Novel Is Not Always Better: On the Relation between Novelty and Dominance Pruning

Joschka Groß, Álvaro Torralba, Maximilian Fickert

UNIVERSITÄT DES SAARLANDES

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

Classical Planning

Definition. *A planning task is a 4-tuple* $\Pi = (V, A, I, G)$ *where:*

- V *is a set of state variables, each* $v \in V$ *with a finite domain* D_v.
- A *is a set of actions; each* $a \in A$ *is a triple* (pre_a, eff_a, c_a)*, of precondition and effect (partial assignments), and the action's cost* $c_a \in \mathbb{R}_0^+$.
- *Initial state* I *(complete assignment), goal* G *(partial assignment).*

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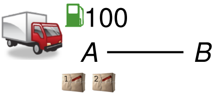
Running Example:



- $V = \{t, p_1, p_2, f\}$
  with $D_t = \{A, B\}$ and $D_{p_i} = \{t, A, B\}$, $D_f = \{100, 99, 98, \ldots, 0\}$.
- $A = \{load(p_i, x), unload(p_i, x), drive(x, x')\}$

What this is about?

Novelty (Lipovetzky and Geffner, 2012) (Lipovetzky and Geffner, 2017) (Katz, Lipovetzky, Moshkovich and Tuisov 2017) (Fickert 2018)

A (pruning) technique which has greatly improved the state of the art in satisficing planning

Dominance (Torralba and Hoffmann, 2015), (Torralba, 2017), (Torralba, 2018):

A safe pruning technique for cost-optimal planning

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But, why is novelty so good?

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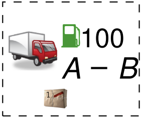

A	B	A	B	T	100	99	98	97
X		X			X			

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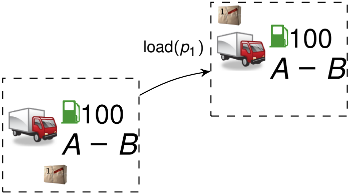

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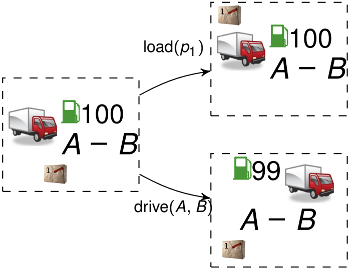

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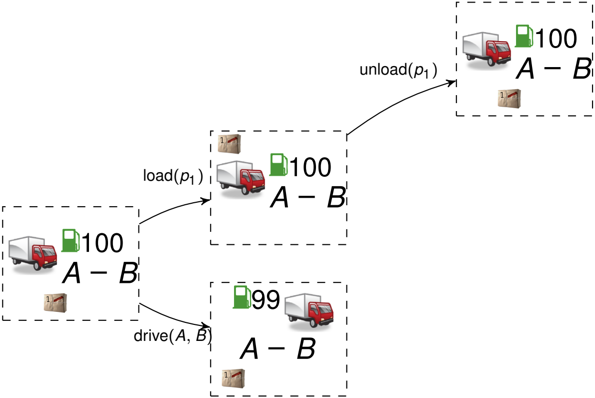

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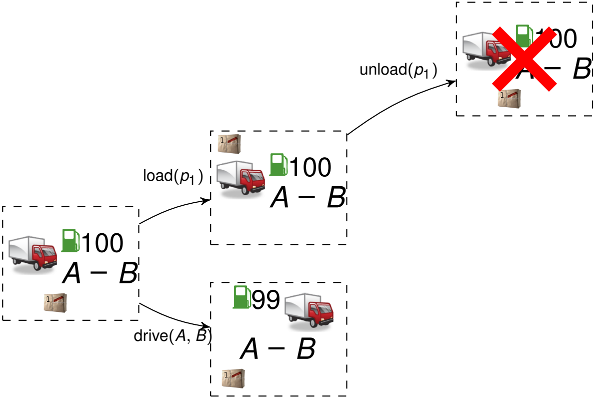

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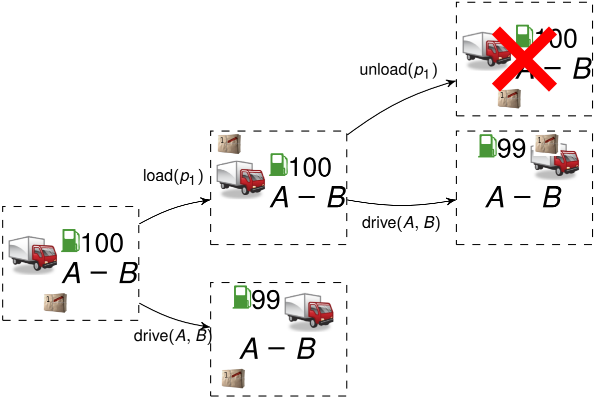

