Partition-Based Pruning in Classical Planning

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Overview

Planning

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.

SAS+

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

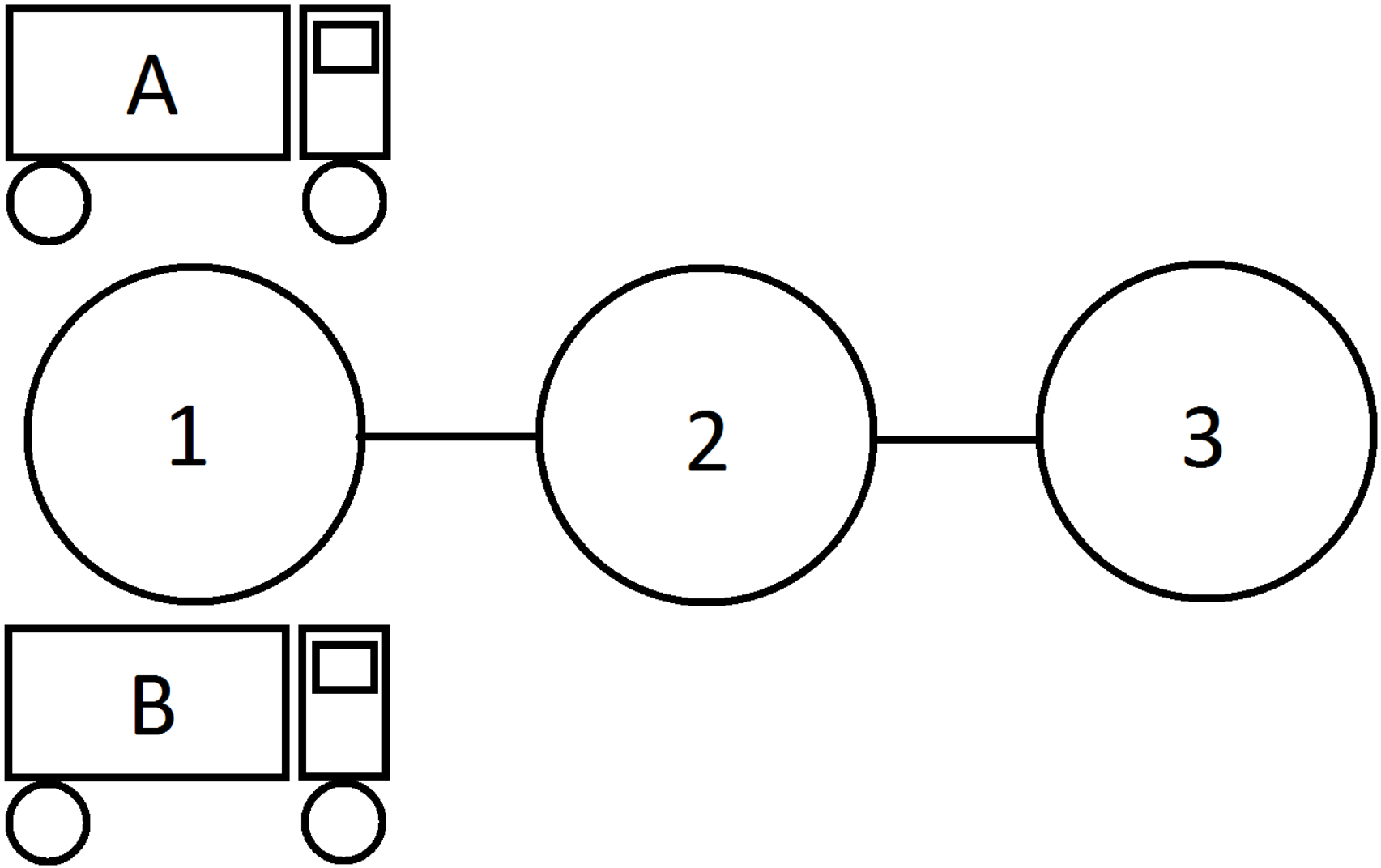
- $V = \{v_1, v_2, \ldots, v_n\}$: Set of variables which can be assigned to a value from the finite domain D_v
- s_0 : Initial state of the problem.
- s_* : Goal conditions.
- A : Set of actions, each defined as $a = \langle pre(a), eff(a) \rangle$
- $cost$: Function mapping each action to a non-negative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

Idea



SAS+ for Partition-Based Pruning

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

- $A_i \cap A_j = \emptyset$ 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 $\langle ...a_i, a_j, ... \rangle$ resulting in another valid plan $\langle ...a_j, a_i, ... \rangle$.

