Subset-Saturated Transition Cost Partitioning

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In a Nutshell

- Optimal classical planning
- A* search with admissible heuristic
- Multiple heuristics capture different aspects of task
- Beneficial to combine information of these heuristics
- Cost partitioning allows admissible combination
- Greedy method: saturated cost partitioning
- Contribution: combine two orthonal generalizations

Induced Transition System

A **Planning task** Π induces a **weighted transition system** $\mathcal{T} = \langle S, L, T, s_0, S_\star, ocf \rangle$ with

- S: set of **states**, L: set of **operator labels**,
- T: set of **transitions** $T \subseteq S \times L \times S$,
- $s_0 \in S$: **initial state**, $S_\star \subseteq S$ set of **goal states**,
- $ocf : L \to \mathbb{R}$ the **operator costs** (nonnegative)

Opt. solution for Π corresp. to **path** $\langle s_0, l_1, s_1 \dots, l_n, s_n \rangle$ in $\mathcal{T}$ where $s_n \in S_\star$ with cheapest cost $\sum_{i=1}^{n} ocf(l_i)$.

Abstractions and Heuristics

- $h(ocf, s)$ is goal distance estimate of state s in S
- h is **admissible** if $h(ocf, s) \leq h^*(ocf, s)$ for all states s and h^* is perfect estimate
- **Abstraction** is simpler version of task where a partitioning of the states S defines the abstract states
- **Abstraction heuristic** maps states to goal distance of corresponding abstract state in the abstraction
- Abstraction heuristics are admissible

Saturated Cost Partitioning (SCP)

Saturated cost partitioning algorithm

for heuristic h in sequence $h_1, \dots, h_n$ **do**
  $ocf_i \leftarrow saturate(h, ocf)$
  $ocf \leftarrow ocf - ocf_i$
end for

- $saturate$ computes a fraction ocf_i of ocf which preserves $h(ocf, s)$ of (later: subset of) all states S
- $\langle ocf_i, \dots, ocf_n \rangle$ is a cost partitioning (CP)
- **CP property:** $\forall l \in L : \sum_{i=1}^{n} ocf_i(l) \leq ocf(l)$
- $h_1(ocf_i, s) + \dots + h_n(ocf_n, s)$ is admissible

Generalizations of SCP

generalization (2) →; generalization (1) ↓

	all states	subset of states
operators	(a) saturated operator CP	(b) subset-saturated operator CP
transitions	(c) saturated transition CP	(d) **subset-saturated transition CP**

(1) Costs partitioned among transitions

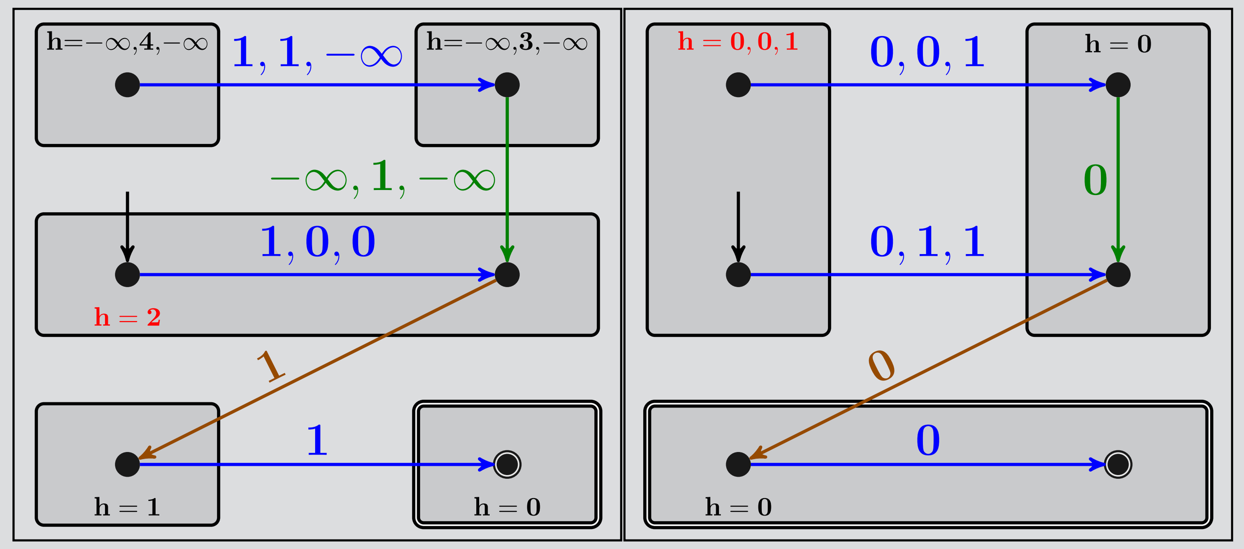
- $saturate$ returns $tcf_i : T \to \mathbb{R}$ instead of ocf_i
- More economical: often uses fewer costs
- Tractability depends on tcf_i, often manageable

(2) Saturate for subset of states S'

- E.g. reachable, closer to goal, or single state
- $saturate$ preserves estimates of only states S'
- More economical: often uses fewer costs

Our Contributions

- **Unify (1) and (2)**



  - Initial costs $ocf(l) = 1$ for all $l \in L$
  - Edge and node denotations (b),(c),(d)
  - (b) and (d) saturate for reachable states
  - $h(s_0)$: $h^{(b)} = h^{(c)} = 2 + 0 < 2 + 1 = h^{(d)}$
- **Fast computation of** $h(tcf, s)$
  - Backward search in abstraction avoiding abstract weight computations
  - Make use of lower bound 0 because tcf is always nonnegative
- **Restrictions on** tcf_i (as alternative to ocf_i)
  - Heuristic estimate in unsolvable state is ∞ independent of tcf_i
  - Almost no value in cost assignment $\neq 0$

Experiments

	(a)	(b)	(c)	(d)
(a)	–	47	164	59
(b)	**488**	–	**390**	55
(c)	**345**	236	–	34
(d)	**683**	**400**	**482**	–
Coverage	1056	1061	1024	**1083**