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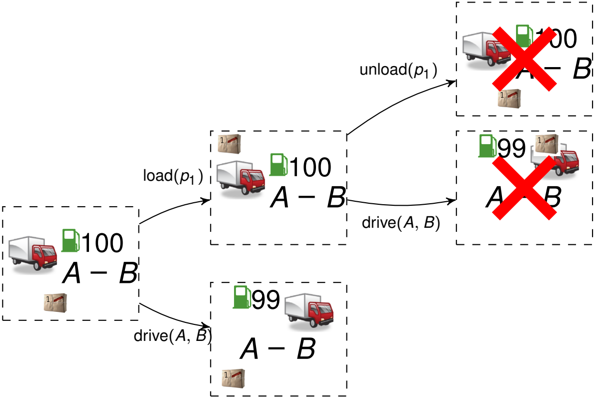

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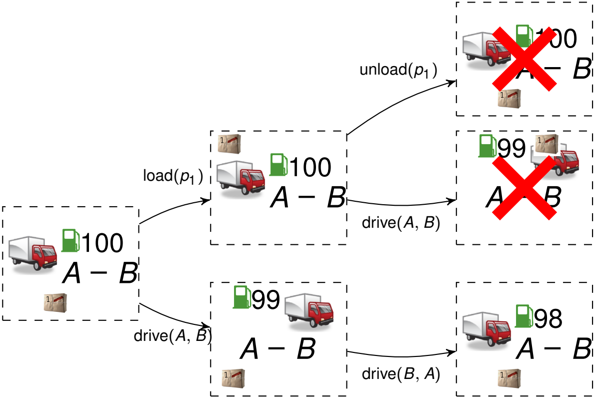

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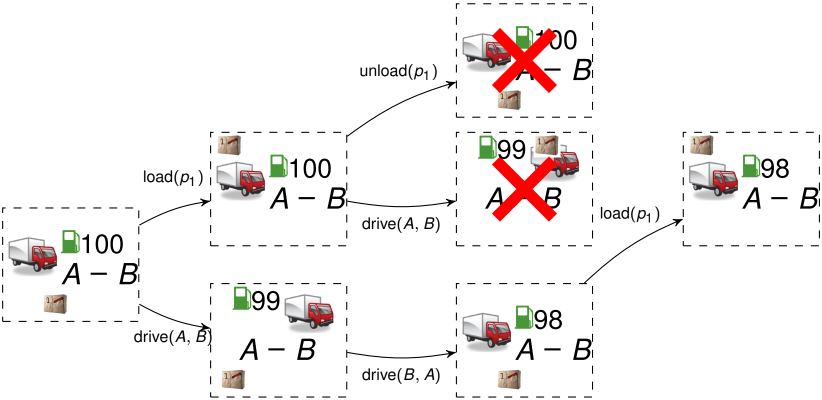

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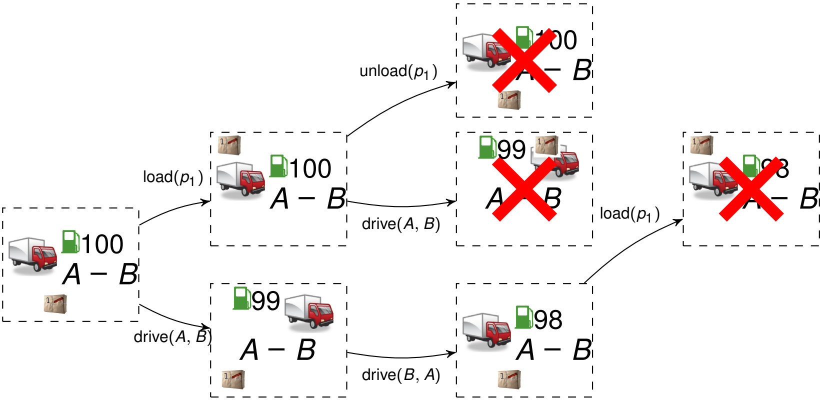

