A Comparison of Cost Partitioning Algorithms for Optimal Classical Planning

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Cost Partitioning

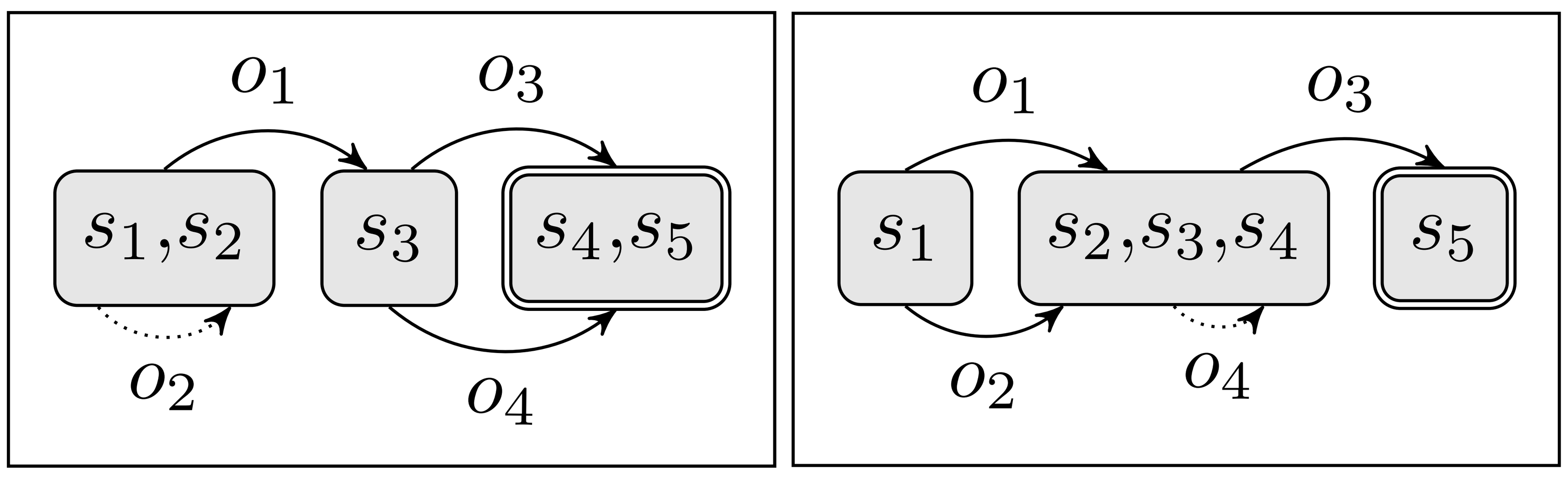
Distributing operator costs among multiple cost functions $\mathcal{C} = \langle cost_1, \dots, cost_n \rangle$, where

$$\sum_{i=1}^{n} cost_i(o) \leq cost(o) \text{ for all operators } o,$$

makes sum of heuristic values under $\mathcal{C}$ admissible:

$$h^{\mathcal{C}}(s) := \sum_{i=1}^{n} h_i(s, cost_i).$$

Example Abstractions



$cost(o_1) = cost(o_3) = 4,\ cost(o_2) = cost(o_4) = 1$

$\Rightarrow h^{\text{OCP}} = h^{\text{SCP}} = 8,\ h^{\text{OUCP}} = 7,\ h^{\text{UCP}} = 6,\ h^{\text{PHO}} = h^{\text{CAN}} = h^{\text{GZOCP}} = 5$

Cost Partitioning Algorithms

Optimal Cost Partitioning

- Cost partitioning with highest heuristic value for a given state among all cost partitionings

Post-hoc Optimization

- Let $\langle w_1, \dots, w_n \rangle$ be a solution to the linear program that maximizes $\sum_{i=1}^{n}(w_i \cdot h_i(s))$ subject to

$$\sum_{i \in \{1,\dots,n\}: o \text{ relevant for } h_i} w_i \leq 1 \text{ for all operators } o$$
$$w_i \geq 0.$$

- Use costs $w_i \cdot cost(o)$ if o is relevant for h_i, otherwise 0

Greedy Zero-one Cost Partitioning

- Order heuristics
- Use full costs for the first relevant heuristic

Saturated Cost Partitioning

- Order heuristics
- For each heuristic h:
  - Use minimum costs preserving all heuristic estimates for h
  - Use remaining costs for subsequent heuristics