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.

Public / Private actions

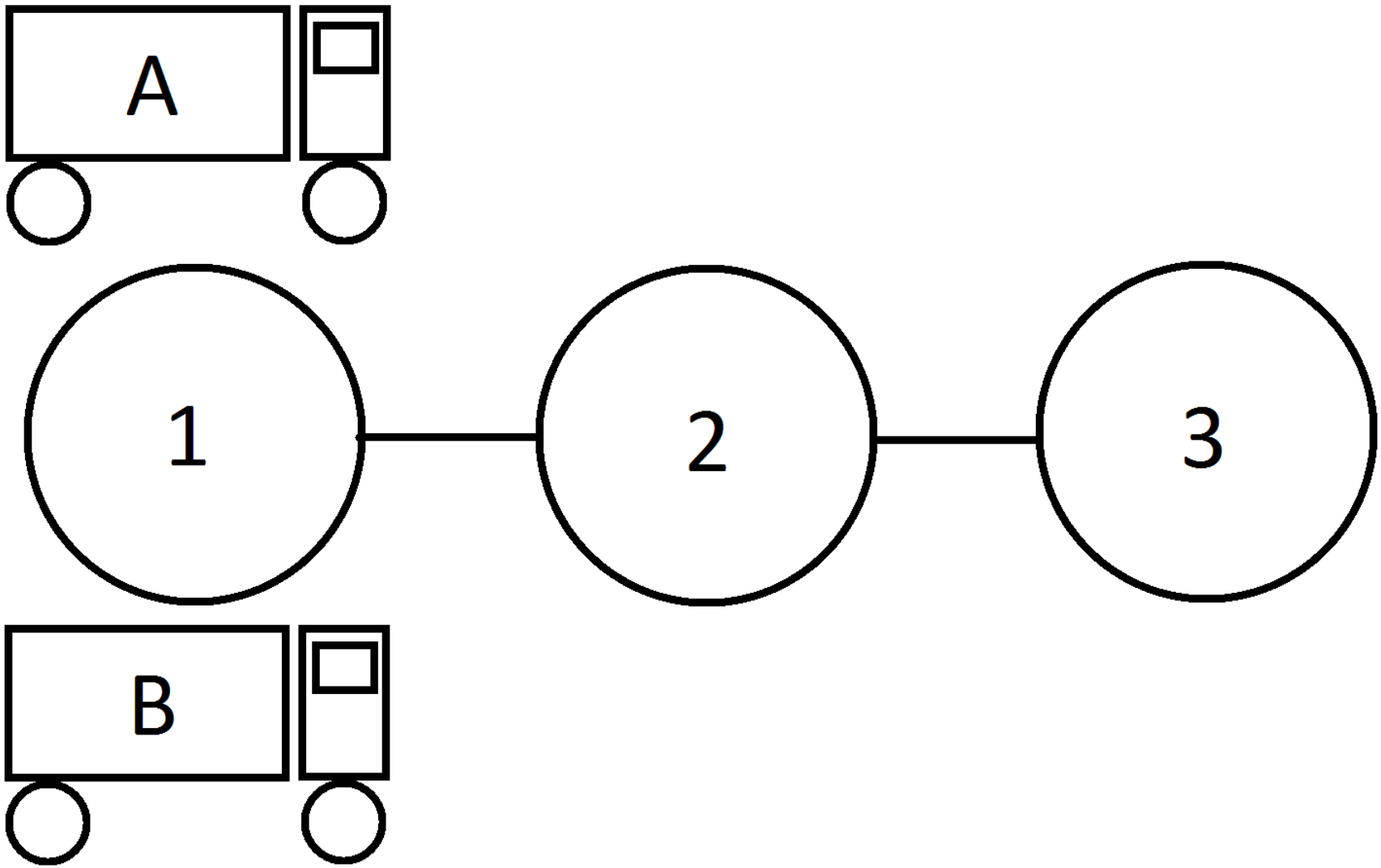
An action $a_i \in A_j$ is public if

- 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.