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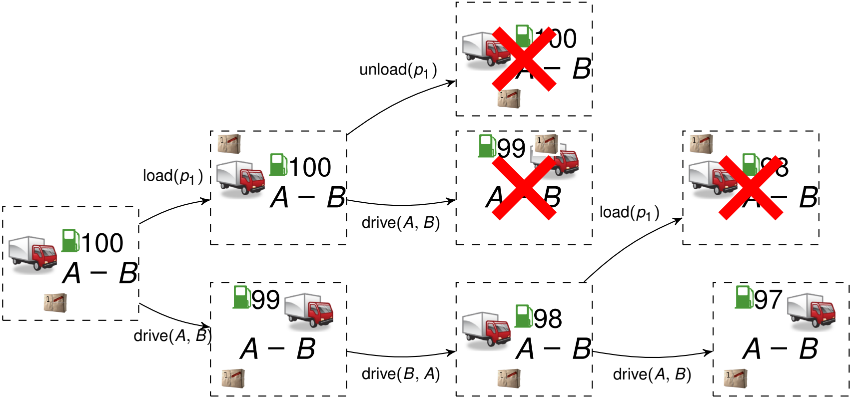

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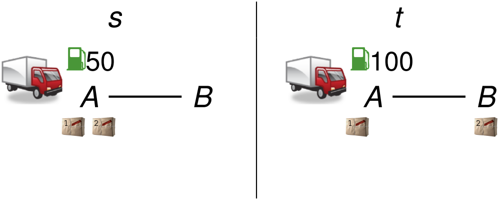
Dominance Analysis

Compare states: Which one is better?



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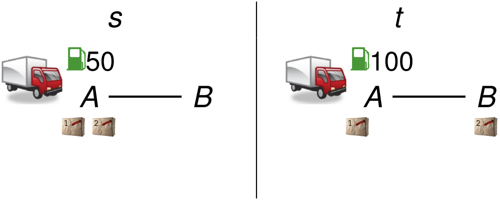

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If $s \preceq t$, then $h^*(s) \geq h^*(t)$: t is at least as good as s

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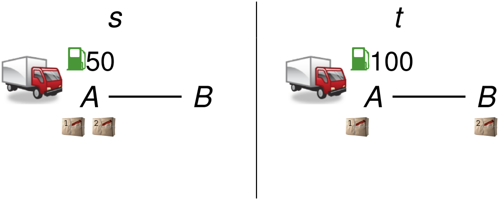

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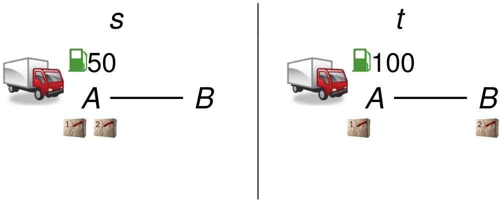

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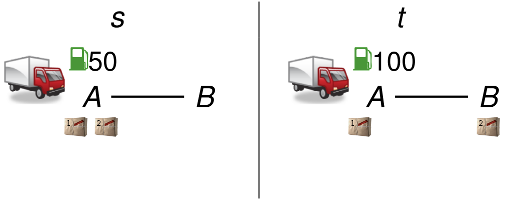

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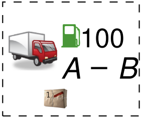
: $A \preceq B$ : $A \preceq B$  $0 \preceq 1 \preceq 2 \preceq 3 \dots$

(no matter the position of other packages or trucks)

Dominance Pruning

Prune s if there exists t s.t. $g(t) \leq g(s)$ and $s \preceq t$



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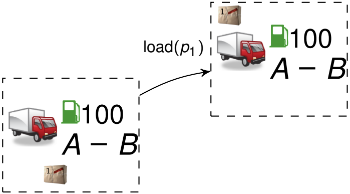

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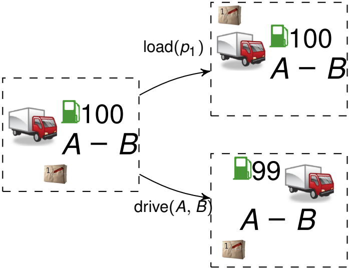

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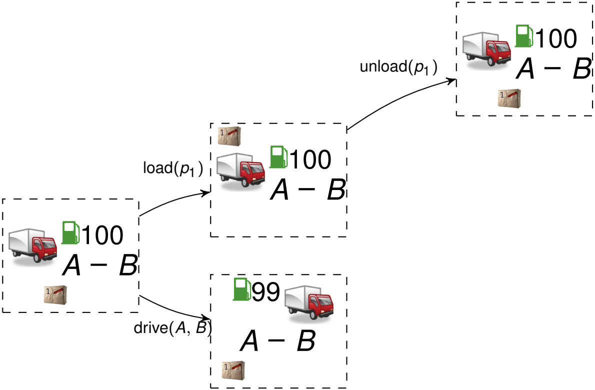

