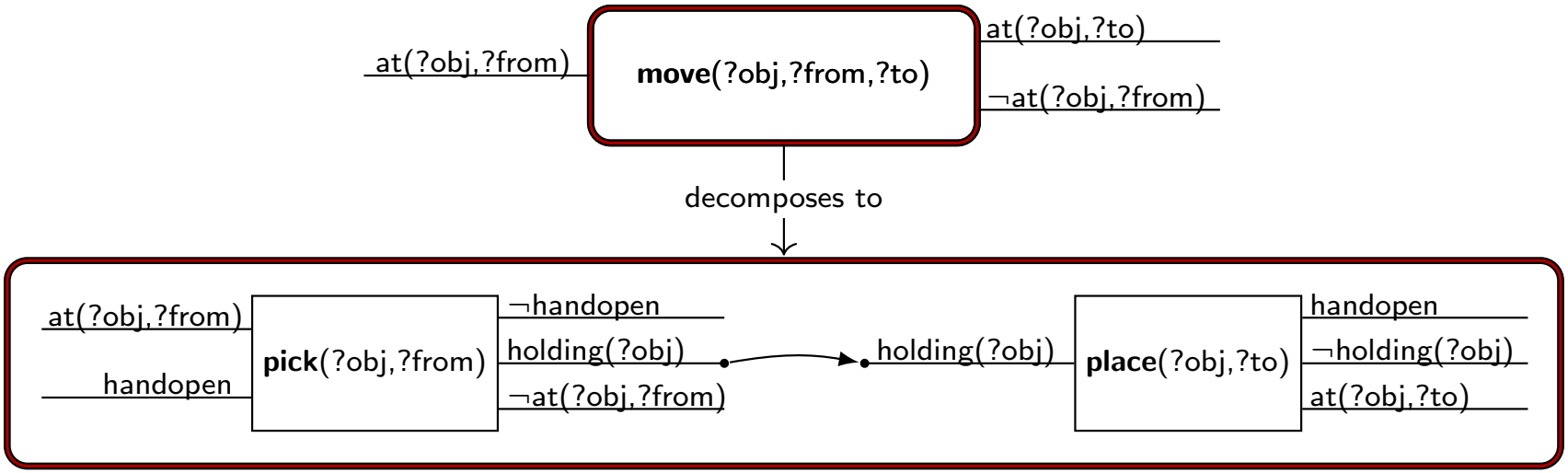

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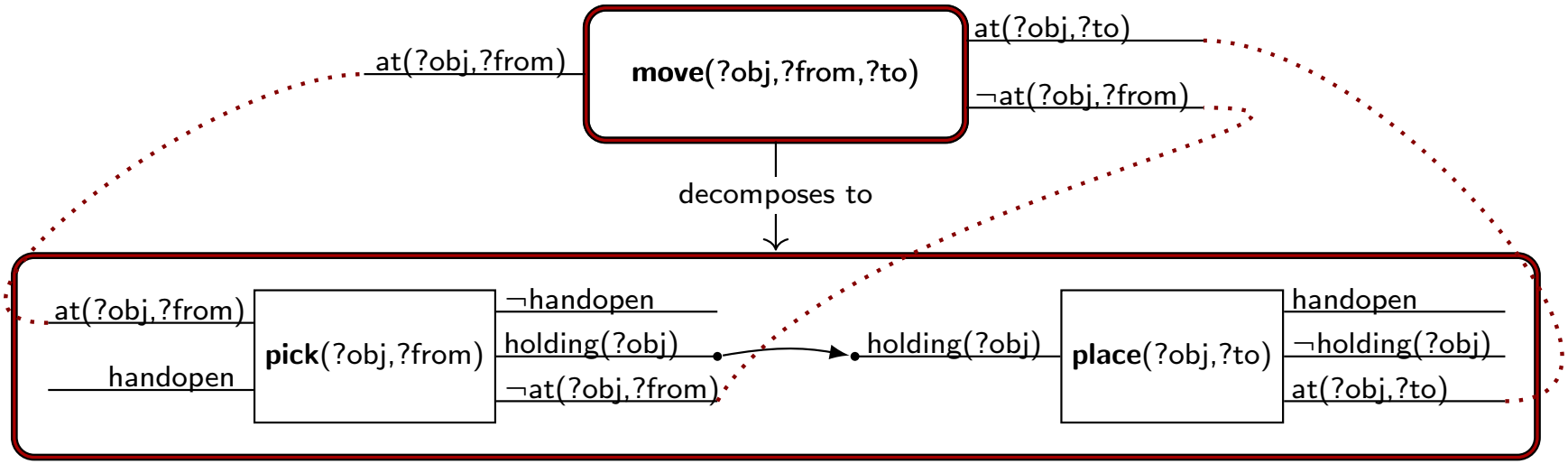