Pruning rule

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


A
1
2
3
B

Path-Pruning A*

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.

Partitioning

- Generate action graph.
- Partition graph with METIS

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

Symmetryscore

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

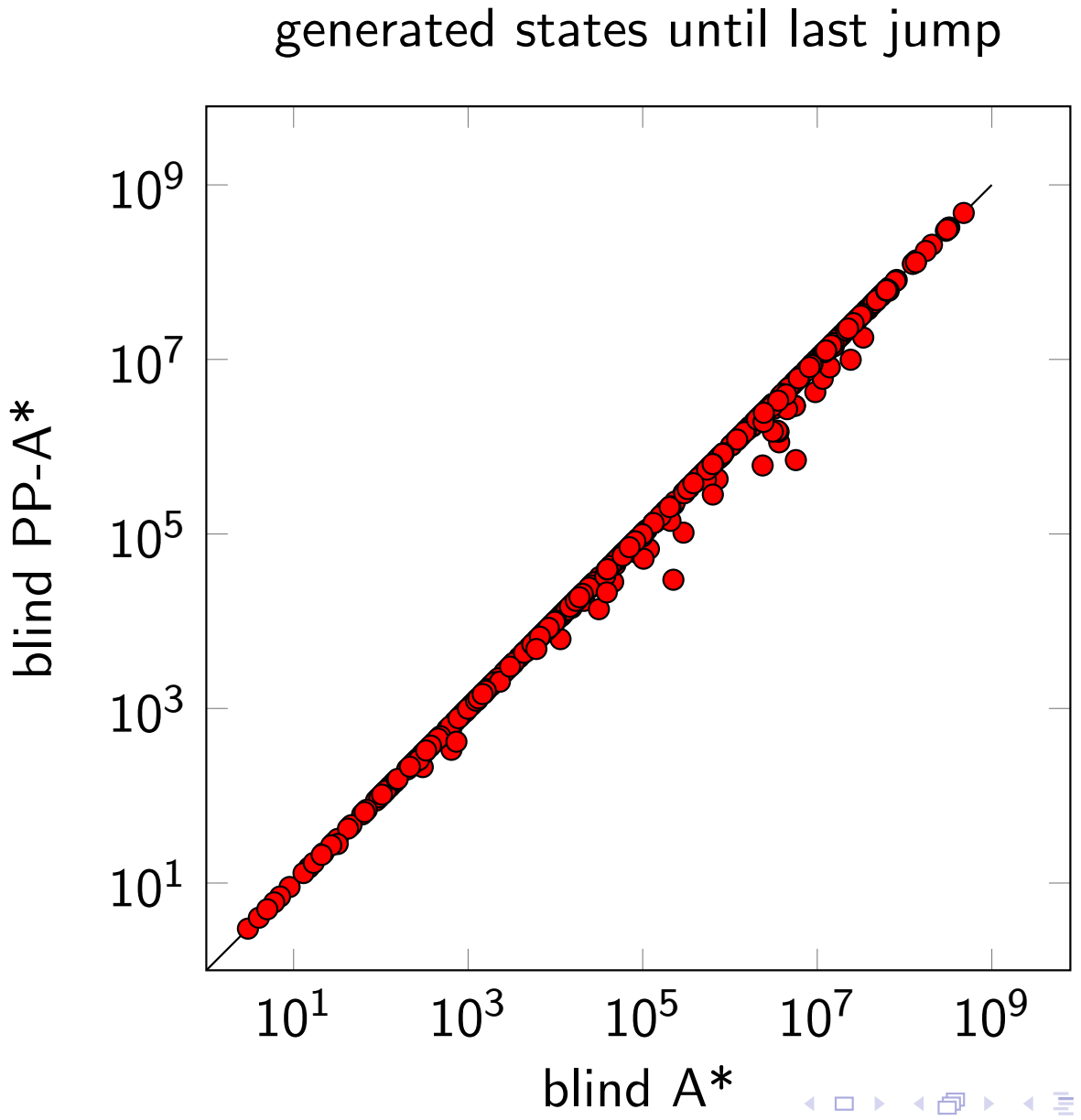
$$\Gamma(\{A_i\}_{i=1}^{k}) := \sum_{i=1}^{k} \left(\frac{|\{a | a \in A_i \text{ and a is private}\}|}{|A_i|} * \frac{|A \backslash A_i|}{|A|} \right)$$

Local Search

Local search to determine the number of partitions used.

