

Partition-Based Pruning in Classical Planning

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1 Introduction

- Planning
- SAS+

2 Partition-Based Pruning

- SAS+ for Partition-Based Pruning
- Pruning rule
- Path-Pruning A*
- Partitioning

3 Evaluation

Given

Description of a state space

Goal

Plan : sequence of actions leading from the initial state to a goal state.

Optimal planning

The returned plan has to be one of the cheapest possible.

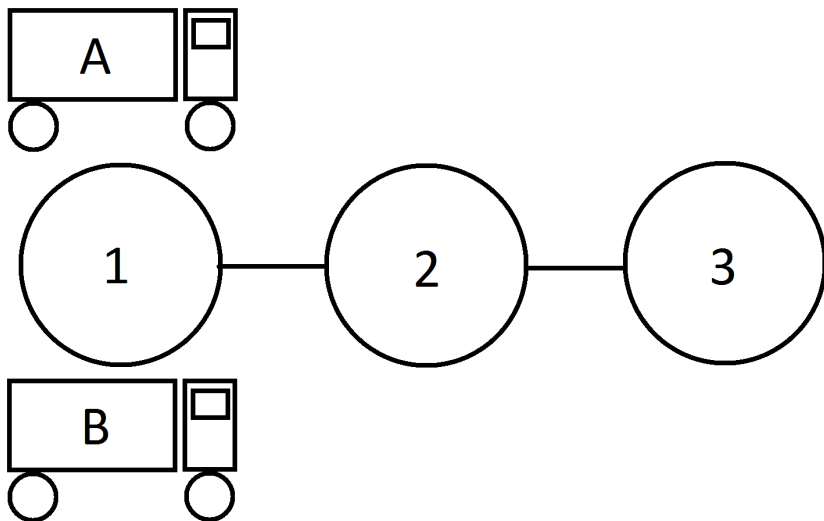
$$\Pi = \langle V, s_0, s_*, A, cost \rangle$$

- $V = \{v_1, v_2, \dots, v_n\}$: Set of variables which can be assigned to a value from the finite domain D_v
- s_0 : Initial state of the problem.
- s_* : Goal conditions.
- A : Set of actions, each defined as $a = \langle pre(a), eff(a) \rangle$
- $cost$: Function mapping each action to a non-negative value as it's cost.

- Problem: Size of the state space induced by complex problems.
- Approaches:
 - Informed search: Use heuristic function.
 - Pruning: Exclude not needed parts of the search.

Partition-Based Pruning

- Pruning method introduced by Nissim et al. in the paper "Tunneling and Decomposition-Based State Reduction for Optimal Planning"
- Pruning based on the previously applied action leading to the state.
- Optimality preserving



$$\Pi = \langle V, s_0, s^*, \{A_i\}_{i=1}^k, cost \rangle$$

- $A_i \cap A_j = \emptyset$ for $i \neq j$
- $\bigcup_{i=1}^k A_i = A$

Commutativity of actions

Two actions a_i and a_j are commutative if their position can be switched in a plan $\langle \dots a_i, a_j, \dots \rangle$ resulting in another valid plan $\langle \dots a_j, a_i, \dots \rangle$.

Two actions are commutative if

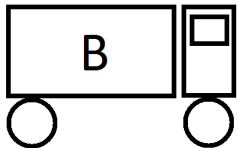
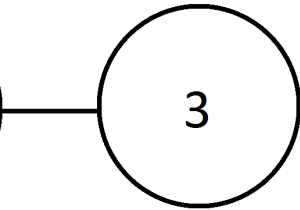
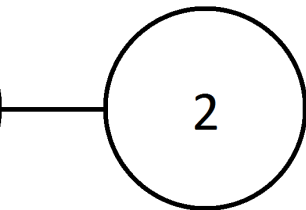
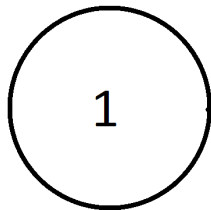
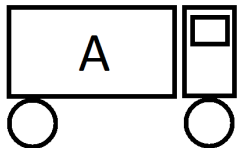
- Neither action destroys a precondition of the other.
- Neither action achieves a precondition of the other.
- The actions do not have conflicting effects.

An action $a_i \in A_j$ is public if

- there exists an action $a_n \in A_m$ with $j \neq m$ and a_i and a_n are not commutative.
- it achieves a goal condition of the problem

All other actions are considered as private.

In a state with a private creating action $a \in A_i$, all actions outside of its partition A_i are pruned.



Variation of A* to preserve optimality when using partition-based pruning.