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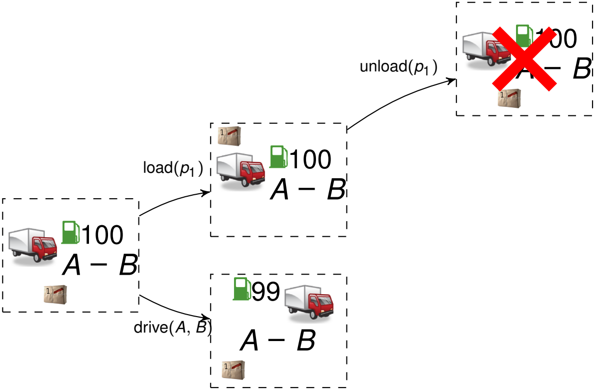

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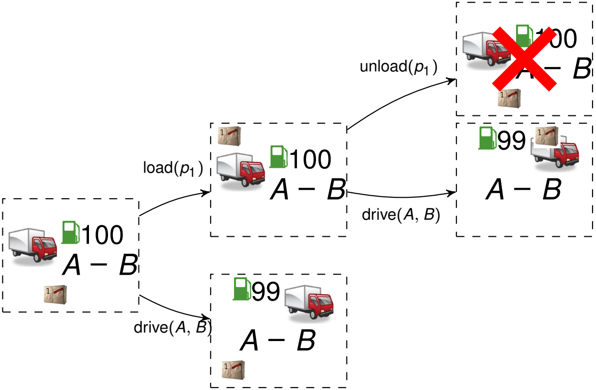

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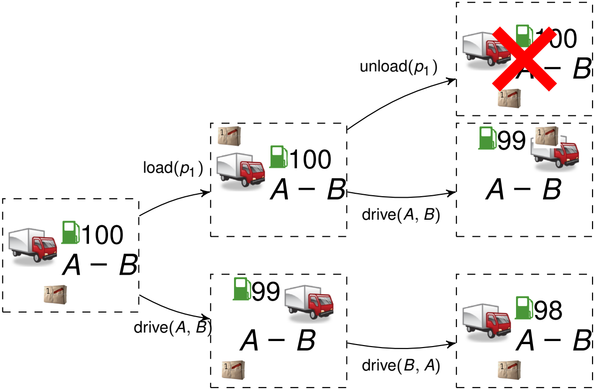

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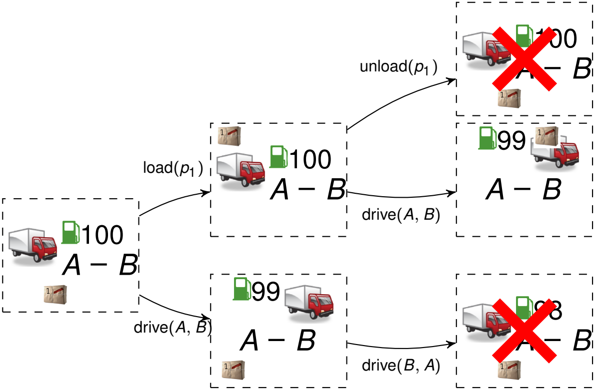

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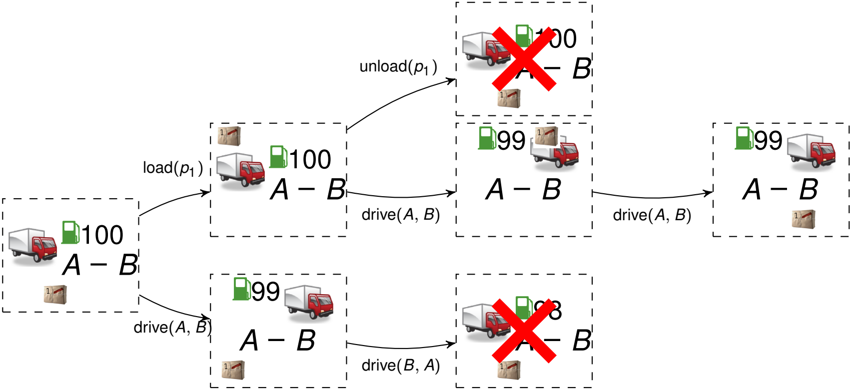