- Starts with 2 partitions
- Uses symmetryscore to detect promising partitions.

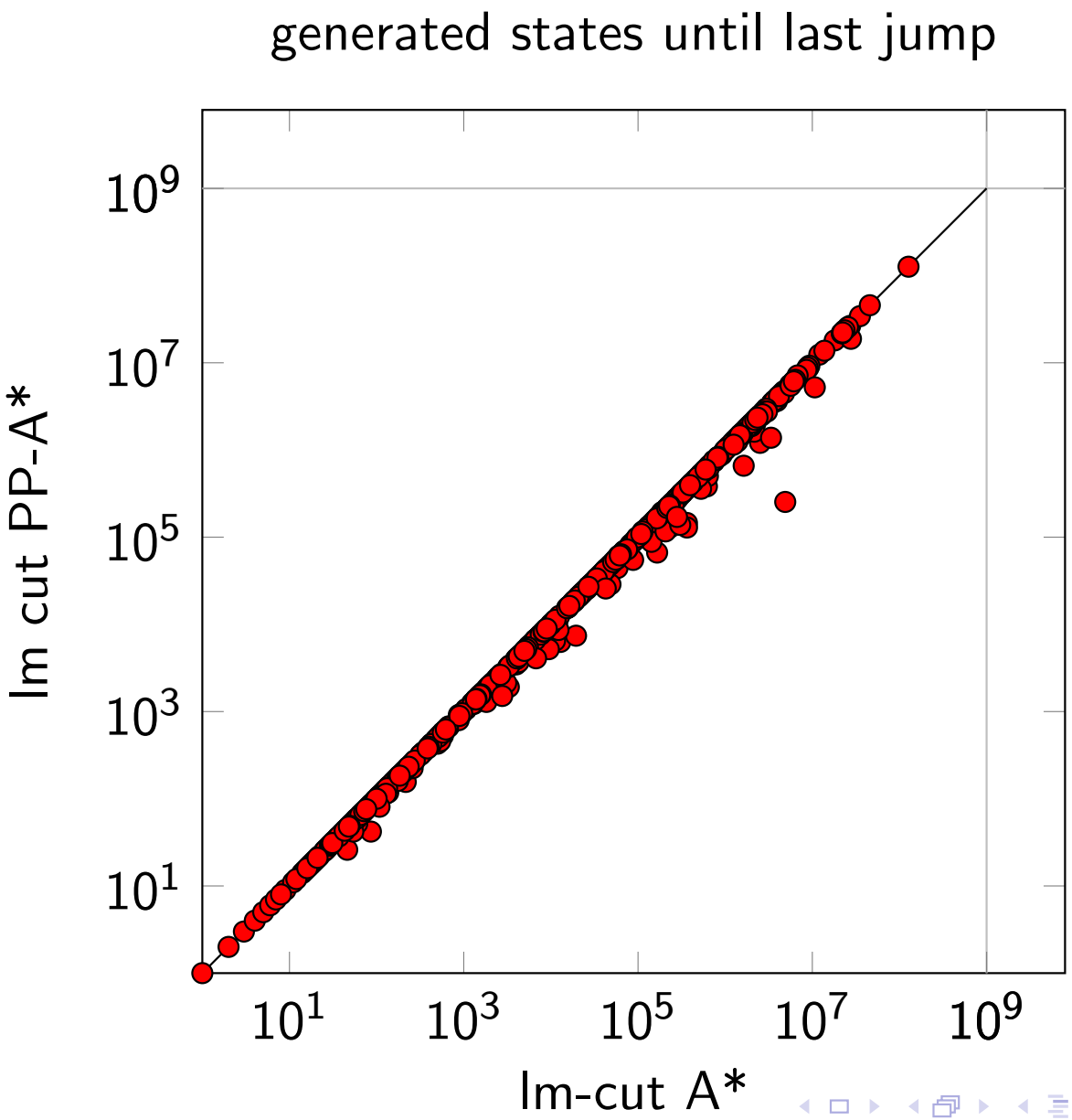
Uninformed Search



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**

Informed Search



Informed Search

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**

Partitioning

- 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.