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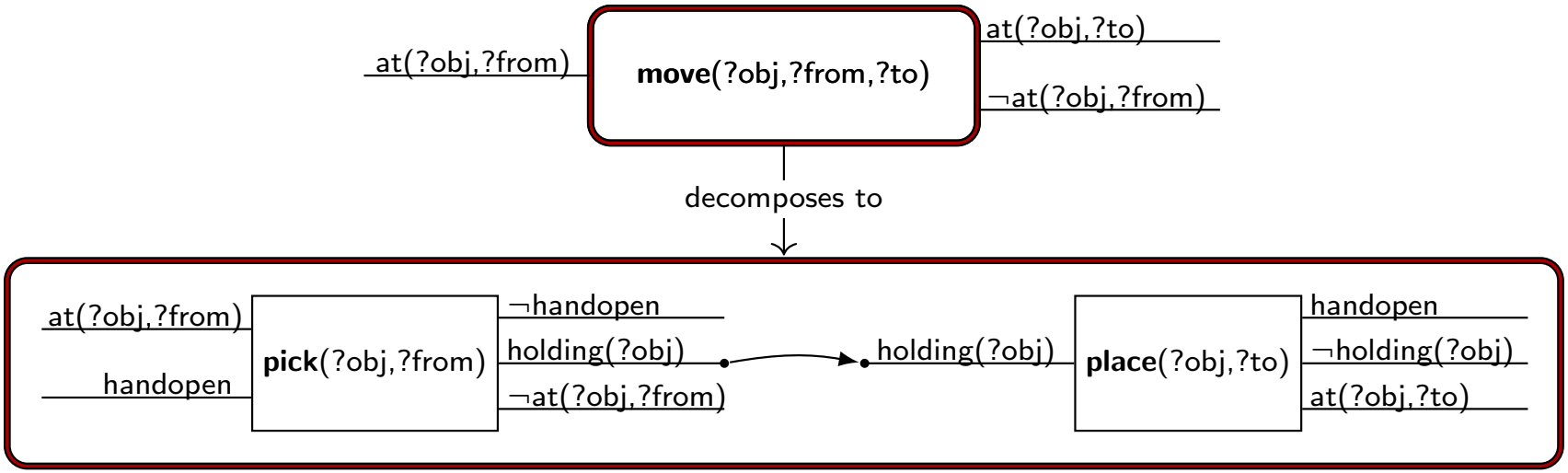

- Several formalizations allow to specify preconditions and effects for abstract tasks. Why?
  - To find abstract solutions,
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  - to allow modeling assistance (restrict to legal methods).
- However, most complexity results are only known for HTN planning, where abstract tasks are just names.

Hybrid Planning Framework

Hybrid planning fuses

- Hierarchical Task Network (HTN) planning with
- Partial-Order Causal-Link (POCL) Planning.

→ Here, also abstract tasks have preconditions and effects.

Planning problem and solutions:

- The planning problem is given in terms of an initial plan.
- Solutions are plans that
  - are executable and satisfy the goal and
  - they are refinements of the initial plan.