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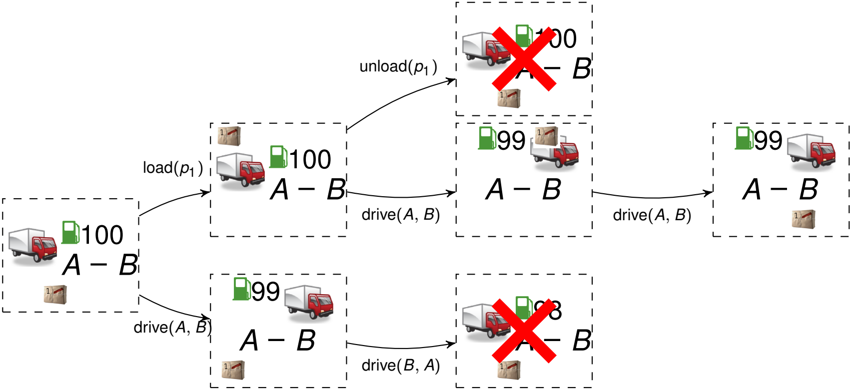

→Dominance pruning preserves at least an optimal solution.

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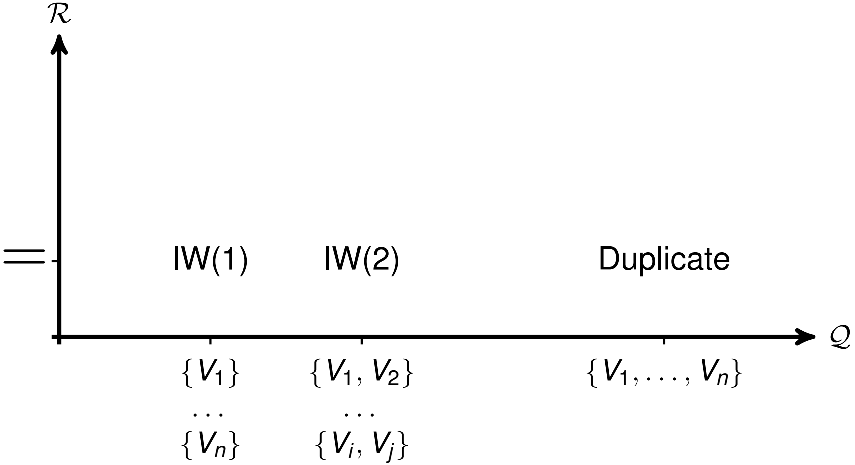
Let $\mathcal{R} = \{\preceq_1, ..., \preceq_k\}$ be a set of relations on P.
Let $\mathcal{Q}$ be a set of subsets of V.

$$\forall Q \in \mathcal{Q} : \exists t \in \mathcal{T} : \forall v \in Q : s[v] \preceq t[v]$$

Unsafe Dominance Pruning



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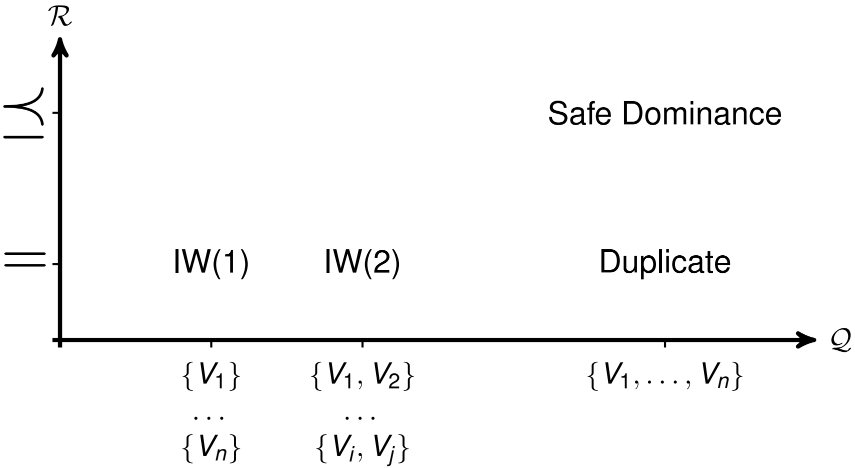