Differences to A* with reopening

- Search node contains all actions which led to it's state with the lowest cost.
- An action is applied if there exists an incoming action that allows it's use with respect to the pruning rule.
- If an already open state is reached again with the same path cost via another action it is added to the list of generating actions in the search node.
- If a closed state is reached again with the same path-cost it's being reopened.

- Generate action graph.
- Partition graph with METIS

METIS is a tool capable of partitioning a bidirectional graph into a given number of parts.

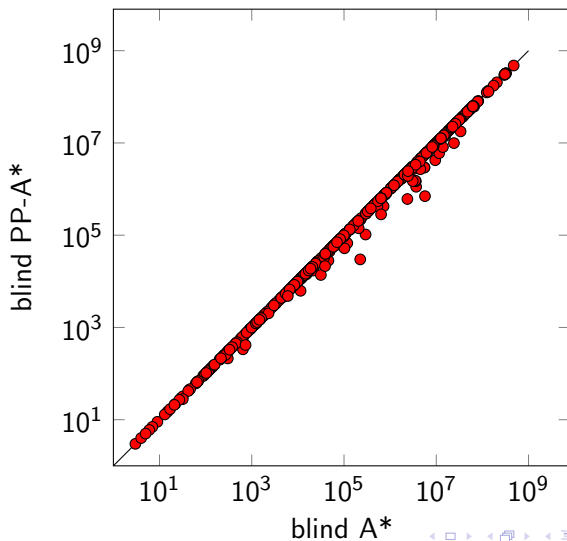
The Symmetrystore estimates how valuable a given partitioning is in the search.

$$\Gamma(\{A_i\}_{i=1}^k) := \sum_{i=1}^k \left(\frac{|\{a \in A_i \text{ and } a \text{ is private}\}|}{|A_i|} * \frac{|A \setminus A_i|}{|A|} \right)$$

Local search to determine the number of partitions used.

- Starts with 2 partitions
- Uses symmetry score to detect promising partitions.

generated states until last jump



Uninformed Search

| domain | A* coverage | PP-A* coverage |
|--------------------------|-------------|----------------|
| elevators-opt08-strips | 10 | 9 |
| elevators-opt11-strips | 8 | 7 |
| floortile-opt11-strips | 2 | 1 |
| mprime | 18 | 17 |
| mystery | 15 | 14 |
| parcprinter-08-strips | 10 | 9 |
| parcprinter-opt11-strips | 6 | 5 |
| psr-small | 48 | 47 |
| scanalyzer-08-strips | 12 | 9 |
| scanalyzer-opt11-strips | 9 | 6 |
| transport-opt14-strips | 4 | 5 |
| Sum | 142 | 129 |
| Others | 456 | 446 |
| Sum | 598 | 575 |

generated states until last jump

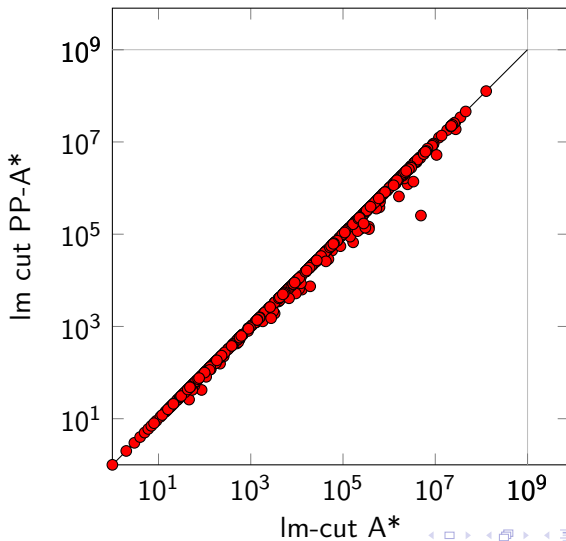


Table: Informed search results by domain

| domain | A* coverage | PP-A* coverage |
|--------------------------|-------------|----------------|
| openstacks-opt08-strips | 19 | 18 |
| openstacks-opt11-strips | 14 | 13 |
| openstacks-opt14-strips | 3 | 2 |
| psr-small | 49 | 48 |
| satellite | 7 | 12 |
| scanalyzer-08-strips | 16 | 12 |
| scanalyzer-opt11-strips | 13 | 10 |
| woodworking-opt08-strips | 17 | 19 |
| woodworking-opt11-strips | 12 | 13 |
| Sum | 150 | 147 |
| Others | 724 | 724 |
| Sum | 874 | 871 |

- Symmetryscore is a good estimation and has proven useful in choosing the partitions.
- Local search finds good partitions in a short time, if a low number of partitions is useful.

Thank you for your attention.