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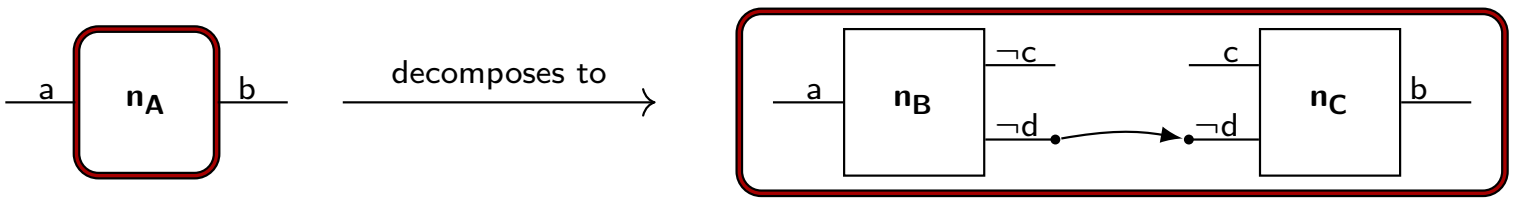
$\rightarrow$ **Paper provides a survey and discussion.**

Legality Criteria (cont'd)

Definition (Downward Compatible, Bercher et al., ECAI-2016)

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

- If $\varphi \in pre$, then φ exists as precondition of a task in P with no causal link pointing towards it.
- If $\varphi \in eff$, then φ exists as effect of a task in P.



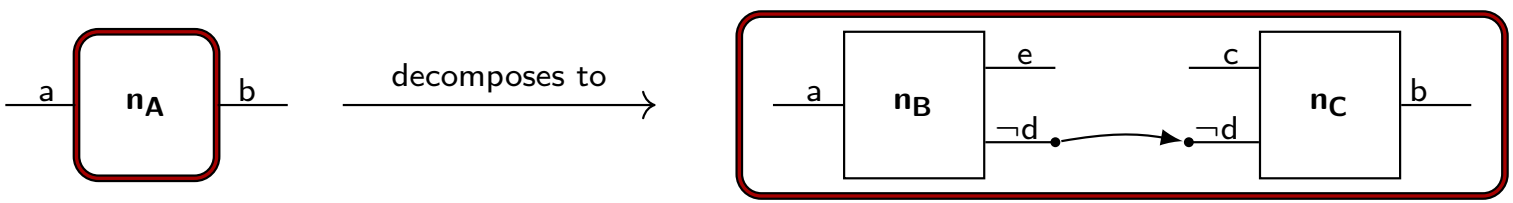
(this method satisfies the criterion)

Legality Criteria (cont'd)

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, $s \models eff$.



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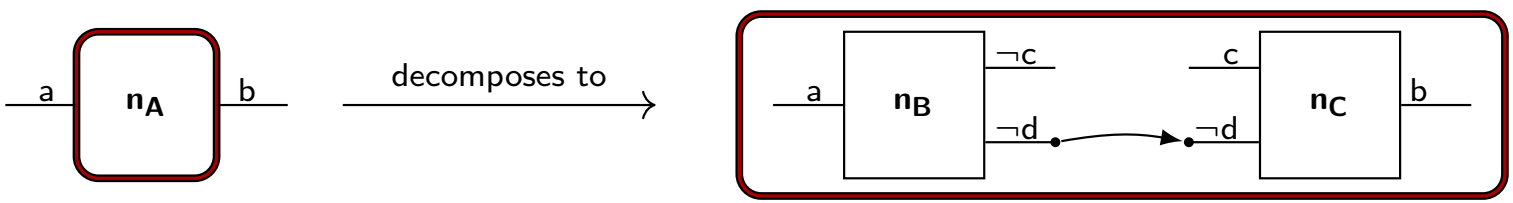

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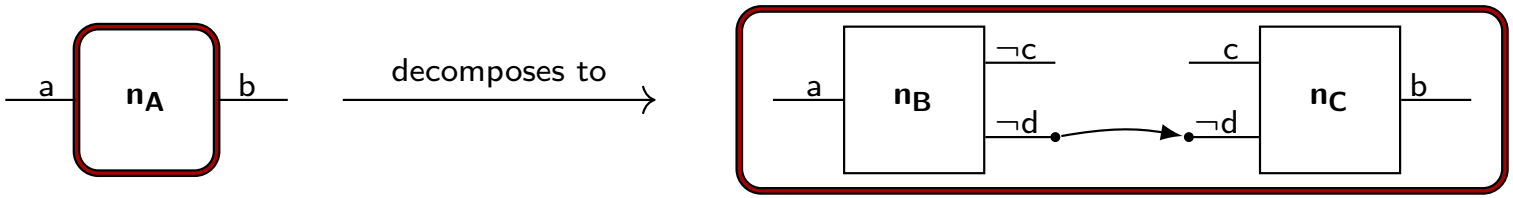
Legality Criteria (cont'd)

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.



