Cost-Partitioned Merge-and-Shrink Heuristics for Optimal Classical Planning

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TL;DR

Setting/Background

- classical planning
- merge-and-shrink (M&S) framework
- cost partitioning (CP): optimal and saturated (OCP/SCP)

Goals/Contributions

- investigate how CP can be applied for M&S
- investigate how M&S interacts with CP
- improve M&S heuristics through CP in practice

Theoretical Contributions

Label Cost Partitioning

cost partitioning defined for factored transition systems:

- works with label reduction
  (labels differ from original labels used in the cost partitioning)
- works with factors from different factored transition systems
  (factors can have different labels)

Impact of M&S Transformations on CP Heuristics

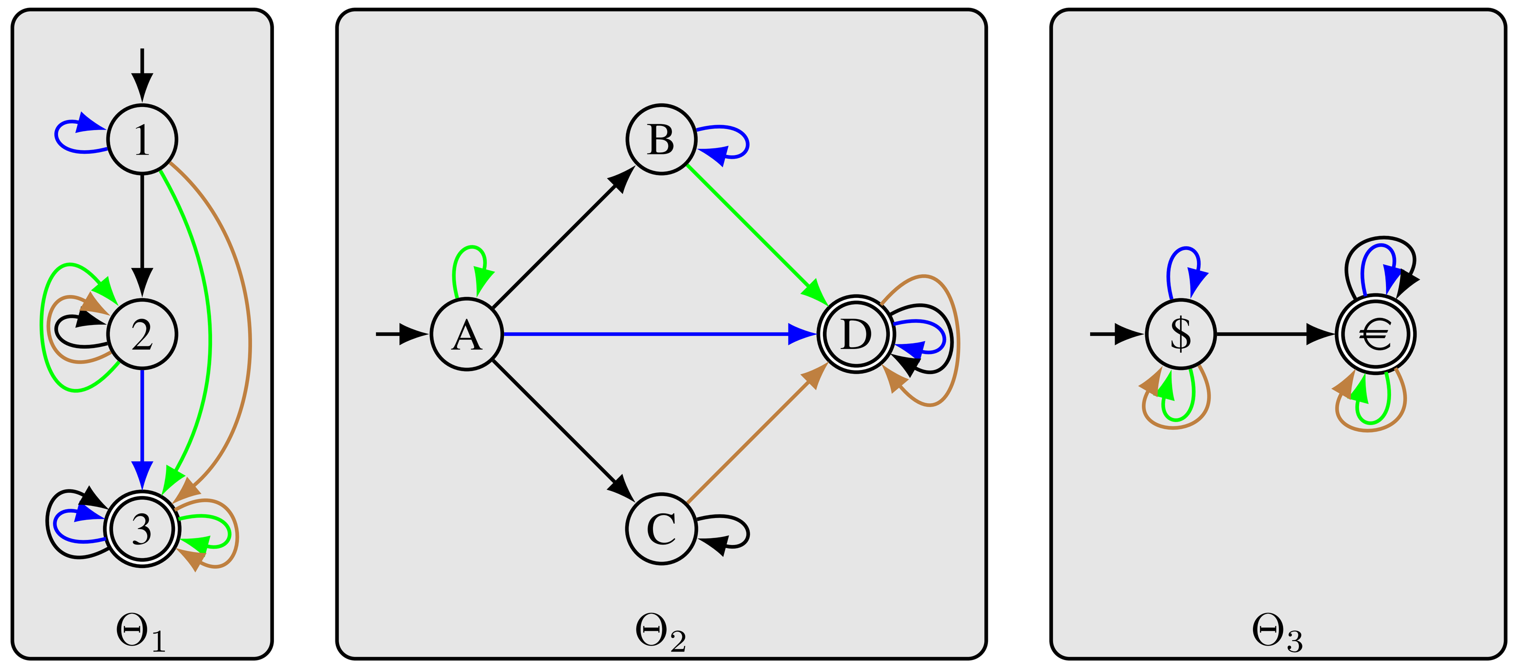
transformation	OCP	SCP
exact label reduction	preserved	preserved
h-preserving shrinking	not increased	preserved
merging	not decreased	incomparable

