Eliminating Redundant Actions from Plans using Classical Planning

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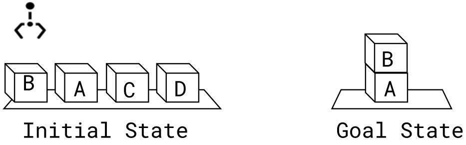
Introduction

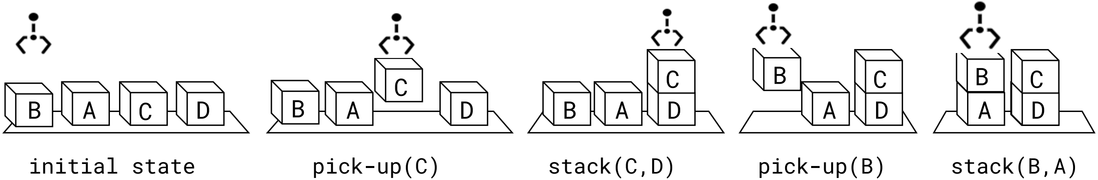
- Automated Planning: model based approach for autonomous behavior
- Classical Planning tasks:
  - Initial state
  - Set of actions (with preconditions and effects) that define state transitions
  - Goal description (partial state)
- Plan: sequence of actions that achieves the goals
- Plans generated by satisficing planners still contain redundant actions
- Identifying redundant actions in plans (perfect justification) is NP-complete
- Contribution: automatic reformulation to planning task to identify redundant actions

Plan justification - Example

- Blocksworld Task



- Plan - Can we justify why we need all actions?



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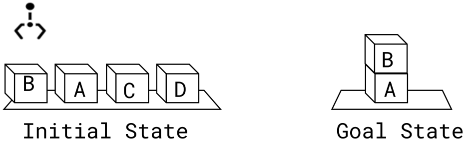

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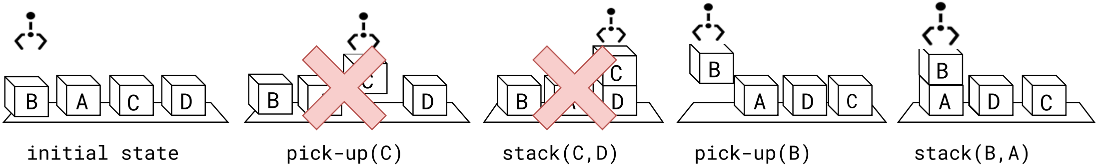
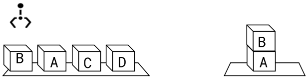


Minimal Reduction

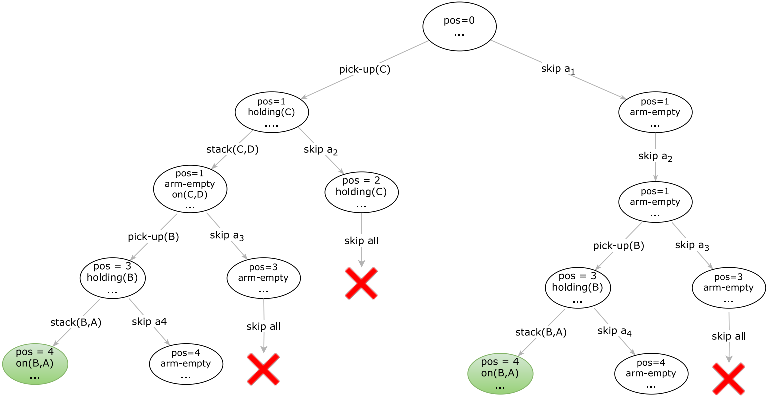
- **Minimal Reduction (MR)**: least cost perfectly justified plan reduction
- Minimal reduction as a classical planning task:
  - Inputs:
    - $\Pi = \langle \mathcal{V}, \mathcal{A}, \mathcal{I}, \mathcal{G} \rangle$ planning task (in SAS$^+$ formalism)
    - $\pi = \langle a_1, ..., a_n \rangle$ valid plan
  - Define a new planning task Π' where:
    - Actions from π can either be executed or skipped
    - Any plan π' for Π' is a **subsequence of** π
    - π' **achieves the goals when applied from** $\mathcal{I}$

Perfect Justification as AP - Example Blocks



Initial State Goal State

1. *pick-up*(C)
2. *stack*(C, D)
3. *pick-up*(B)
4. *stack*(B, A)



Plan Action Landmarks

- A plan action landmark (PAL) is an action that must be part of any plan reduction
- Can greatly reduce average branching factor of the problem
- Two variants: **Trivial Plan Action Landmarks** (TPAL) and **Fixpoint Plan Action Landmarks** (FPAL)
- Encapsulate consecutive FPALs in macro operators