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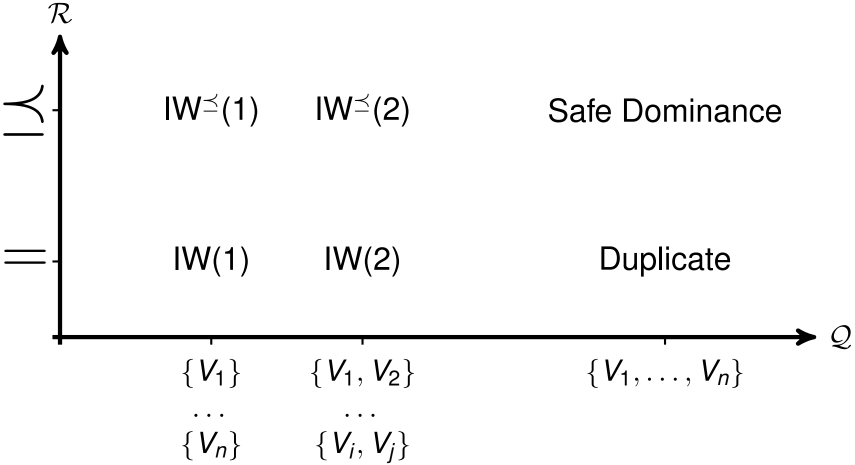
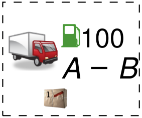
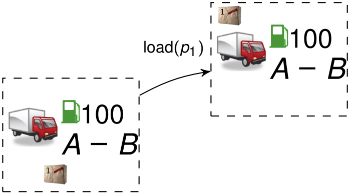


Example IW$_{\preceq}$(1)



Example $IW^{\preceq}(1)$



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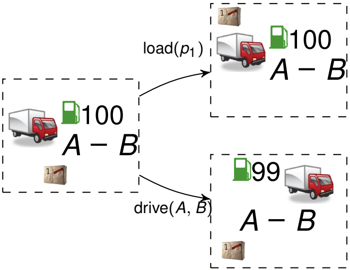

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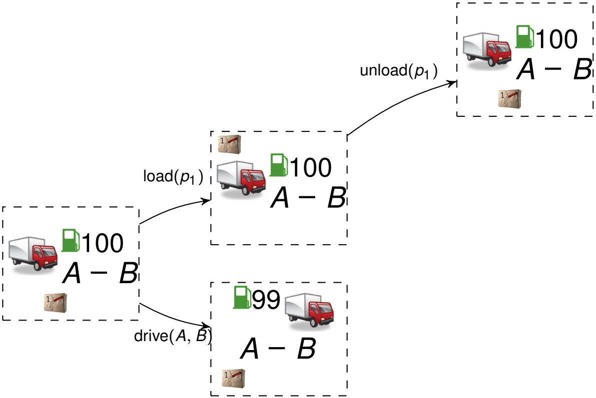

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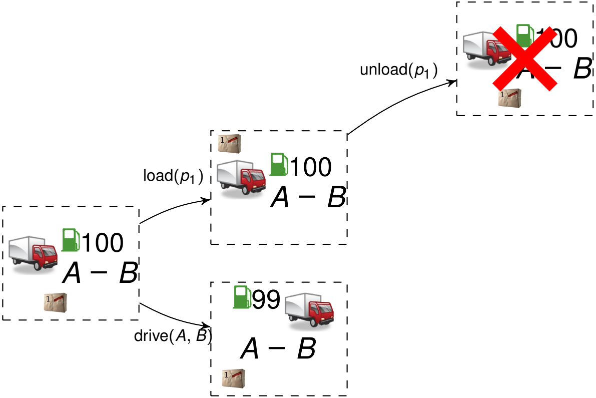

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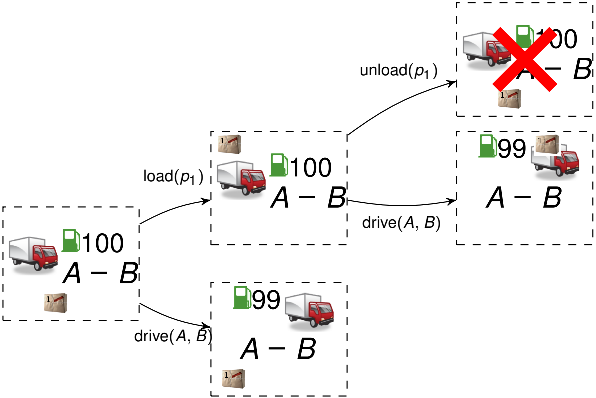

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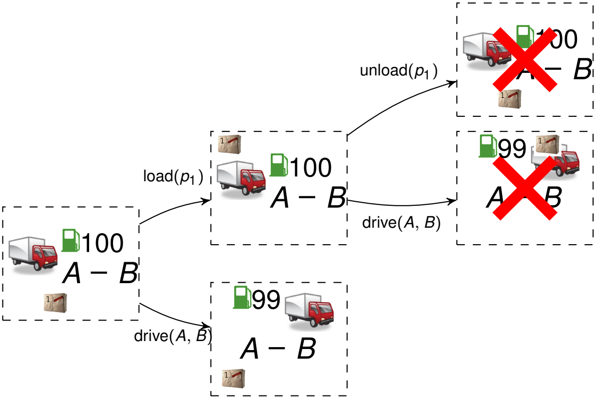