Merge-and-Shrink Algorithm with SCP Added

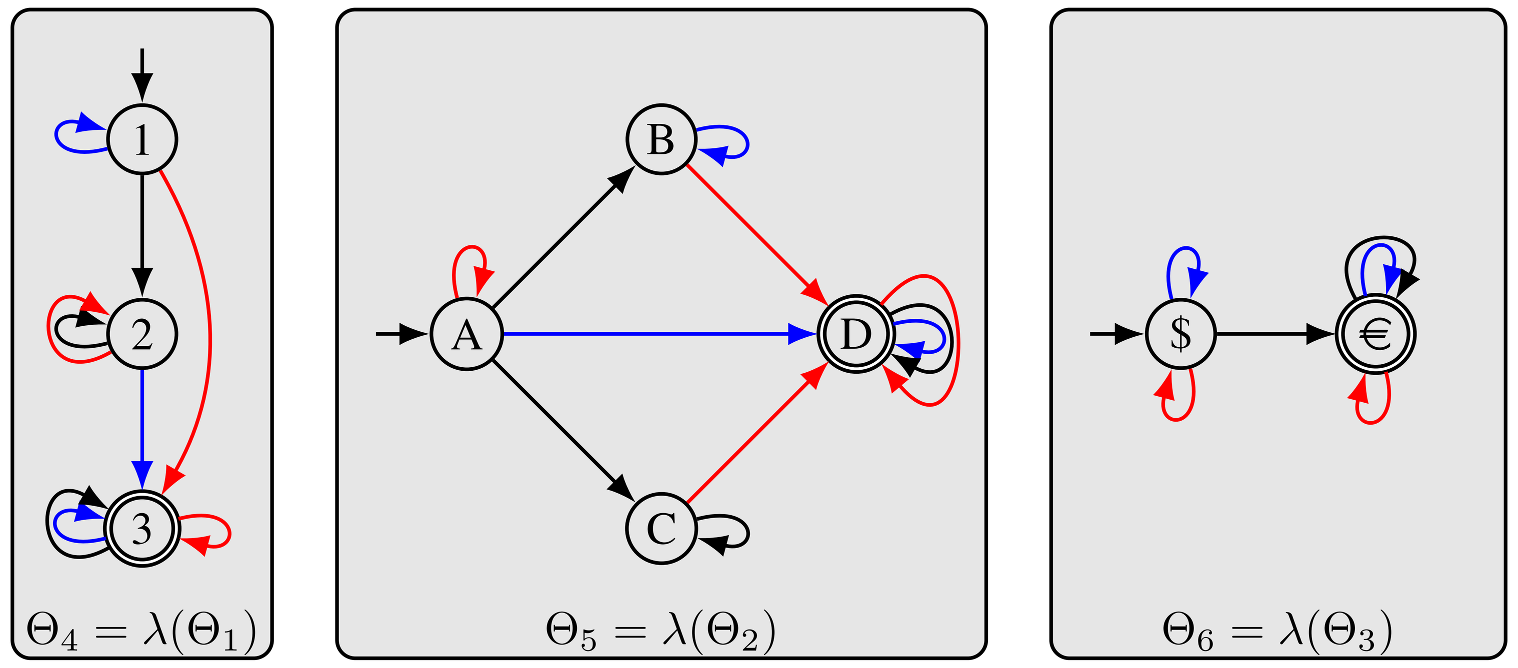
procedure MERGEANDSHRINK(Planning Task Π)
  $F \leftarrow$ factored transition system of Π
  $\mathcal{H} \leftarrow \emptyset$
  while not TERMINATE() **do**
    apply label reduction to F
    $\mathcal{H} \leftarrow \mathcal{H} \cup \{\text{COMPUTESCP}(F)\}$
    select two factors Θ_i, Θ_j from F
    optionally shrink Θ_i and/or Θ_j
    replace Θ_i and Θ_j by their product in F
  end while
  $\mathcal{H} \leftarrow \mathcal{H} \cup \{\text{COMPUTESCP}(F)\}$
  return $h^{\text{M\&S}} = \max_{\Theta \in F} h^*_\Theta$ ▷ original M&S
  return $h^{\text{M\&S+SCP}} = \max_{h \in \mathcal{H}}$ ▷ M&S + SCP
end procedure

