Delete Relaxations for Planning with State-Dependent Action Costs

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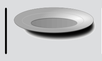
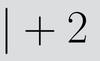
Motivation

Cost of operator application may depend on current state:

cost(dish washing) $= 1 \cdot |$  $| + 2 \cdot |$  $| + 5 \cdot |$  $|$

Action Cost Functions

Action a costs

$$c_a : \mathcal{D}_1 \times \mathcal{D}_2 \times \cdots \times \mathcal{D}_k \to \mathbb{N}$$

where $\mathcal{D}_i = \{0, \ldots, n_i\}$ is the domain of variable v_i on which the cost function c_a depends, $i = 1, \ldots, k$.

Additive Heuristic: Example

- $s(A) = s(B) = 0$. Question: $h_s^{add}(A = 1) = ?$
- Action a adds fact $A = 1$ at cost $2 - 2B$.
- Action b adds fact $B = 1$ at cost 1.
- With a: 00 —$a : 2$→ 10
- With (b, a): 00 —$b : 1$→ 01 —$a : 0$→ 11 ⇒ cheaper!

Additive Heuristic for State-Dependent Action Costs

$$h_s^{add}(fact) = \begin{cases} 0 & \text{if } s \models fact \\ \min\limits_{\text{achiever } a \text{ of } fact} \left[h_s^{add}(pre(a)) + C_s^a \right] & \text{otherwise,} \end{cases}$$

where $C_s^a = \min\limits_{\hat{s} \text{ valuation of variables in } c_a} [c_a(\hat{s}) + h_s^{add}(\hat{s})]$

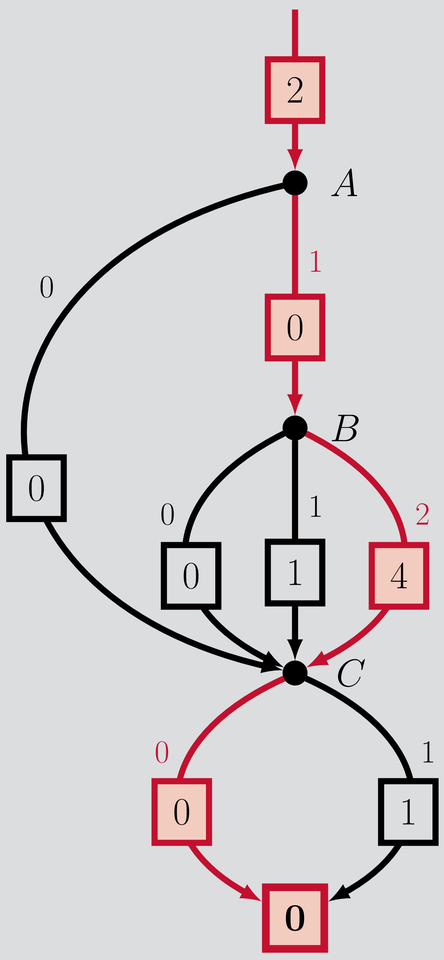
Edge-Valued Multi-Valued Decision Diagrams