Uniform Cost Partitioning

- Distribute costs uniformly among relevant heuristics

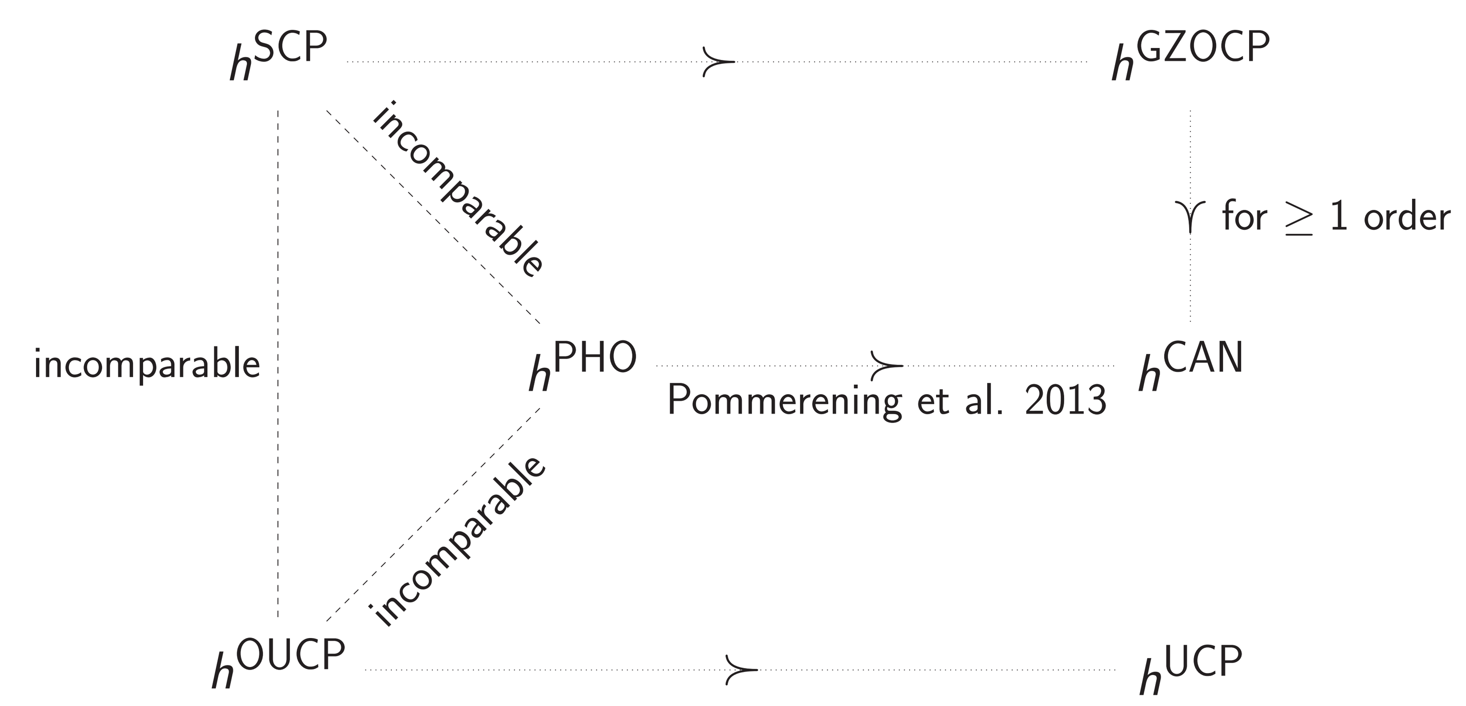
Opportunistic Uniform Cost Partitioning (New)

- Order heuristics
- For each heuristic h:
  - Distribute costs uniformly among relevant *unconsidered* heuristics
  - Use remaining costs for subsequent heuristics