Initialization and First Iteration of M&S

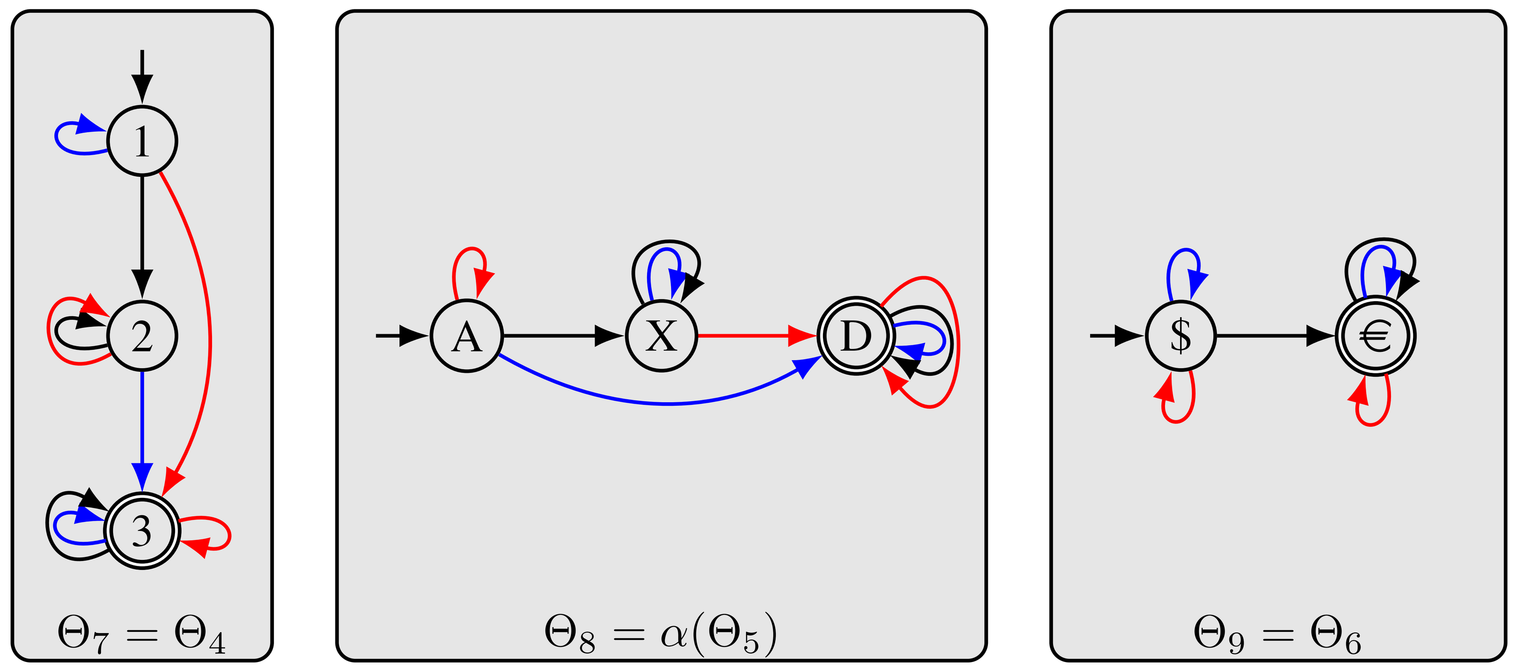
atomic FTS:



