Efficient Evaluation of Large Abstractions for Decoupled Search: Merge-and-Shrink and Symbolic Pattern Databases

Daniel Gnad and Silvan Sievers and Álvaro Torralba

Linköping University, Basel University, Aalborg University

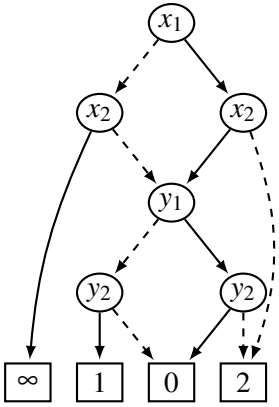
LINKÖPING UNIVERSITY

Large Abstraction Heuristics for Decoupled Search

- Setting: optimal classical planning.
- Large abstraction heuristic: Merge-And-Shrink, symbolic Pattern Database Heuristics.
- **How to efficiently evaluate such heuristics in decoupled search?**

Compatibility between Compact Datastructures

ADD (symbolic PDB):



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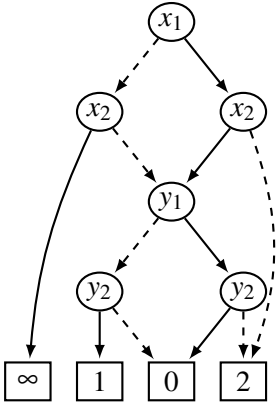
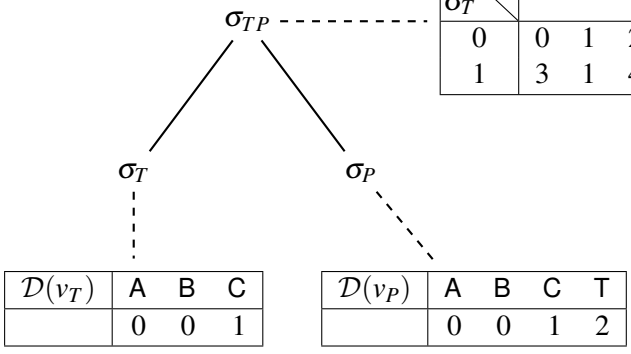


Factored Mapping (M&S):



σ_T \ σ_P	0	1	2
0	0	1	2
1	3	1	4

$\mathcal{D}(v_T)$	A	B	C
	0	0	1

$\mathcal{D}(v_P)$	A	B	C	T
	0	0	1	2

Decoupled State Representation

- Factoring $\mathcal{F}$ of state variables into center C and leaves $L_1, \ldots, L_n$.
- Leaves: enumerate leaf states reached via leaf actions; store **price** for leaf states.

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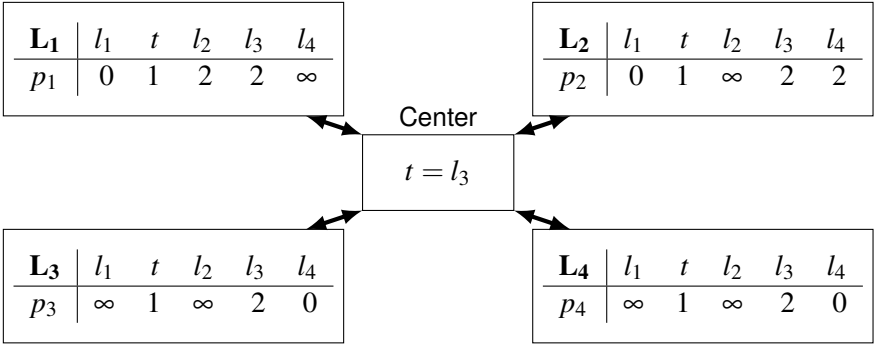

Enumerate Member States

- Decoupled state represents exponentially many expl. states (cross-product of leaves).
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We want a specialized algorithm that does not “unpack” compact datastructures.

Complexity of Exactly Computing the Decoupled Heuristic

Theorem

*Let A be an ADD that represents a PDB heuristic h, $s^{\mathcal{F}}$ a decoupled state, and $B \in \mathbb{R}^+ \cup \{\infty\}$ a bound. It is **NP**-complete to decide if $h_{\mathcal{F}}(s^{\mathcal{F}}) < B$.*

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Corollary

*Let σ be an FM that represents a merge-and-shrink heuristic h and $s^{\mathcal{F}}$ a decoupled state. It is **NP**-complete to decide if $h_{\mathcal{F}}(s^{\mathcal{F}}) < B$.*

Compliance of Decoupling with ADD

Definition (Compliant ADDs)

A variable ordering is *compliant* with a factoring $\mathcal{F}$ if:

$\forall_{v<v'<v''}(\mathcal{F}(v) = \mathcal{F}(v'') \neq C) \implies \mathcal{F}(v') \in \{\mathcal{F}(v), C\}$

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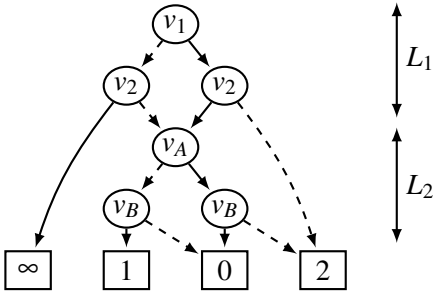

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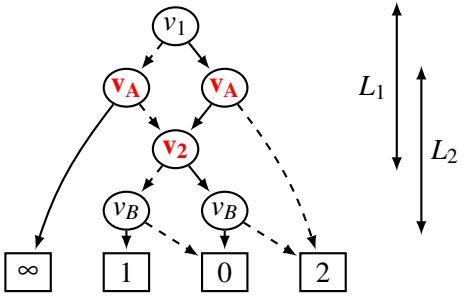