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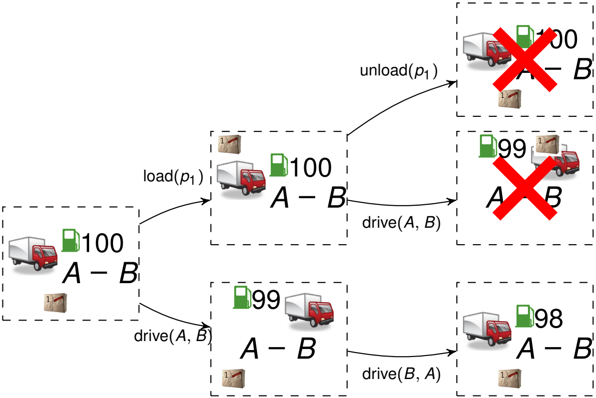

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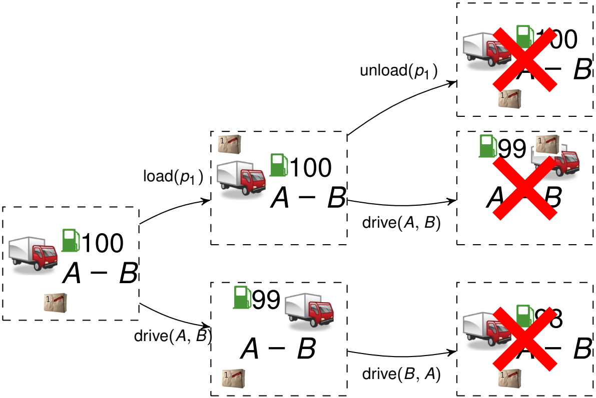

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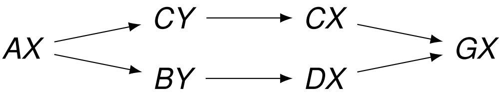

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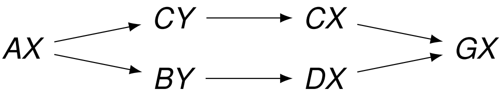
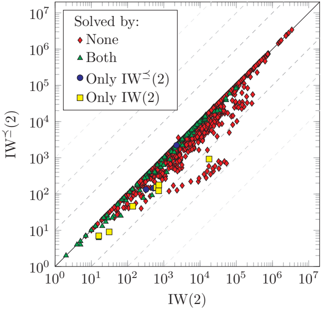
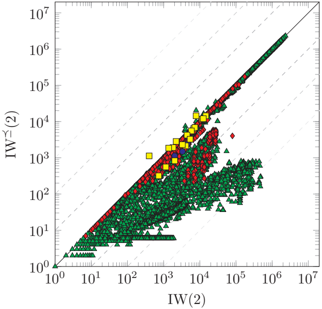


- However, there are also tasks that are solved when using $\preceq$ but not when using $=$

Effective Width Analysis



IPC Instances



1-goal instances

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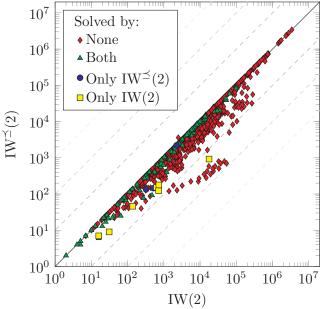

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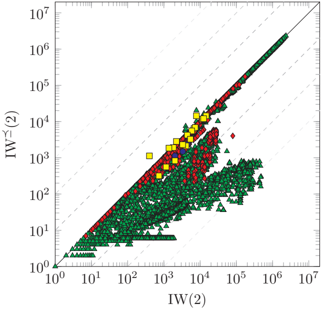

1-goal instances

→In practice, replacing $=$ by $\preceq$ increases pruning without making it more unsafe!

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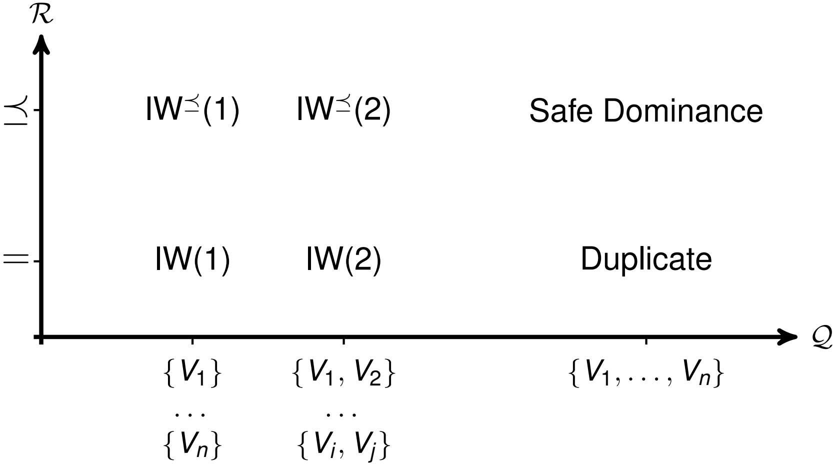