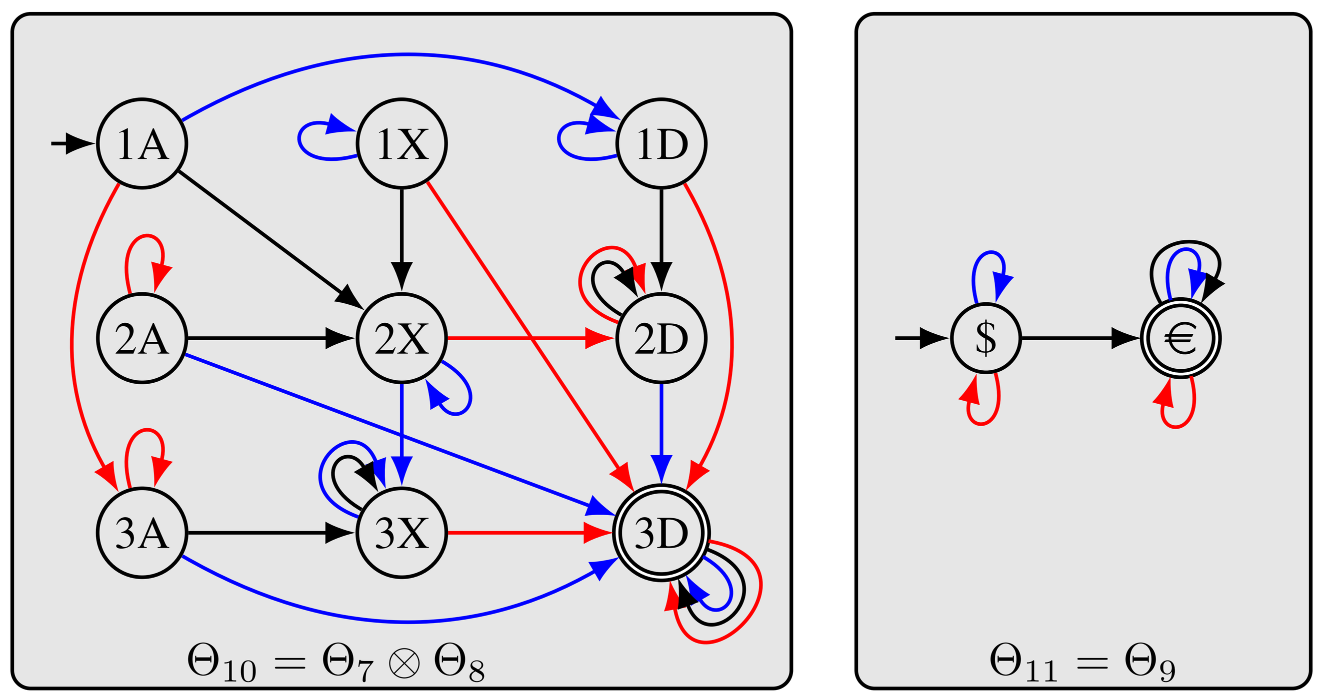
after label reduction (with label mapping λ applied to all factors):



after shrinking (with abstraction α applied to Θ_5):



after merging (of Θ_7 and Θ_8):