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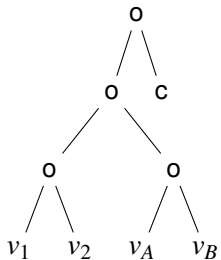

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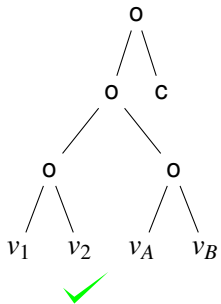

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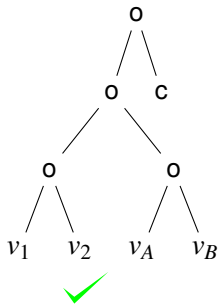

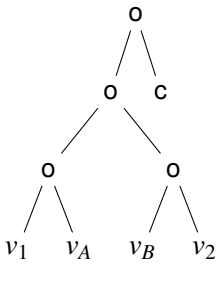

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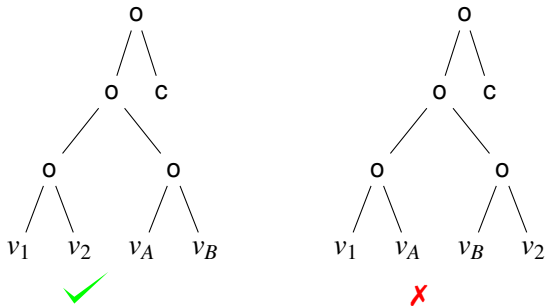

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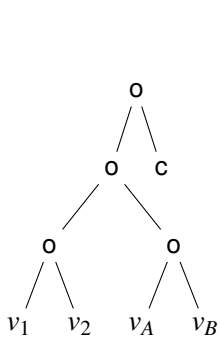

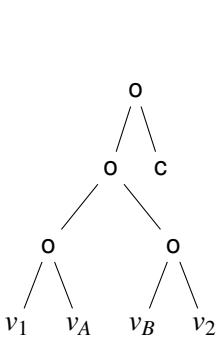

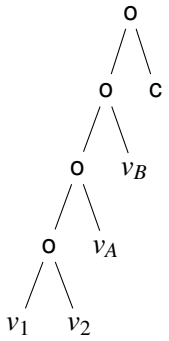

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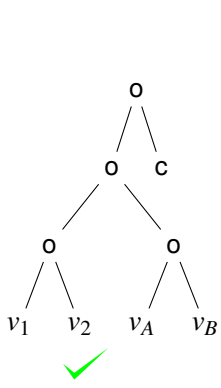
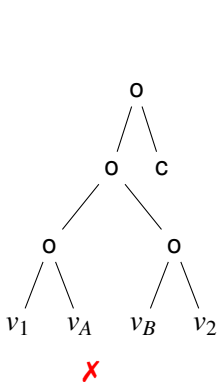
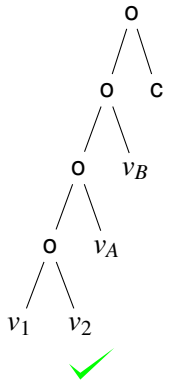
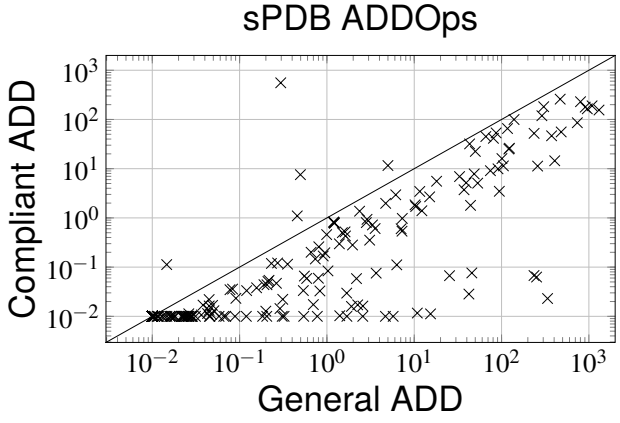






Experiments – Runtime symbolic PDBs



Experiments – Coverage

	Merge-and-Shrink						Symbolic PDBs					
	Ex. Search		Decoupled Search				Ex. Search		Decoupled Search			
			Enumerate		DP				Enumerate		AOps		DP
Domain	**g**	**c**	**g**	**c**	**g**	**c**	**g**	**c**	**g**	**c**	**g**	**c**	**c**

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driverlog	30	**12**	**12**	5	5	10	10	**6**	**6**	5	5	5	5	5
openstacks	30	**6**	**6**	4	4	4	4	**6**	**6**	4	4	4	4	4
transport	30	**14**	**14**	11	11	11	11	**16**	**16**	15	15	15	15	**16**
∑	621	211	210	176	175	223	**234**	226	224	205	203	227	235	**271**

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elevators	30	8	8	**10**	**10**	9	9	9	9	**10**	**10**	9	9	9
nomystery	30	11	11	7	7	**24**	**24**	7	7	7	7	15	15	**16**
zenotravel	30	14	14	13	13	**16**	**16**	11	10	12	11	15	15	**16**
tpp	30	4	4	5	4	**17**	**17**	2	3	5	5	7	14	**27**
parcprinter	27	**20**	**20**	7	7	12	**20**	9	9	7	7	6	8	**27**
woodworking	28	4	5	5	5	5	**7**	8	7	7	7	**9**	8	**9**
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
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Future Work:

- M&S for unsolvability.
- Combine multiple heuristics via e.g. cost partitioning.

Thank you!

Questions?