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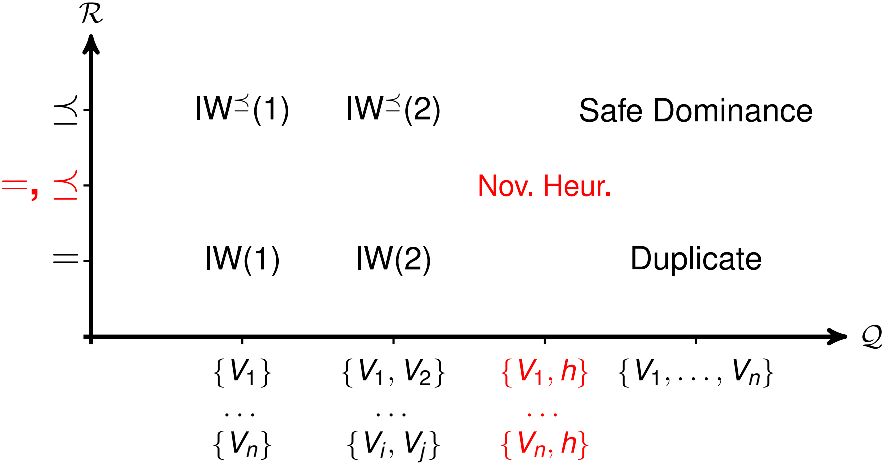

Quantify Novelty

How non-novel is a state?

Quantify Novelty

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This work: for each fact, count the number of states that have been seen with the same or better h value

$\rightarrow$Estimate the probability that the state is really dominated

Overview of Results:

We analyze three variants:

1. Changing $\mathcal{R}$: = vs. $\preceq$
2. Changing $\mathcal{Q}$
3. Changing quantification of non-novel states

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Changing $\mathcal{R}$: = vs. $\preceq$

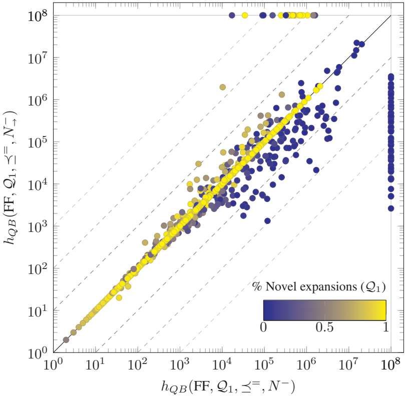
- Decreases the number of novel states
- Expansions similar to baseline
- Performance decreases due to overhead

Changing $\mathcal{Q}$

	$\mathcal{Q}_1$	$\mathcal{Q}_2$	$\mathcal{Q}^{cg}_{1,2}$	$\mathcal{Q}^{pre}_{1,2}$	$\mathcal{Q}^{cg}$	$\mathcal{Q}^{pre}$	Total
$\mathcal{Q}_1$	–	14	8	9	8	9	1564
$\mathcal{Q}_2$	**17**	–	6	6	8	6	1551
$\mathcal{Q}^{cg}_{1,2}$	**20**	**15**	–	7	10	10	1609
$\mathcal{Q}^{pre}_{1,2}$	**17**	**16**	**8**	–	9	7	1618
$\mathcal{Q}^{cg}$	**20**	**20**	**15**	**13**	–	6	1630
$\mathcal{Q}^{pre}$	**17**	**17**	**13**	**15**	**8**	–	**1634**

→Best configuration in practice: choose subsets of variables that appear together in action preconditions

Non-novel priority: N^{-} vs. $N^{-}_{\rightarrow}$



- Our non-novel priority is superior to the previous one!
- But, not good synergy with changing $\mathcal{Q}$

Conclusions

Dominance: Compare states by looking at their outgoing plans

Novelty: Compare states by looking at their facts

→Our new framework on unsafe dominance generalizes both

Can we use this to devise better variants of novelty?

- $\mathcal{Q}$: Use dominance relations in novelty
- $\mathcal{R}$: Look at different subsets of variables
- Non-novel priority

→Inspire new ideas to further improve novelty methods!