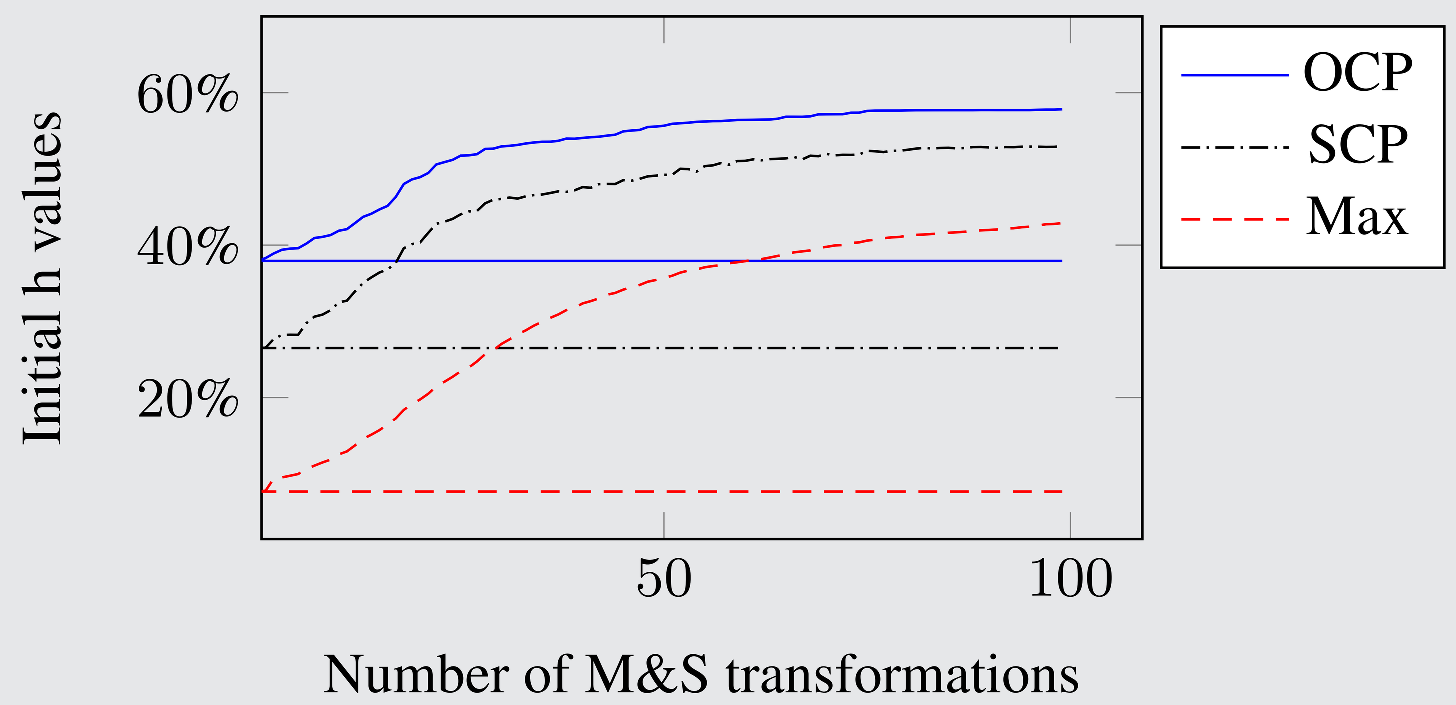


Heuristic Values for the Example

perfect heuristic	$h^*(init) = 3$ (example optimal plan: → → →)
best SCP in iteration 1 (over $F = \langle \Theta_4, \Theta_5, \Theta_6 \rangle$)	$h^{\text{M\&S+SCP}}_{\langle 4,5,6 \rangle}(init) = 1 + 0 + 1 = 2$
best SCP after main loop (over final $F = \langle \Theta_{10}, \Theta_{11} \rangle$)	$h^{\text{M\&S+SCP}}_{\langle 10,11 \rangle}(init) = 2 + 1 = 3$
original M&S heuristic (over final $F = \langle \Theta_{10}, \Theta_{11} \rangle$)	$h^{\text{M\&S}}(init) = \max(2, 1) = 2$
M&S+SCP heuristic (max over collected SCPs)	$h^{\text{M\&S+SCP}}(init) = \max(2, 3) = 3$

Experiments

SCP vs OCP



How often to Compute an SCP & Memory-efficient Variant

	after label reduction			
	$i = 1$	$i = 2$	$i = 5$	$i = 10$
full	922	923	923	916
shallow	**933**	930	926	917

When to Compute an SCP

$i = 1$, shallow	
after label r.	**933**
after shrinking	**933**
after merging	925

Comparing Interleaved and Offline SCPs computed over Different Orders/with Order Diversification Strategies

	rnd	otn	nto	mhsc	mh	msc
h^{SCP}_{int}	**933**	932	928	928	927	930
h^{SCP}_{off}	841	836	905	869	905	837
$h^{\text{SCP}}_{off\text{-}div}$	915	841	904	887	907	838