Canonical Heuristic

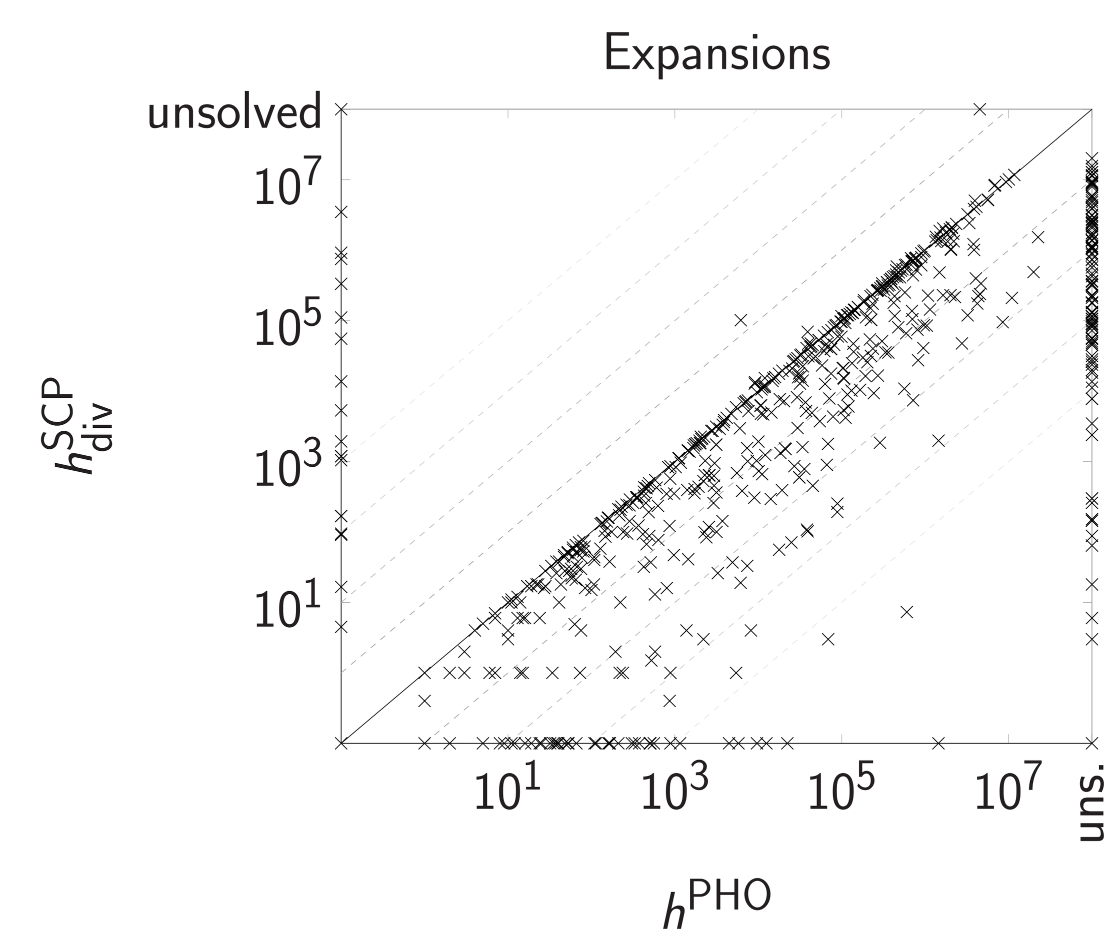
- Maximum over additive (independent) heuristic subsets

Theoretical Comparison



Experimental Comparison: Systematic PDBs

	h^{UCP}	$h^{\text{OUCP}}_{\text{one}}$	$h^{\text{OUCP}}_{\text{div}}$	$h^{\text{GZOCP}}_{\text{one}}$	$h^{\text{GZOCP}}_{\text{div}}$	$h^{\text{SCP}}_{\text{one}}$	$h^{\text{SCP}}_{\text{div}}$	h^{CAN}	h^{PHO}	h^{OCP}	coverage	std. dev.
h^{UCP}	–	0	3	15	3	4	0	11	10	30	709.0	–
$h^{\text{OUCP}}_{\text{one}}$	14	–	9	22	8	6	0	14	13	31	744.9	3.07
$h^{\text{OUCP}}_{\text{div}}$	13	8	–	22	7	6	0	14	14	31	734.6	2.01
$h^{\text{GZOCP}}_{\text{one}}$	3	1	4	–	3	0	0	9	11	29	694.0	2.58
$h^{\text{GZOCP}}_{\text{div}}$	15	12	14	20	–	9	0	13	13	30	749.9	1.66
$h^{\text{SCP}}_{\text{one}}$	20	19	17	23	16	–	0	18	21	32	775.7	4.47
$h^{\text{SCP}}_{\text{div}}$	27	26	24	28	22	22	–	23	26	33	**854.9**	2.33
h^{CAN}	8	7	7	17	5	8	2	–	13	28	656.0	–
h^{PHO}	9	7	7	15	7	6	3	10	–	31	737.0	–
h^{OCP}	4	4	4	4	4	4	3	5	3	–	471.0	–



Discussion of Experimental Comparison

- Results for hill climbing PDBs, Cartesian abstractions and landmark heuristics in paper
- Beneficial to reuse unused costs, to assign them greedily and to use multiple orders
- Saturated cost partitioning method of choice in all tested settings

Comparison of Different Heuristics (Using h^2 Mutexes)

	HC+$h^{\text{SCP}}_{\text{div}}$	Sys2+$h^{\text{SCP}}_{\text{div}}$	Cart.+$h^{\text{SCP}}_{\text{div}}$	LM+$h^{\text{SCP}}_{\text{one}}$	$h^{\text{LM-cut}}$	$h^{\text{M\&S}}$	h^{SEQ}	SymBA$^*_2$	coverage
HC+$h^{\text{SCP}}_{\text{div}}$	–	7	9	19	15	21	25	17	845.0
Sys2+$h^{\text{SCP}}_{\text{div}}$	10	–	11	18	18	23	24	16	878.5
Cart.+$h^{\text{SCP}}_{\text{div}}$	19	14	–	24	19	24	28	17	**1017.9**
LM+$h^{\text{SCP}}_{\text{one}}$	8	9	4	–	9	13	23	9	934.0
$h^{\text{LM-cut}}$	15	11	8	14	–	20	23	10	927.0
$h^{\text{M\&S}}$	8	7	5	14	10	–	20	6	797.0
h^{SEQ}	5	5	6	6	8	12	–	7	779.0
SymBA$^*_2$	20	18	16	23	20	23	27	–	1008.0