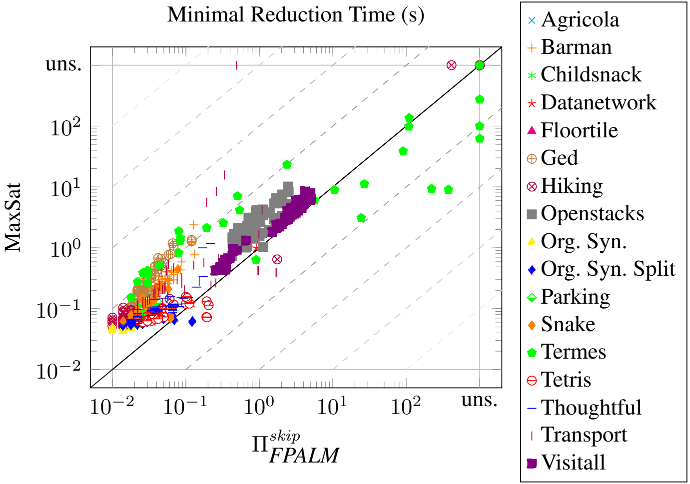
  - **TPAL** base case: a_j single goal achiever
  - **TPAL**: a_i single achiever of some precondition of a_j

  - **FPAL** base case: a_j is a TPAL
  - **FPAL**: a_i single achiever of some precondition of a_j after another TPAL is a TPAL

Experimental Setting

- Approaches
  - Π^{skip}, Π^{skip}_{TPAL}, Π^{skip}_{FPAL}, Π^{skip}_{FPALM}
  - Weighted Partial MaxSAT [Balyo et al., 2014]
- Satisficing tracks of the 2014 and 2018 IPCs
- Fast-Downward (FD) [Helmert, 2006]

Experiments Results



Conclusions & Future Work

- Automated Planning based approach for minimal reduction
- Comparable results to current state of the art
- Future work
  - Characterize situations where the proposed approach outperforms SAT-based and vice-versa
  - Incorporate action elimination on relevant settings, such as top-k planning and plan recognition
  - Suboptimal action elimination
  - Action elimination outside of classical planning

References

Balyo, T., Chrpa, L., and Kilani, A. (2014).
On different strategies for eliminating redundant actions from plans.
In *Seventh Annual Symposium on Combinatorial Search*.

Helmert, M. (2006).
The fast downward planning system.
Journal of Artificial Intelligence Research, 26:191–246.

Extra - Formal compilation

- Define $\Pi^{skip} = \langle \mathcal{V}', \mathcal{A}', \mathcal{I}', \mathcal{G}' \rangle$ where:
  - $\mathcal{V}' = \{v \in \mathcal{V} \mid |\mathcal{D}'(v)| > 1\} \cup \{pos\}$
  - $\mathcal{D}'(v) = \{d \in \mathcal{D}(v) \mid \langle v, d \rangle \in F_\pi\} \cup \Theta$
    - $F_\pi = \bigcup_{a_i \in \pi} pre(a_i) \cup \mathcal{G}$
    - $\mathcal{D}'(v) = \{d \in \mathcal{D}(v) \mid \langle v, d \rangle \in F_\pi\} \cup \Theta$
    - $\Theta = \{\theta\}$ if $\langle v, d \rangle \notin F_\pi$ but $\langle v, d \rangle \in \mathcal{I}$ or $\exists\ a_i \in \pi$ with $\langle v, d \rangle \in eff(a_i)$
    - $\Theta = \emptyset$ otherwise
  - $\mathcal{I}' = (\mathcal{I} \cap F_\pi) \cup \{\langle v, \theta \rangle \mid v \in \mathcal{V}', \langle v, d \rangle \in (\mathcal{I} \setminus F_\pi)\} \cup \{\langle pos, 0 \rangle\}$
  - $\mathcal{G}' = \mathcal{G} \cup \{\langle pos, n \rangle\}$

Extra - Formal compilation

$$\mathcal{A}' = \{a'_i \mid 1 \leq i \leq n\} \cup \{skip_i \mid 1 \leq i \leq n\}$$

- An a'_i action for every action a_i in π

$$pre(a'_i) = pre(a_i) \cup \{\langle pos, i-1\rangle\}$$
$$eff(a'_i) = \{\tau(f) \mid f \in eff(a_i)\} \cup \{\langle pos, i\rangle\}$$
$$\tau(\langle v, d\rangle) = \langle v, d\rangle \, if \, \langle v, d\rangle \in F_\pi \, and \, \langle v, \theta\rangle \, otherwise$$

- One skip action per action in π
- $skip_i$ actions just increase the value of pos from $i-1$ to i