Decision diagram [Ciardo & Siminiceanu, 2002] for function

$c_a = AB^2 + C + 2$

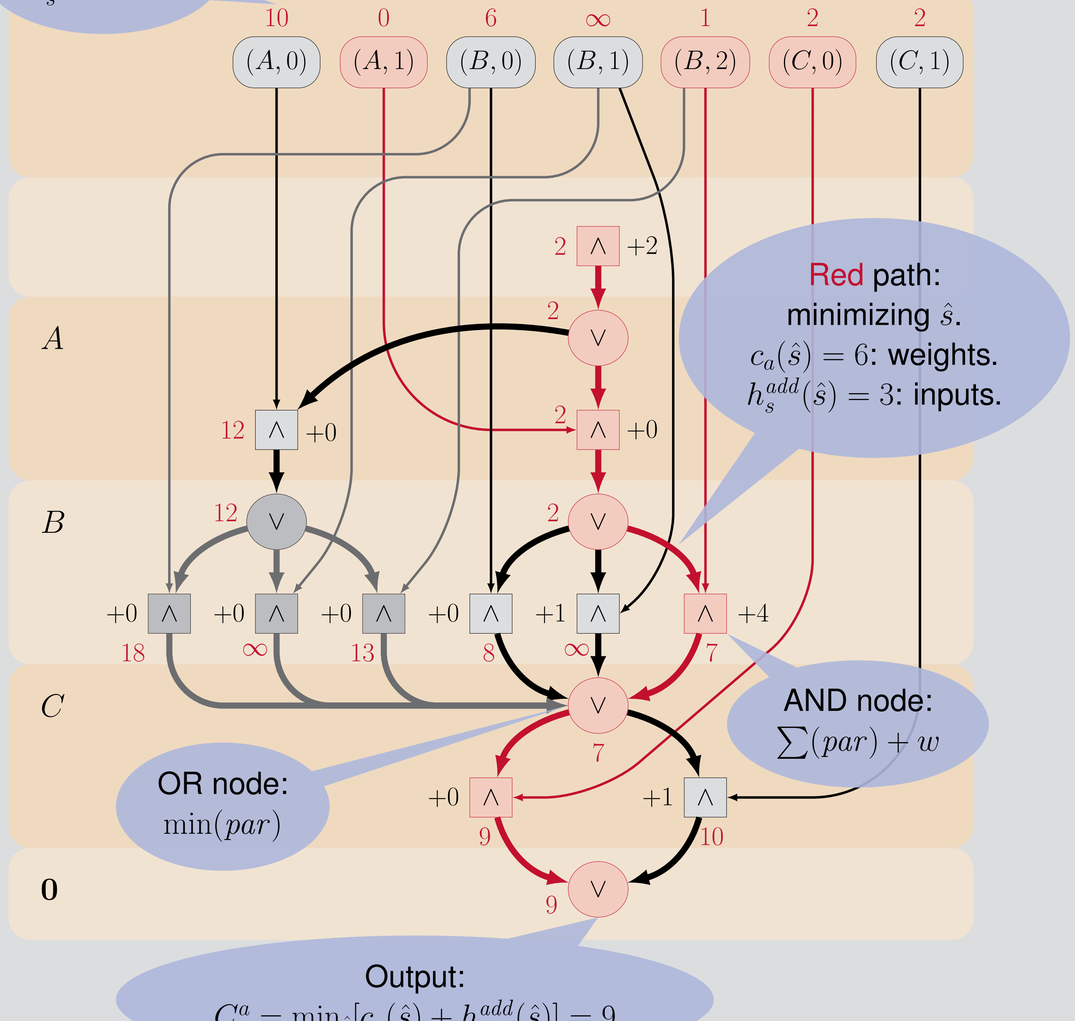
with $\mathcal{D}_A = \mathcal{D}_C = \{0, 1\}$, and $\mathcal{D}_B = \{0, 1, 2\}$

E.g., $c_a(1, 2, 0) = 2 + 0 + 4 + 0 = 6$.



Test variables on all paths.

Add inputs for facts.



Main Theoretical Result

With $h_s^{add}(fact)$ values as inputs, the output of the AND/OR graph is C_s^a.

Use of the Result

- Generate AND/OR graph.
- Embed AND/OR graph in RPG.
- Compute generalized h^{add}.

Experiments

ACADEMIC ADVISING domain (IPPC 2014), PROST planner [Keller & Eyerich, 2012].

Instance	2	4	6	8	10
Variables	20	30	40	50	60
Actions	11	16	21	26	31
Variables in c_a	8	8	11	10	12
AND/OR graph	$26 + 33$	$26 + 33$	$35 + 45$	$32 + 41$	$38 + 49$
Plan cost IDS	**46.24**	202.19	202.90	201.67	201.51
Plan cost h^{add}	**45.80**	**63.41**	**76.15**	**109.02**	**125.52**