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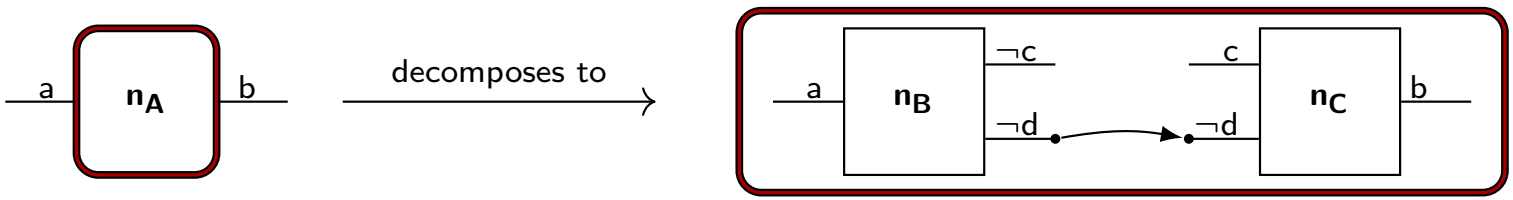
Legality Criteria (cont'd)

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.



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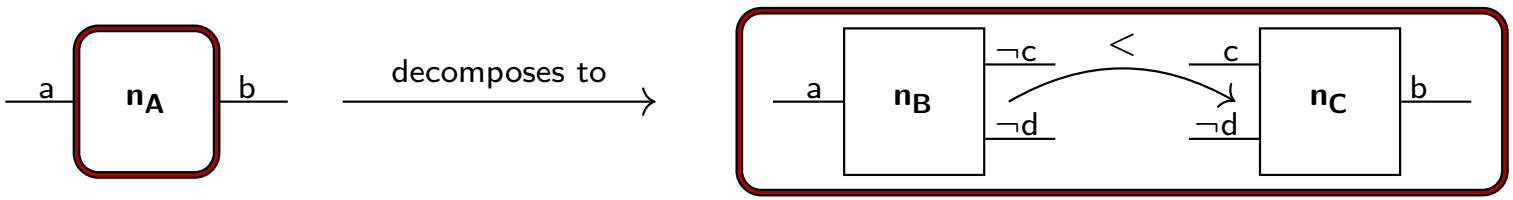

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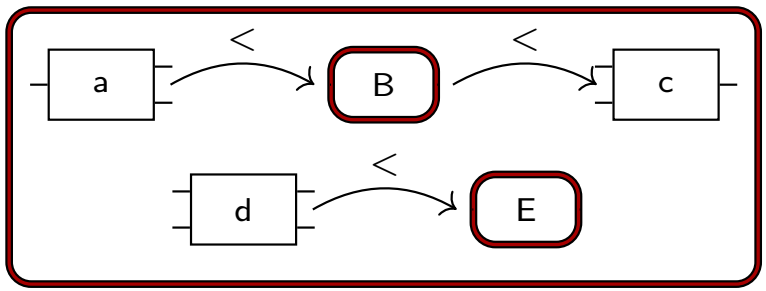
More than a Name?

- Which impact have the legality criteria on the expressivity?
- We show that every HTN problem π can be transformed into a hybrid planning problem π', such that:
  - π and π' have the same set of solutions,
  - π' 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.



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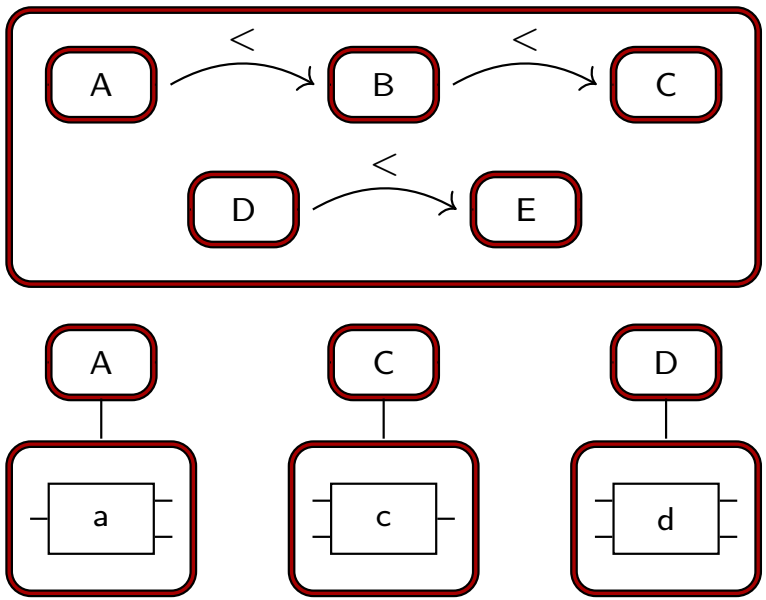

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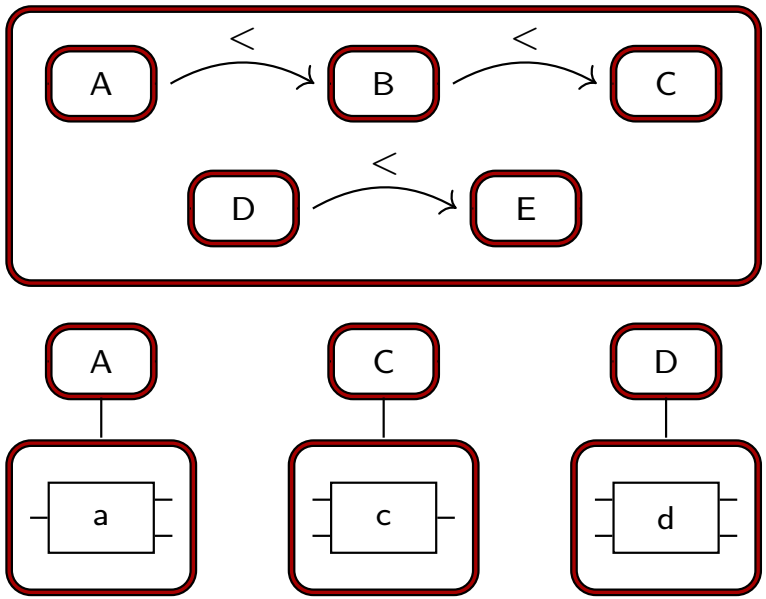

Properties:

- 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 π' satisfy all legality criteria.

Complexity Results (Plan Verification)

- General case:
  - Corresponds to standard HTN plan verification.
  - Is **NP-complete**, as in HTN planning.
- Without hierarchy, i.e., no abstract tasks:
  - Corresponds to standard POCL plan verification.
  - Is in **P** (commonly known).
  - Interestingly, this problem is **NP-hard** in HTN planning.

Complexity Results (Plan Existence)

Theorem

Hybrid planning is strictly semi-decidable.

Proof.

semi-decidable:

- Enumerate all plans of a certain length (from 0 to ∞).
- Verify each plan in **NP**.
- Continue until a solution is found.

undecidable:

- Reduce the undecidable HTN plan existence problem to hybrid planning (using the encoding).

□

Complexity Results (Plan Existence)

Corollary

Several sub classes of hybrid planning are as hard as in HTN planning: tail-recursive, acyclic, totally-ordered, and delete-relaxed.

Proof.

The class of a problem is preserved by the transformation. □

Summary

- Provided formalization for HTN planning, where abstract tasks have preconditions and effects.
- Gave survey and discussion about legality criteria in hierarchical planning.
- Theoretically investigated their impact on:
  - The *plan verification* problem and
  - the *plan existence* problem.

Conclusions and Future Work

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- For many special cases, membership results are still missing. Thus, complete relationship between HTN and hybrid planning is yet unknown.
- We did not yet investigate the impact of task insertion.